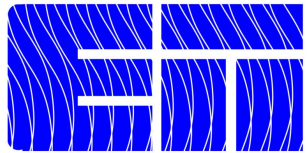
OSB Summary

Marica Branchesi, Archisman Ghosh, Michele Maggiore

ET Annual Meeting, Opatija Nov. 11-14, 2025



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some highlights:

- recap of the OSB Roadmap
- core PP program
- ESO expanding horizon call
- eIB-OSB joint section
- contributed talks

Reflections on the ‘post-BB’ phase of the OSB

- Reflection started this Spring together with div coordinators
  - presentations by div coordinators at Bologna Symposium
  - identification of important problems/objectives/milestone for each division and concrete proposals for collaborations among divs
  - OSB input to the ‘core program’

A Roadmap for OSB activities

August 26, 2025

The OSB Chairs: Marica Branchesi, Archisman Ghosh, Michele Maggiore

The OSB Division Coordinators: Michal Bejger, Laura Bernard, Monica Colpi, Elena Cuoco, Giulia Cusin, Tim Dietrich, Irina Dvorkin, Gabriele Franciolini, Giancarlo Ghirlanda, Gianluca Guidi, Ik Siong Heng, Tanja Hinderer, Andrew Levan, Marco Limongi, Michele Mancarella, Michela Mapelli, Andrea Maselli, Samaya Nissanke, Micaela Oertel, Cristiano Palomba, Paolo Pani, Harald Pfeiffer, Rafael Porto, Tania Regimbau, Angelo Ricciardone, Mairi Sakellariadou, Anuradha Samajdar, Bangalore Sathyaprakash, Patricia Schmidt, Riccardo Sturani, Nicola Tamanini

Abstract

This internal ET document presents the outcome of reflections started in the OSB after the completion of the “BlueBook”, with the aim of identifying the most important scientific goals to be pursued by the OSB in the medium-term future (also as an OSB input to the definition of the ET Core Program), developing collaborative projects across divisions, and discussing the practical organization of the work.

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1 Div. 1. Fundamental Physics 3
1.1 Main scientific goals . . . 3
1.1.1 Goals specific to the division . . . 3
1.1.2 Collaborative projects across divisions . . . 4
1.2 Proposals for the organization of the work . . . 4

an internal document has been finalized: ET-0422A-25

it will be a “Living document” (an Overleaf for updates has been set up)

aims of the Roadmap:

- organizing the work of the divisions after the BlueBook
- OSB input to the Core Program
- a way for newcomers/people not yet much involved to find their way into ET activities. Do read it!

Code	Access	Title	Date	Author(s)
ET-0422A-25	ET	A Roadmap for OSB activities	2025-09-15	The OSB Chairs: Marica Branchesi, Archisman Ghosh, Michele Maggiore. The OSB Division Coordinators: Michal Bejger, Laura Bernard, Monica Colpi, Elena Cuoco, Giulia Cusin, Tim Dietrich, Irina Dvorkin, Gabriele Franciolini, Giancarlo Ghirlanda, Gianluca Guidi, Ik Siong Heng, Tanja Hinderer, Andrew Levan, Marco Limongi, Michele Mancarella, Michela Mapelli, Andrea Maselli, Samaya Nissanke, Micaela Oertel, Cristiano Palomba, Paolo Pani, Harald Pfeiffer, Rafael Porto, Tania Regimbau, Angelo Ricciardone, Mairi Sakellariadou, Anuradha Samajdar, Bangalore Sathyaprakash, Patricia Schmidt, Riccardo Sturani, Nicola Tamanini

various collaborative projects already scketched. some random examples:

1.1.2 Collaborative projects across divisions

(In parenthesis people who volunteered to coordinate these projects from the Div1 side More help needed!)

- Tests of GR and ET Mock Data Challenge (F. Crescimbeni)
- Connection with LISA Fund. Phys. Working Group (R. Brito, D. Doneva)
- With Div2: Strong field tests of theories for dark energy
- Connection with Div6: degeneracy with the NS EoS (F. J. Llanes-Estrada)
- Other synergies to further develop: Pop (Div3), Waveform (Div8)

In particular, collaboration is foreseen with:
Division 1: for the configuration and analysis of signals that could reveal alternative theories beyond GR
Division 2: for the stochastic background (SBGW)
Division 3: for the choice of population models to use for injected signals
Division 4: for MDC with EM/neutrino detectors. Organization of low-latency MDC.
Division 5: for MDC with other GW detectors.
Divisions 6, 7, and 8: for the waveforms to inject, also considering different EOSs, and related DA developments.
Division 9: for the development of shared DA pipelines and tools.

Find your way to contribute actively to ET !

2.1.2 Collaborative projects across divisions

- Investigate how a joint detection of a stochastic background of GWs across different frequency bands (PTA, LISA, ET) could provide a better characterization of the properties and origin of such a background. Project in synergy with members from different collaborations (also together with Div. 5).
- Perform code validation among different available pipelines in order to provide more accurate and consistent forecast for standard sirens cosmology.

ET core actvitivy program for science and data analysis
by Project Program Committee (PPC)

Marica Branchesi, Jerome Novak and Stefano Bagnasco
members of the PPC as representative of the OSB and eIB

For the OSB, the roadmap will be integrated into the core activity program.

The program activities will be implemented in the structure of the ETMD

Section	Items		*Short description*
1	**Science Case**		
	1.1	**Fundamental Physics**	Testing GR, probing compact object nature & horizon-scale physics, dark-matter candidates
	1.2	**Cosmology**	Stochastic and primordial GW backgrounds, early and late Universe cosmology, dark matter and LSS
	1.3	**Population Studies**	Population models of binary systems containing BH (primordial, stellar and intermediate) and NS, and population backgrounds.
	1.4	**Nuclear and Subatomic Physics**	Equation of state and properties of matter at supranuclear densities (hot and cold), signatures of phase transitions in the QCD phase diagram.
	1.5	**Stellar Collapse and isolated Neutron Stars**	Core-collapse SN, single rotating NS, bursts and continuous wave signals, neutrino and electromagnetic counterparts
2	**Science targets evaluation for the site selection and instrument optimization**		
	2.2	**Site-dependent Target Science (with the SCB)**	Simulation and science metrics to characterize the site
	2.2	**Science targets (with ISB)**	Simulation and science metrics to optimize the detector

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3	**Modelling and data analysis**		
	3.1	**Waveforms development**	Analytic and numeric approaches, waveform systematics and accuracy requirements, acceleration techniques
	3.2	**Data Analysis Development**	Algorithm development for detection and parameter estimation, machine learning, overlapping signals, null stream
	3.3	**Common Tools, sofware comparison and validation**	Development and maintainance of software tools, code review and comparison, figures of merit, metrics and forecasting
4	**Multi-Messenger and multi-band synergies**		
	4.1	**Multi-messenger Modelling of GW sources**	Modelling of electromagnetic (GRB and KN) and neutrino counterparts of compact object mergers
	4.2	**Synergies with electromagnetic Observatories**	Requirements for space and ground EM observatories, observational strategy and data analysis optimization, GW/EM science perspectives.
	4.3	**Synergies with Neutrino Observatories**	Requirements for neutrino observatories, observational strategy and data analysis optimization, GW/neutrino science perspectives.
	4.4	**Synergies with ground-based and space-born GW Detectors**	Development of science cases in synergy with ground-based and space-born GW observatories, multi-band data analysis

5	**Mock Data Challenges**		
	5.1	**MDC Code development and injection models**	MDC code development, implementation and review
	5.2	**MDC infrastructure**	Tools, services and infrastructure (middleware) specific to the management of MDCs
	5.3	**Data analysis improvements**	MDC to identify data analysis challenges, and help developing data analysis code
	5.4	**Optimization of the instrument through MDC**	MDC to optimize the instruments
	5.5	**Evaluation of computational needs**	Estimates of required computing power for each search. Also, test and evaluation of tools and infrastructure prototypes
6	**Infrastructure requirements and development**		
	6.1	**Detection and Parameter Estimation**	Tools, services and infrastructure for management of offline data analysis activities
	6.2	**Low-Latency Infrastructure Requirements**	Tools, services and infrastructure for low-latency alert generation and management
	6.3	**Data and workload management infrastructure**	Tools, services and infrastructure for data and job management, accounting, databases, resource managers etc.

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http://next.eso.org

ELT - Extremely Large Telescope

Will be the largest optical/infrared telescope ever built or planned (mirror of 39.3 m diameter)

Construction 2015-2030

First Telescope Light: Mar 2029

First Scientific Light: Dec 2030

ESO Mission

We design, build, and operate advanced ground-based observatories

We foster international collaboration for astronomy

What ESO's next programme could be

The next ESO Programme should be identified **in line with ESO's vision and strategy**. It should be a **transformational facility in the 2040s landscape** that enables scientific benefits in several areas and serves a **large part** of the scientific aspirations of the community.

It could be:

- **A new telescope facility at an existing or new observatory site;**
- **A significant upgrade of an existing facility that is (co-)owned by ESO;**
- **Other ideas or combinations,**

Important: ESO does not operate as a funding agency. The new facility will be **led and owned** by ESO **alone** or in **partnership** with other organisations.

Senior Science Committee (SSC)

- **Angela Adamo**, University of Stockholm (ESO STC, Galaxies)
- **Joss Bland-Hawthorn**, University of Sydney (Astrophotonics)
- **Marica Branchesi**, Gran Sasso Science Institute (Multi-messenger)
- **Paul Callanan**, University College Cork (ESO Council, Compact objects, chair)
- **Heather Cegla**, University of Warwick (Life & Habitability)
- **Stéphane Charlot**, Institute d'Astrophysique de Paris (Cosmology)
- **Vik Dhillon**, University of Sheffield (ESO Council, Transients & stars)
- **Norbert Hubin**, formerly ESO (Technology Development, starting 1 Nov 2025)
- **Marcella Marconi**, INAF- Osservatorio Astronomico di Capodimonte (ESO STC, Stellar populations)
- **Nanda Rea**, Institut de Ciències de l'Espai – CSIC (Transients & high-energy)
- **Hans-Walter Rix**, MPIA (Galaxies)
- **Karin Öberg**, Harvard (star/planet formation)

Expanding Horizons timeline

July 2024–Q3 2026

- Present and explain the process to the community
- Trigger dialogue about astronomy challenges & disruptive technologies in 2040s

Jun-Nov 2025

- Launch of call: July
- **White papers due: 15 Dic 2025**
- 3 pages max
- **Science focus.**

Q3 2026–Q2 2027

- Launch of call: Q3 2026
- Letters of Intent due 1 Dec 2026
- Proposals due: 1 Jun 2027

Q3 2027–Q3 2028

- Performed by SSC and ESO Executive
- Transparently share what ideas are being proposed at a dedicated community workshop

Q3–Q4 2028

- Presented at STC and Finance Committee
- Council decision
- Decision is **not** the start of the new Programme

Science & technology in the 2040s

The main focus at the moment

What is/are the main science question(s) in astronomy that need to be answered in the 2040s?

Need to convince the member states to invest resources into the next major ESO facility. **Science must be the driver. That science cannot be done with the facilities available in the 2030s.**

White papers → workshops

The **SSC** decided to open a call for white papers focused purely on the **science questions to focus on for the 2040s**. This will then be a base to organise on-line workshop(s) where the scientific community should discuss which will be the scientific challenges of astronomy in the 2040s in different areas.

Disruptive Technologies Workshops

A place to discuss which potential disruptive technologies may become game changers for a transformational facility in the 2040s;

Is ESO open to astroparticle experiments?

Yes, ESO remains open to considering astroparticle physics experiments when such initiatives are supported by the broader scientific community and demonstrate clear scientific value consistent with ESO's objectives.

For ET, this represents a significant opportunity

- **ESO** is an intergovernmental organization **already managing and operating the most advanced astronomical infrastructures**.
- ESO can offer a robust and solid **management frameworks**, providing extensive experience in **large-scale scientific coordination, project governance, and long-term operational planning**.
- ESO has a **well-established framework for research, development, and innovation**, enabling effective collaboration between scientific institutions and industry through consolidated consolidated processes in **industrial contracting and procurement**

The OSB will answer to the ESO call with white papers

- We will prepare WPs highlighting the open scientific questions that only next-generation GW observatories will be able to address;
- Based on the Blue Book, we will produce 6 white papers (of 3 pages maximum) corresponding covering the broad scientific reach of ET, encompassing multiple research domains (including multi-messenger).

Operatively:

- Due to the strict deadline **(December 15)** , the DIV coordinators may either work directly on their white paper or set up a small task force to assist.
- WPs should be written in a style accessible to a broad scientific audience. The Decadal Survey and Snowmass WPs provide good examples to follow.
- Authorship should reflect people most active in developing each Blue Book chapter, as well as any additional contributors who are helping now.

Div 1 update *Paolo Pani et al.*
Opatija, Croatia 13:20 - 13:30

Div 2 update *Angelo Ricciardone et al.*

Div 3 update *Gabriele Franciolini*
Opatija, Croatia 13:40 - 13:50

Div 4 update *Giancarlo Ghirlanda*
Opatija, Croatia 13:50 - 14:00

Div 5 update *B.S. Sathyaprakash*
Opatija, Croatia 14:00 - 14:10

Div 6 update *Tania Hinderer*
Opatija, Croatia 14:10 - 14:20

Div 7 update *Cristiano Palomba*
Opatija, Croatia 14:20 - 14:30

Div 8 update *Harald Pfeiffer*
Opatija, Croatia 14:30 - 14:40

Div 9 update *Andrea Maselli*
Opatija, Croatia 14:40 - 14:50

Div 10 update *Anuradha Samajdar et al.*

Reports from the divisions

Roadmap starts to be implemented, collaborative projects starting

new collaborative project ET-LISA on stochastic backgrounds

OSB roadmap discussion
Michele Maggiore

OSB @ ET Program + ESO whitepap.
Marica Branchesi

Discussion: resource evaluation
Gonzalo Merino
Opatija, Croatia 11:45 - 12:15

MDC discussion
Opatija, Croatia 12:15 - 13:00

Highlights of updates from division coordinators

Div 1: waveforms + data analysis, MDC for precision fundamental physics
Div 2: synergistic project with LISA, plan for “cosmology day”
Div 3: activity around 5 taskforces w/ O(10) contributors per taskforce
Div 4: several missions and projects
Div 5: collaborative project with LISA, discussion around decihertz synergies
Div 6: dedicated science questions, synergies with other boards + CE STM
Div 7: MM modelling CCSN, effects of CW on MDC
Div 8: (long term) review, software-stack; (cross-div) repos, resources, liaisons
Div 9: “common tools” open space for coordination across divisions
Div 10: activity around new MDC tools, cross-div plans (e.g., with Div 1)

ET computing needs @ eIB+OSB joint session

- Detailed, global computing needs for ET are not yet fully defined. From eIB Div 3 (led by Gonzalo Merino), process initiated for gathering current and future computing requirements from the various ET scientific boards/divisions.
- Meeting held on the 20/06/2025 to kickstart this activity.
  - Representation from eIB, SCB, ISB, OSB + OSB Div coordinators Divs 7-8-9-10
- Acknowledged that detailed computing needs are not yet fully defined.
- Agreed to create a "bottom-up" estimate of requirements.
  - Gather a first estimate for Nov ET meeting.
  - Produce a prioritized list of areas where R&D is expected.
    - how resource requirements could scale in the future
    - which types of sw & hw technologies are being explored as part of these R&D efforts.
  - Establish a formal process to track these requirements in the future.

Credit: Gonzalo Merino

ET computing needs @ eIB+OSB joint session

Input received from different boards

- SCB + ISB: 3D seismic simulations → Newtonian noise modelling
  - computationally expensive: massively parallel tasks that require HPC allocations
  - preliminary estimates (based on extrapolation of realistic runs)
    - 300 MCPUhrs for a CPU-only resource.
    - 50 MCPUhrs + 6.25 MGPUhrs (A100 equivalent) for a CPU+GPU resource (8 CPUcores/GPU).
  - R&D efforts ongoing to reduce these costs
  - detailed estimate expected in the next months
- OSB: Heavy and diverse needs
  - long duration searches, waveform development, searches and parameter estimation
  - input solicited via survey in OSB Divs 7-8-9-10: limited number of responses received
    - 500-100k CPU hrs (per responder), 1-2k GPU hrs (per responder)
    - 2-25 GB RAM (per responder), upto 4 TB of storage (per responder)
  - still need to move from raw data to integrated estimates

ET computing needs @ eIB+OSB joint session

More general discussion

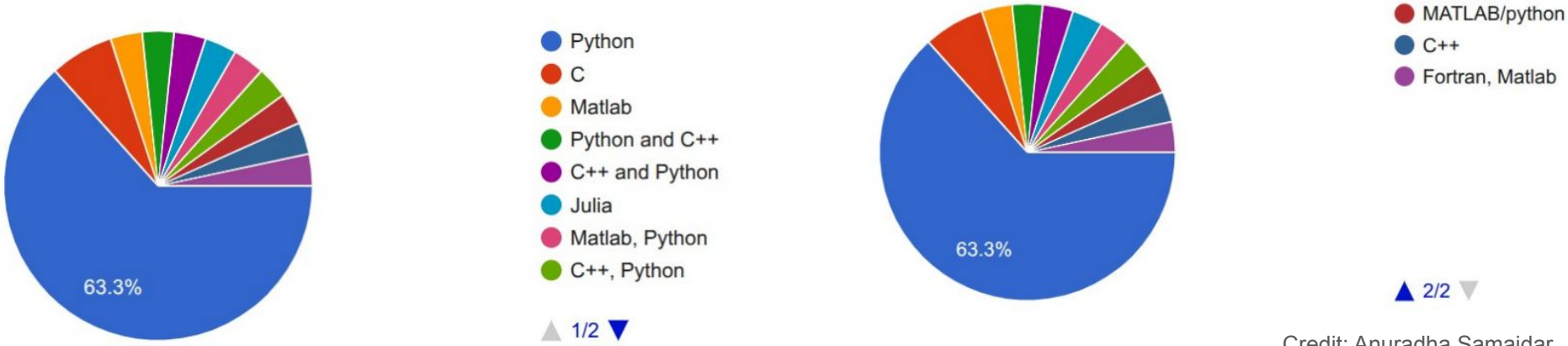
- Job schedulers: Slurm, HTCondor
- Containerization: Apptainter
- CI/CD integration
- Whether current IGWN environment sufficient for ET needs

Summary

- clear trend: traditional CPU-based computing → GPU-based architectures
- well-supported, stable software environment is critical to ensure adoption of common tools and collaborative efficiency
- aim to avoid short-term solutions that are not sustainable
- Process has started: regular discussion expected (2× /y) – stay tuned!

MDC discussion @ eIB+OSB joint session

- Clear preference for Python as coding language



Credit: Anuradha Samajdar

- Python-based MDC codebase now available
  - significant community engagement
  - ability to deal generate glitches, overlapping signals, AI/ML-based CBC param inference
  - publicly available: https://gitlab.et-gw.eu/osb/div10/resources_3G_data_analysis
- Next steps: stress-testing and review; path forward jointly with eIB

contributed talks

Beyond GR tests with Einstein Telescope *Andrea Begnoni*
Opatija, Croatia 15:50 - 16:10

Spin-induced quadrupole moment test for eccentric compac…
Syed Naqvi

Detection prospects of parity-violating gravitational waves i.
Hannah Duval

Multi-probe Cosmology with Standard Sirens: a GWxHI Cros…
Matteo Schulz

From Astrophysics to Cosmology: forecasting Einstein Tele.
Giovanni Antinozzi

QTAM: Qtransform from visualization to phy
Francesco Sarandrea …
Opatija, Croatia 11:30 - 11:45

Population Properties of Binary Black Holes…
Alessandro Trani

Probing increasingly younger neutron stars
Lorenzo Pierini

Gravitational wave properties of the HESS J1731-347 Object as a Twin Compact Star
Dr David Alvarez Castillo

An incremental approach for all-sky searche for continuous gravitational wave signals
Cristiano Palomba

Recent results on the high-energy emission from GRB jets
Prof. Zeljka Bosnjak
Opatija, Croatia 10:20 - 10:40

Test of a deep anomaly detection algorithm using MDC1
Dr Huw Haigh

Fast and accurate parameter estimation of h
Filippo Santoliquido

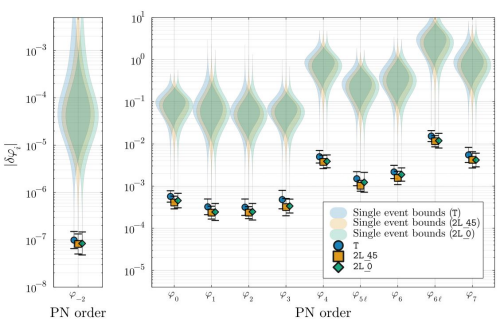
Overlapping signals in next-generation grav
Harsh Narola

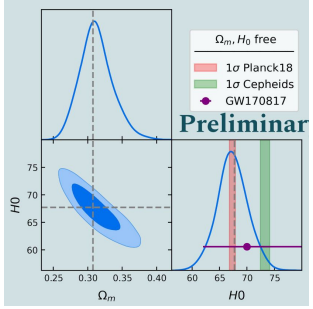
Hierarchical Subtraction with Neural Density Estimators as a General Solution to Overlapping Gravitational Wave Signals
Qian Hu

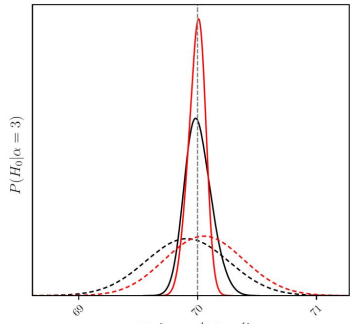
Fast glitch removal method *Edoardo Milotti*
Opatija, Croatia 15:00 - 15:20

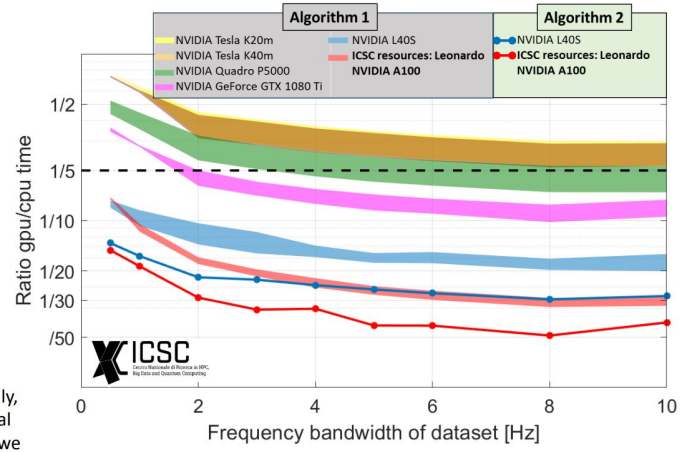
Bayesian Calibration of Gravitational-Wave .
Chun-Fung Wong

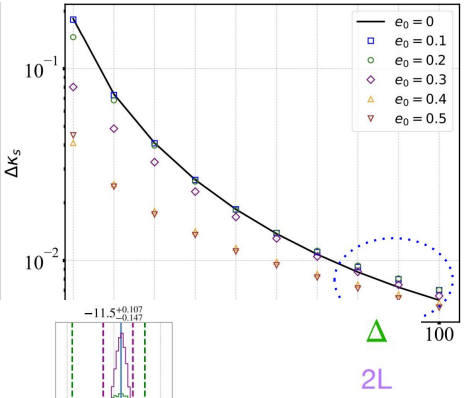
Fast likelihood evaluation of eccentric–prec…
Dr Soumen Roy









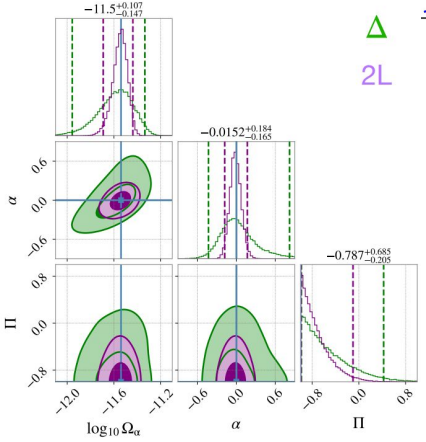


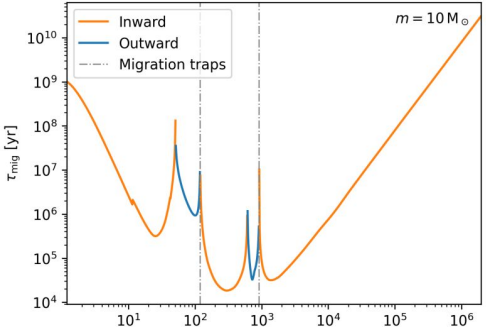
T_w (months)	CR_2	n_{files}	$\mathcal{M}$ (TB)	$\mathcal{L}$
3	3.5	664075	2.97 (11.9)	1.12
3	3	664075	17.2 (68.9)	1.07
3	2.5	664075	79.3 (317.2)	1.01
3	2.0	664075	290.5 (1162)	1
4	3.5	664075	2.97 (11.9)	1.08
4	3	664075	17.2 (68.9)	1.02
4	2.5	664075	79.3 (317.2)	1
6	3.5	664075	2.97 (11.9)	1.01
6	3	664075	17.2 (68.9)	1

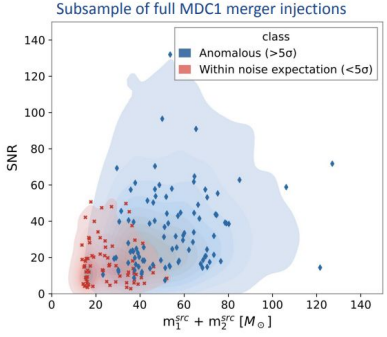
Loss = 1 means that, theoretically, the sensitivity of the incremental analysis would be better, but if we use the same selection criteria as in the standard case it reduces to the same level.

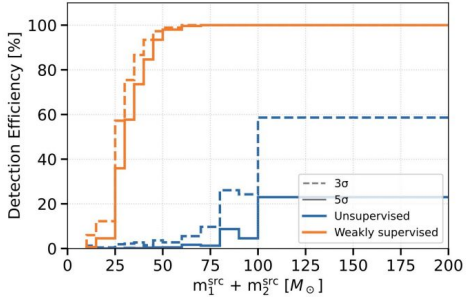
Assuming 100 sky point maps are stored in each file.

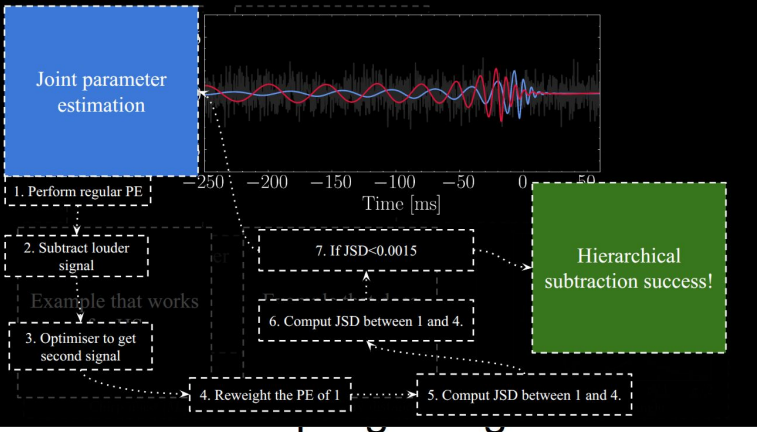
Minimum (and maximum) **total** occupation of incremental maps.
Can be further reduced representing the map in single precision, rather than double as it is now.

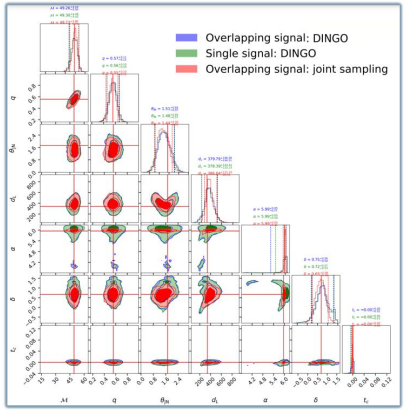




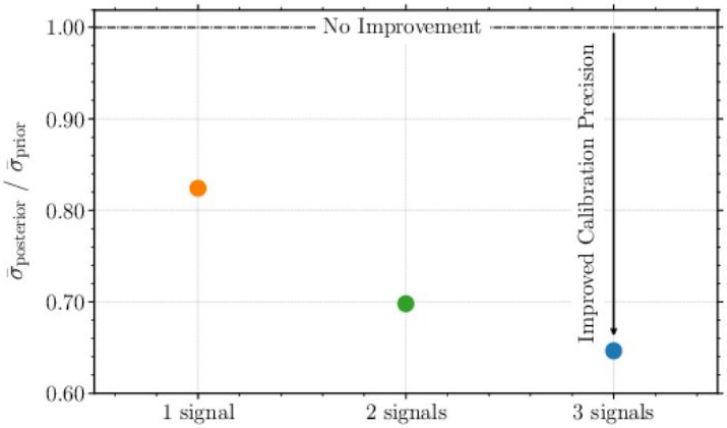


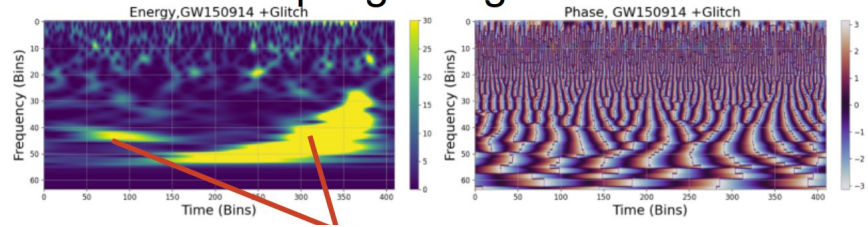




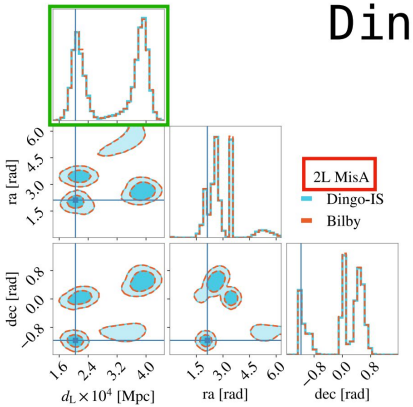


- Hierarchical subtraction recovers DINGO PE for single source





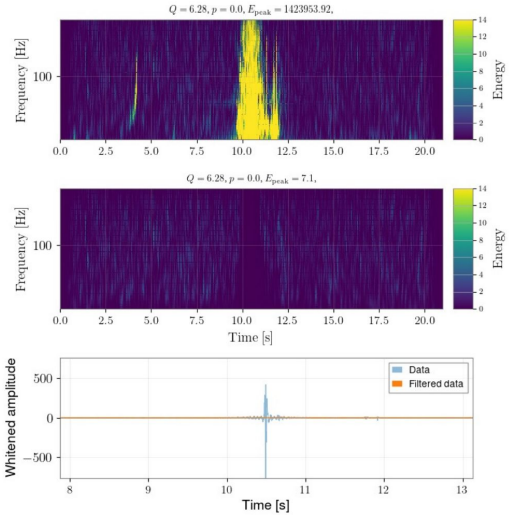
Dingo-IS vs. Bilby

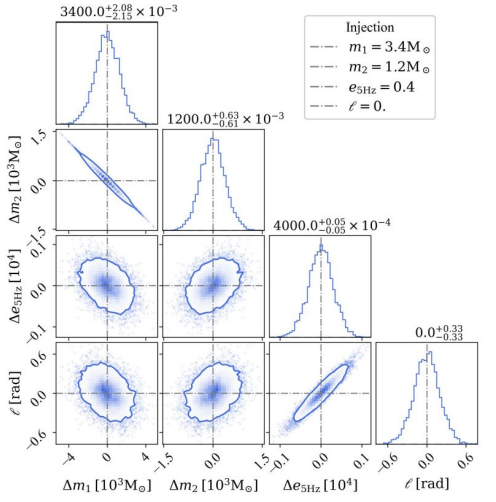


Perfect agreement between `Dingo-IS` and `Bilby`

10 min vs. 7 hours

Multimodalities in luminosity distance and sky localisation





Div1 Fundamental Physics: F2F meetings

- Survey showed interest for focused F2F meetings, not connected to Annual Meetings or Symposia (e.g., avoiding teaching terms)
- ECR workshop organized by ECRs belonging to OSB, ISB, SCB

https://sites.google.com/view/et-ecr-workshop-2026-sapienza

SOC

- Francesco Crescimbeni
- Ulyana Dupletsa
- Francesco Iacovelli
- Maria Antonietta Palaia
- Romeo Felice Rosato
- Michele Vacatello