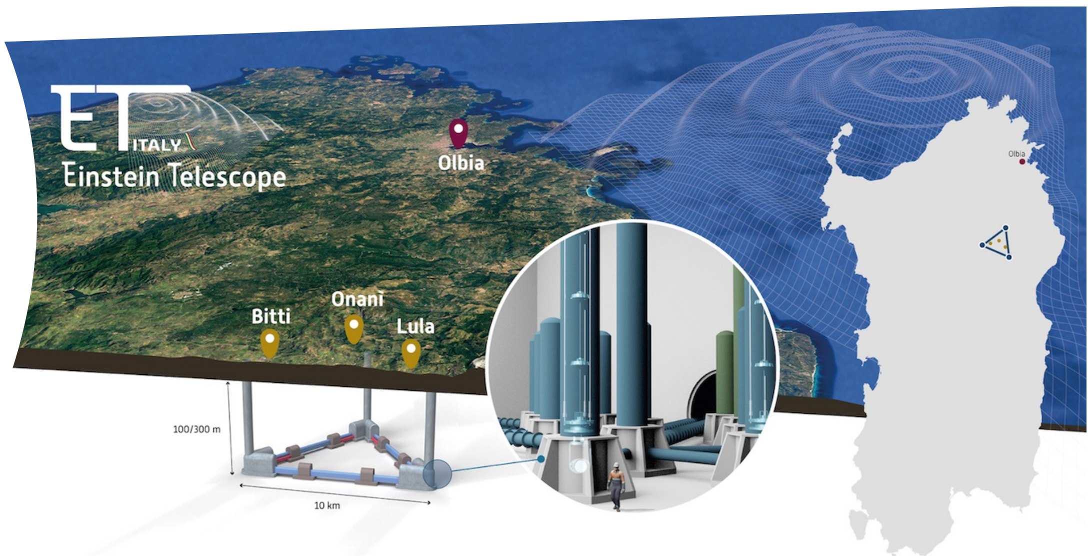
Istituto Nazionale di Fisica Nucleare
Piano Triennale
2024 | 2026

Trieste
Stazione Marittina
27 | 28 giugno 2023

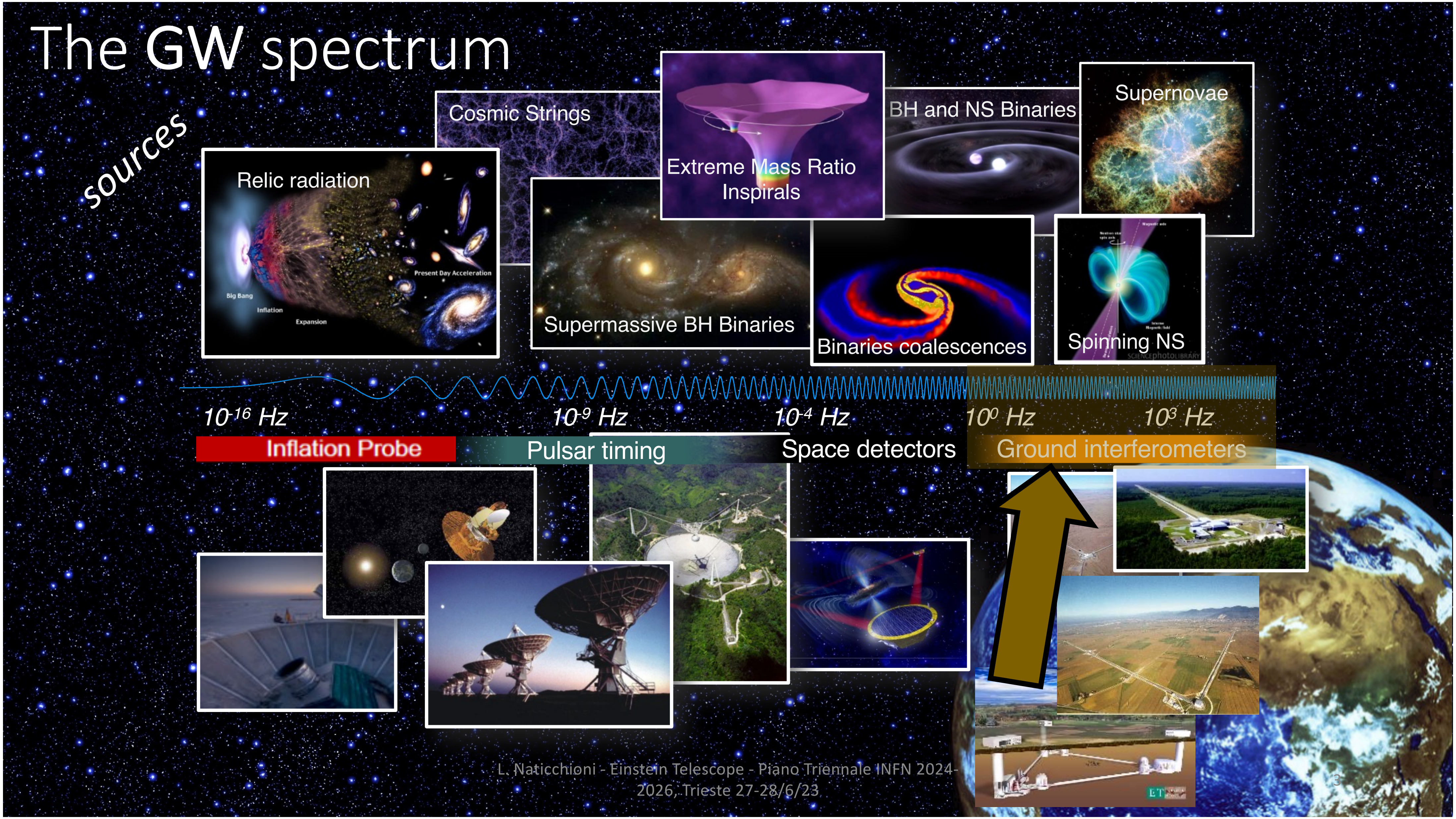
Einstein Telescope

Luca Naticchioni
INFN Roma



Summary

- **GW science with ET**
- From Virgo to ET
- ET: Infrastructure, detector, technologies
- The ET collaboration
- Towards ET in Italy
- Conclusions


The GW spectrum
sources
Relic radiation
Big Bang
Inflation
Expansion
Present Day Acceleration
Cosmic Strings
Supermassive BH Binaries
Extreme Mass Ratio Inspirals
BH and NS Binaries
Binaries coalescences
Supernovae
Spinning NS
10-16 Hz
10-9 Hz
10-4 Hz
100 Hz
103 Hz
Inflation Probe
Pulsar timing
Space detectors
Ground interferometers
L. Naticchioni - Einstein Telescope - Piano Triennale INFN 2024-2026, Trieste 27-28/6/23

GW Science with ET ... in a nutshell

ASTROPHYSICS

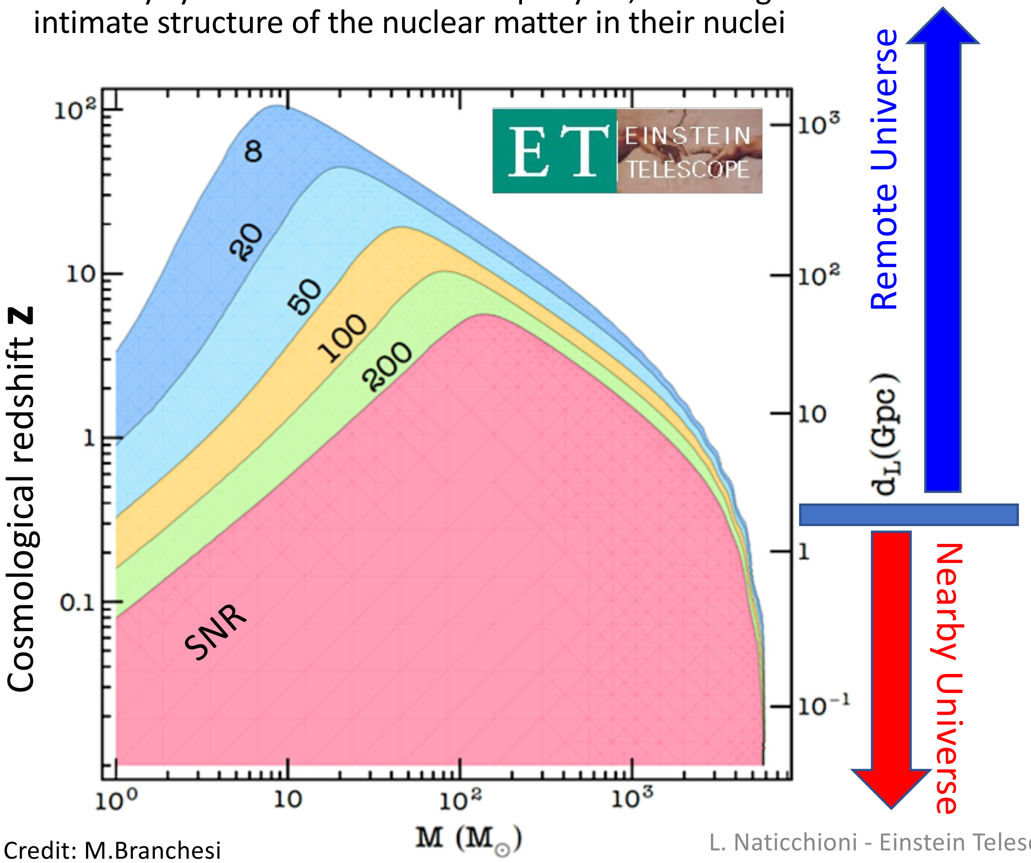
- **Black hole properties**
  - origin (stellar vs. primordial)
  - evolution, demography
- **Neutron star properties**
  - interior structure (QCD at ultra-high densities, exotic states of matter)
  - demography
- **Multi-band and -messenger astronomy**
  - joint GW/EM observations (GRB, kilonova,...)
  - multiband GW detection (LISA)
  - neutrinos
- **Detection of new astrophysical sources**
  - core collapse supernovae
  - isolated neutron stars
  - stochastic background of astrophysical origin

FUNDAMENTAL PHYSICS AND COSMOLOGY

- **The nature of compact objects**
  - near-horizon physics
  - tests of no-hair theorem
  - exotic compact objects
- **Tests of General Relativity**
  - post-Newtonian expansion
  - strong field regime
- **Dark matter**
  - primordial BHs
  - axion clouds, dark matter accreting on compact objects
- **Dark energy and modifications of gravity on cosmological scales**
  - dark energy equation of state
  - modified GW propagation
- **Stochastic backgrounds of cosmological origin**
  - inflation, phase transitions, cosmic strings

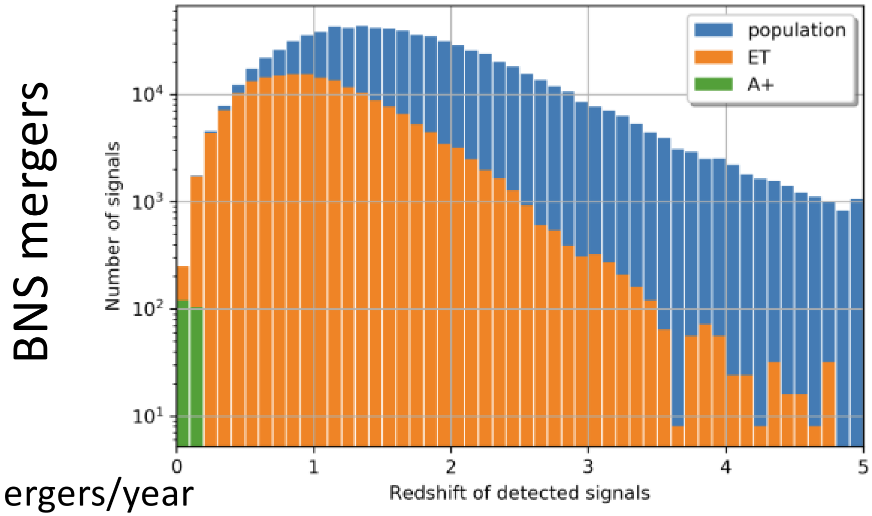
ET Science in a nutshell

- ET will explore almost the entire Universe listening the gravitational waves emitted by black hole, back to the dark ages after the Big Bang
- ET will detect, with high SNR, hundreds of thousands coalescences of binary systems of Neutron Stars per year, revealing the most intimate structure of the nuclear matter in their nuclei

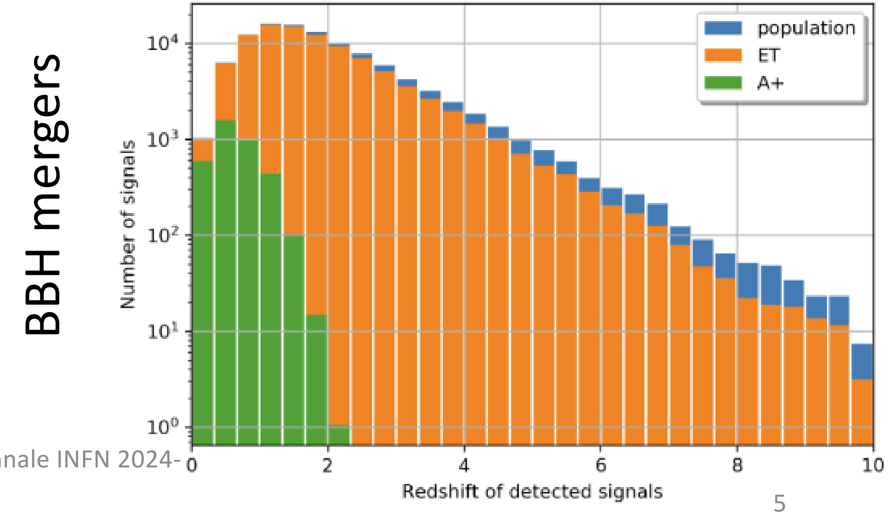


Credit: M.Branchesi

Compact Object Binary Populations



O(10^5) mergers/year



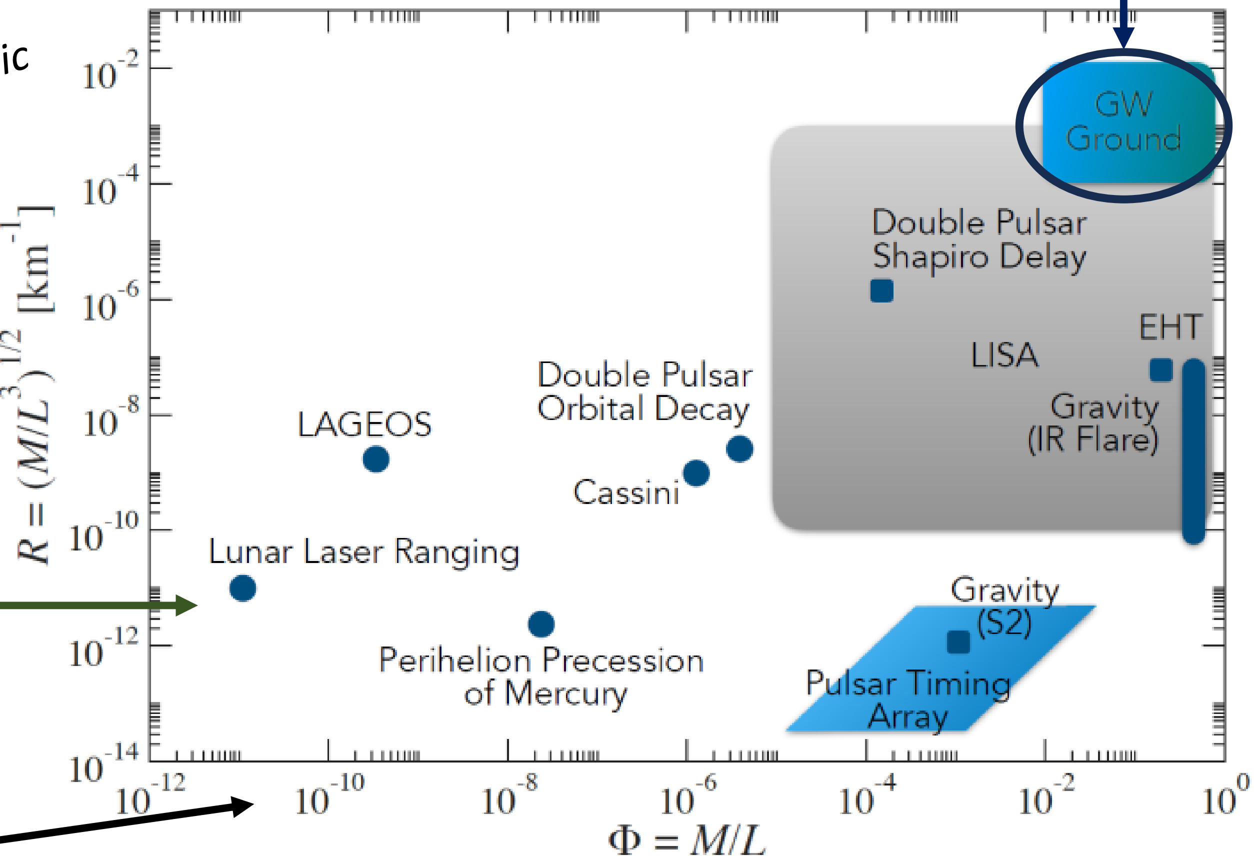
GW Science with ET

GWs from coalescing Binary Black Hole (BBH) allows to test GR in **strong-field** regime

Inverse of the characteristic curvature length scale

Solar System orbital measurements probing the weak-field regime

characteristic gravitational potential

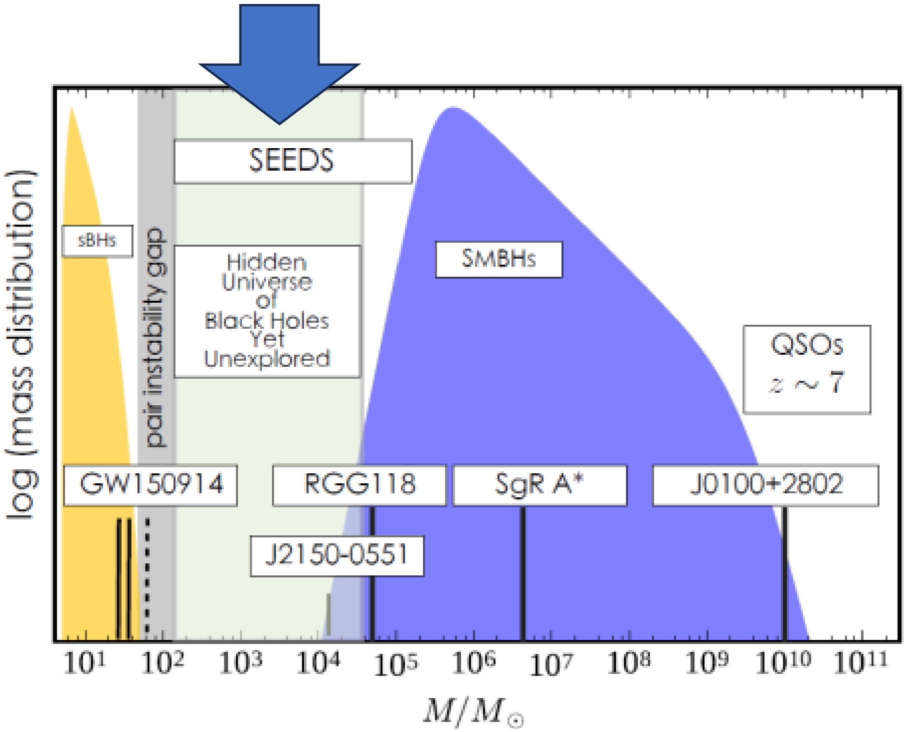


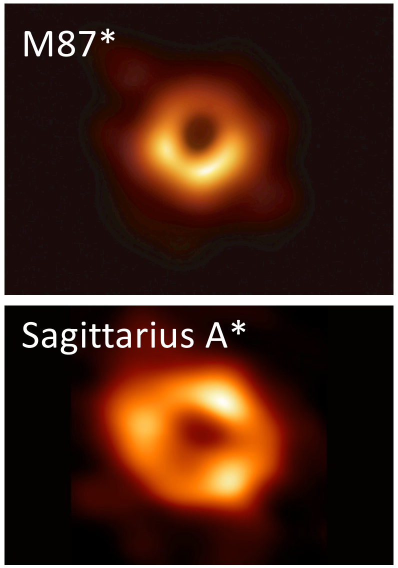
Yunes N. et al.
Phys. Rev. D 94, 084002 (2016)
Edited by ET science case team

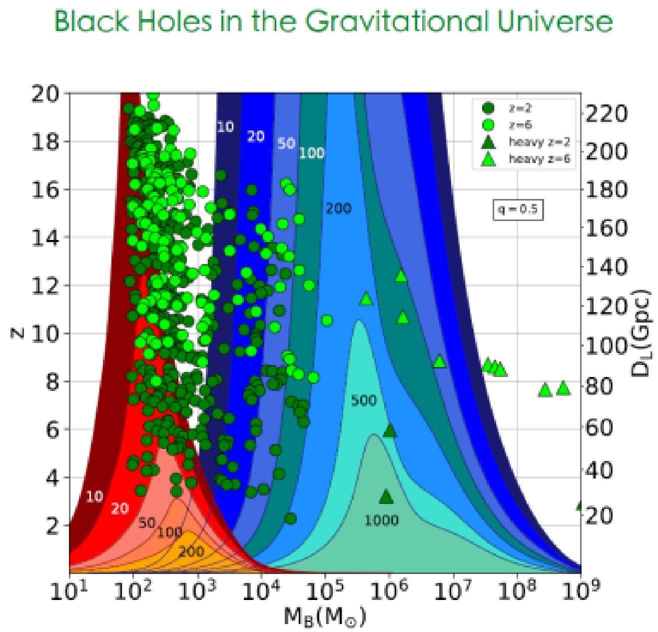
GW Science with ET

Seeds and Supermassive Black Holes

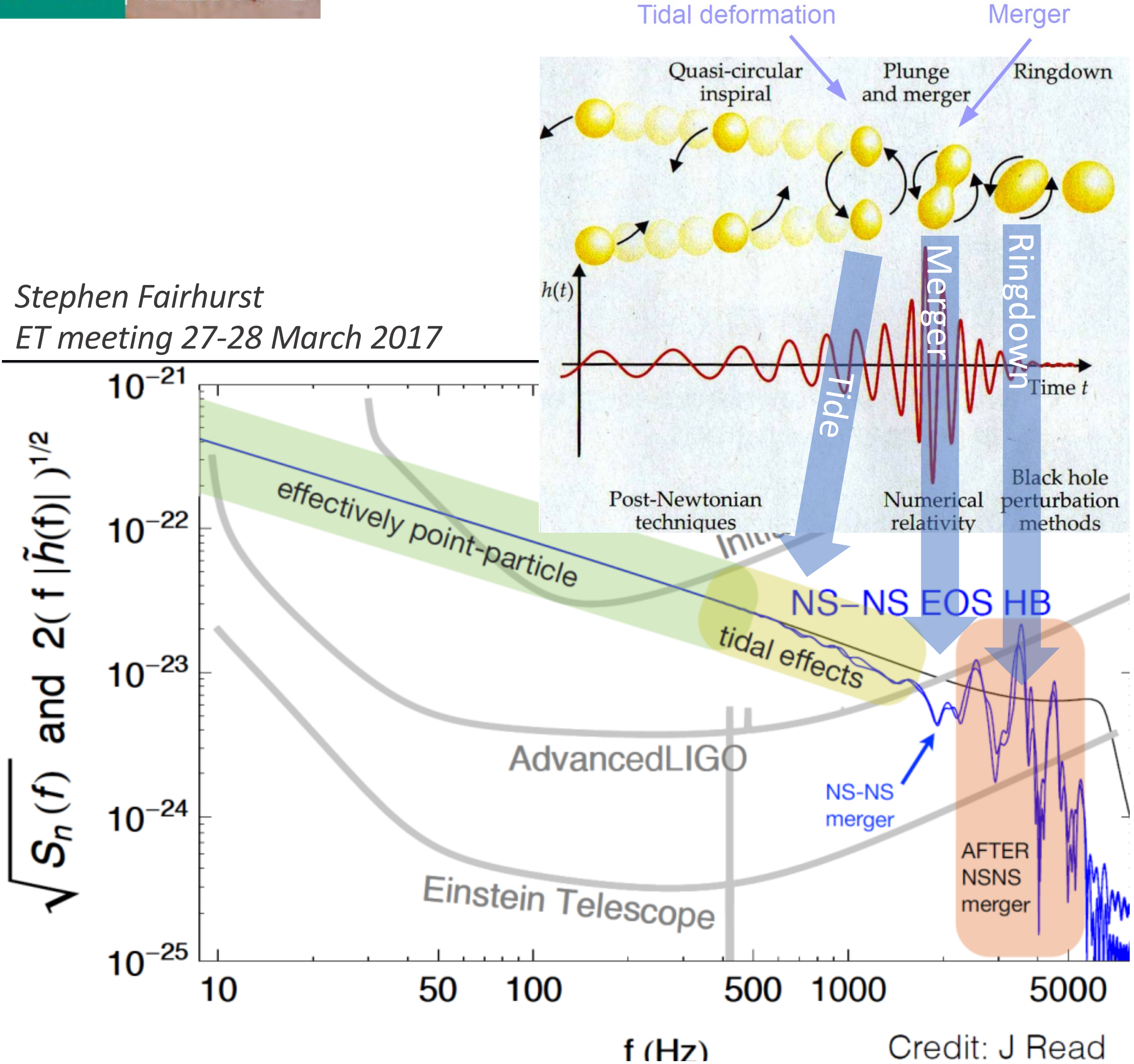
- Supermassive Black Holes (SMBHs) are present at the center of many galaxies:
  - What is their history? How have they formed? What are the seeds?



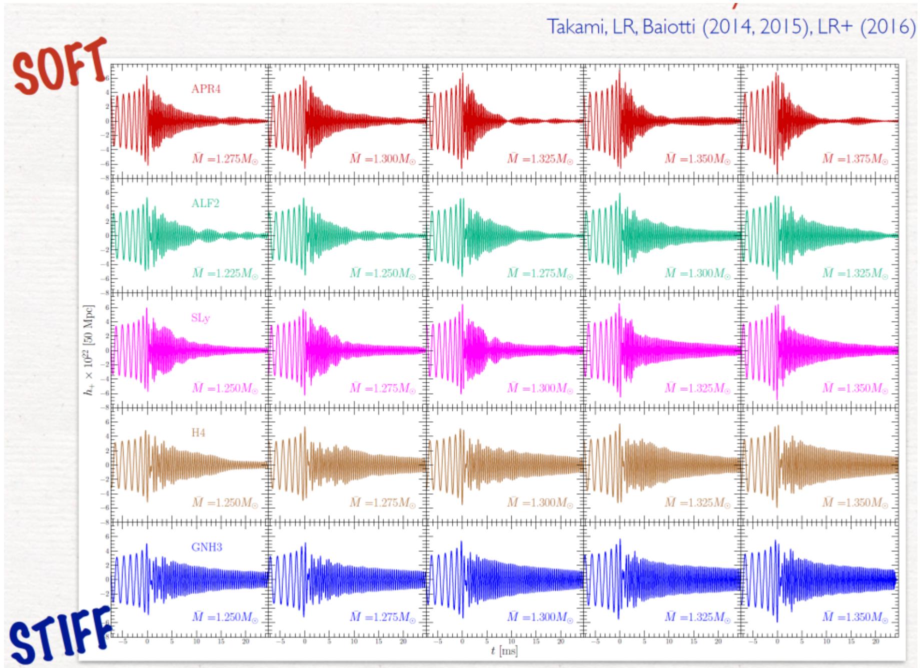




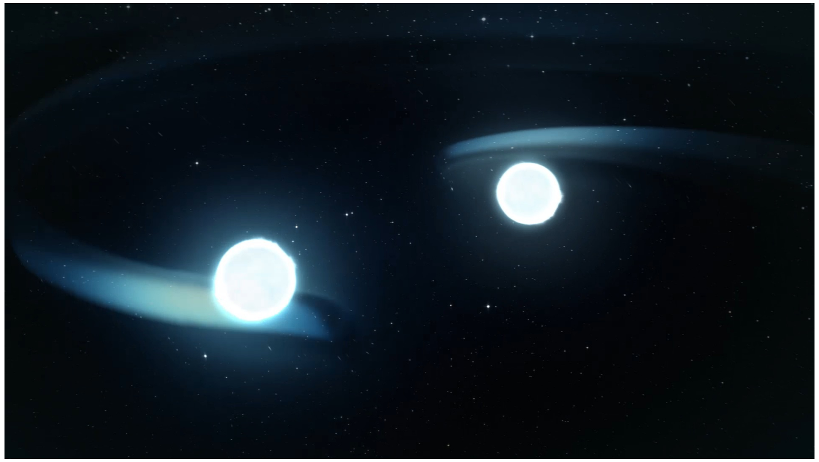
GW Science with ET



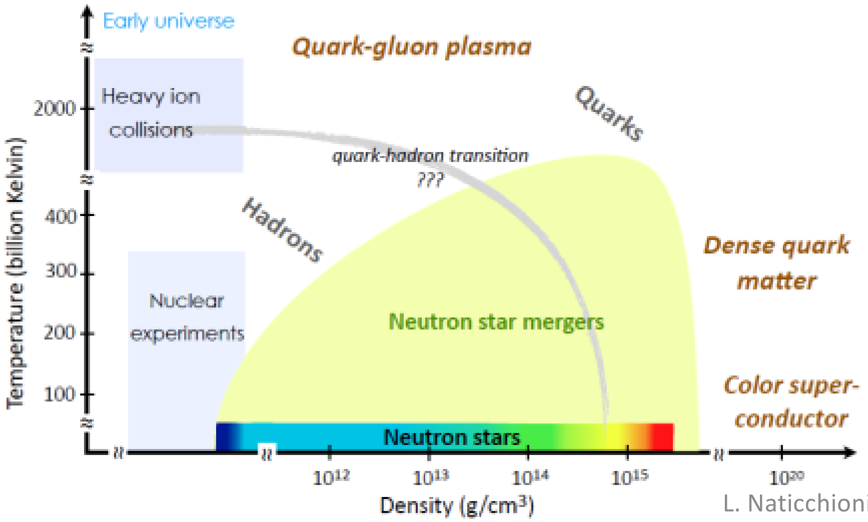
Structure of a Neutron Star: equation of state



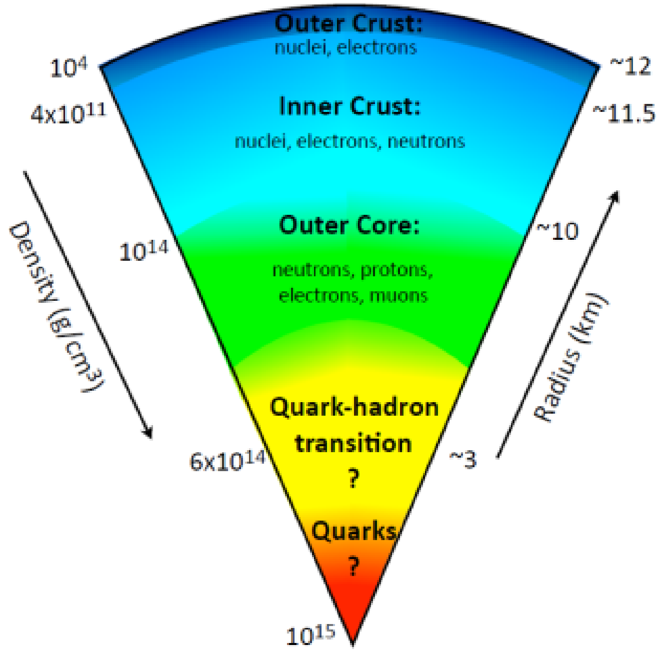
GW Science with ET



- Neutron stars are an **extreme laboratory for nuclear physics**
  - The external crust is a Coulomb Crystal of progressively more neutron-reach nuclei.
  - The core is a Fermi liquid of uniform neutron-rich matter ("Exotic phases"? Quark-Gluon plasma?)



- Tidal deformation from the dephasing in the GW signal → constrain the EOS of the NS.
- EM information → more stringent constrain.
- EOS describes the status of the matter in the over-critical pressure condition.



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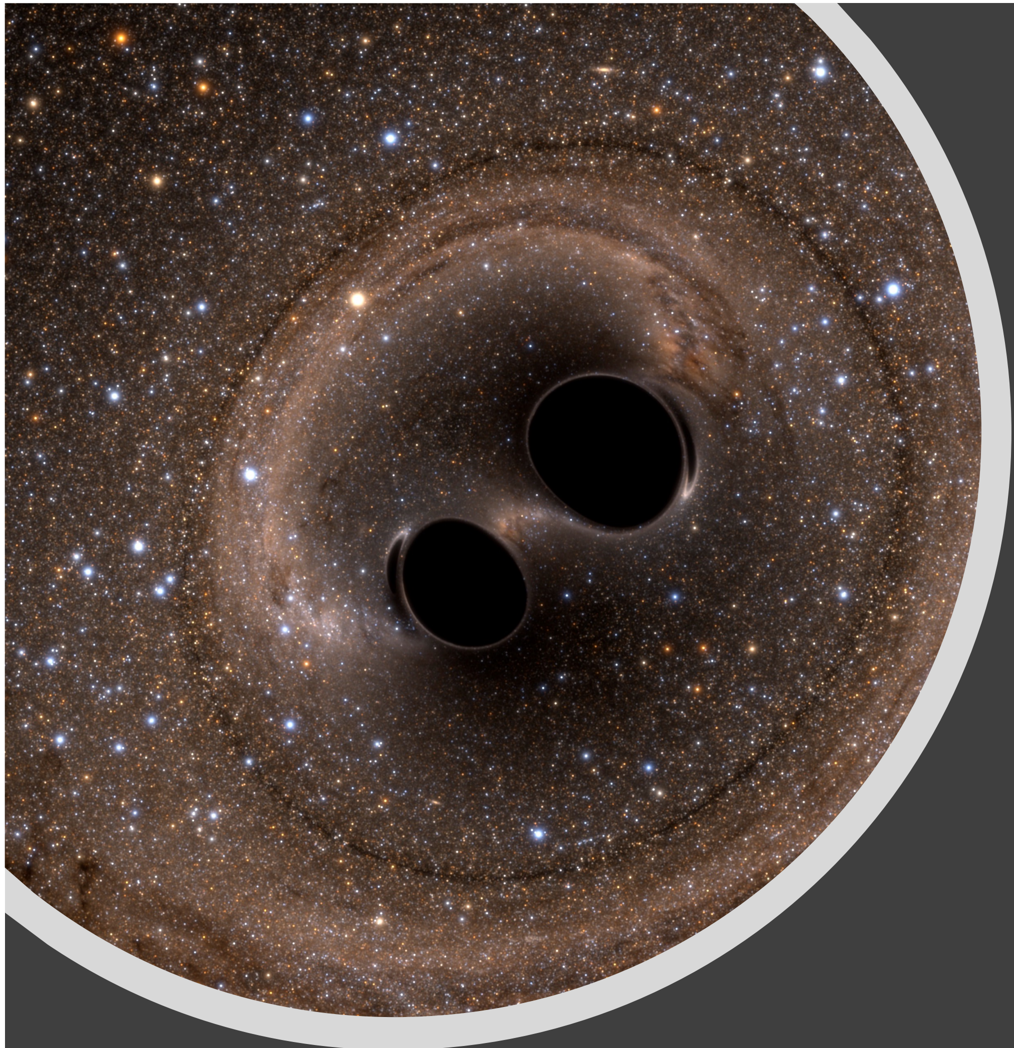
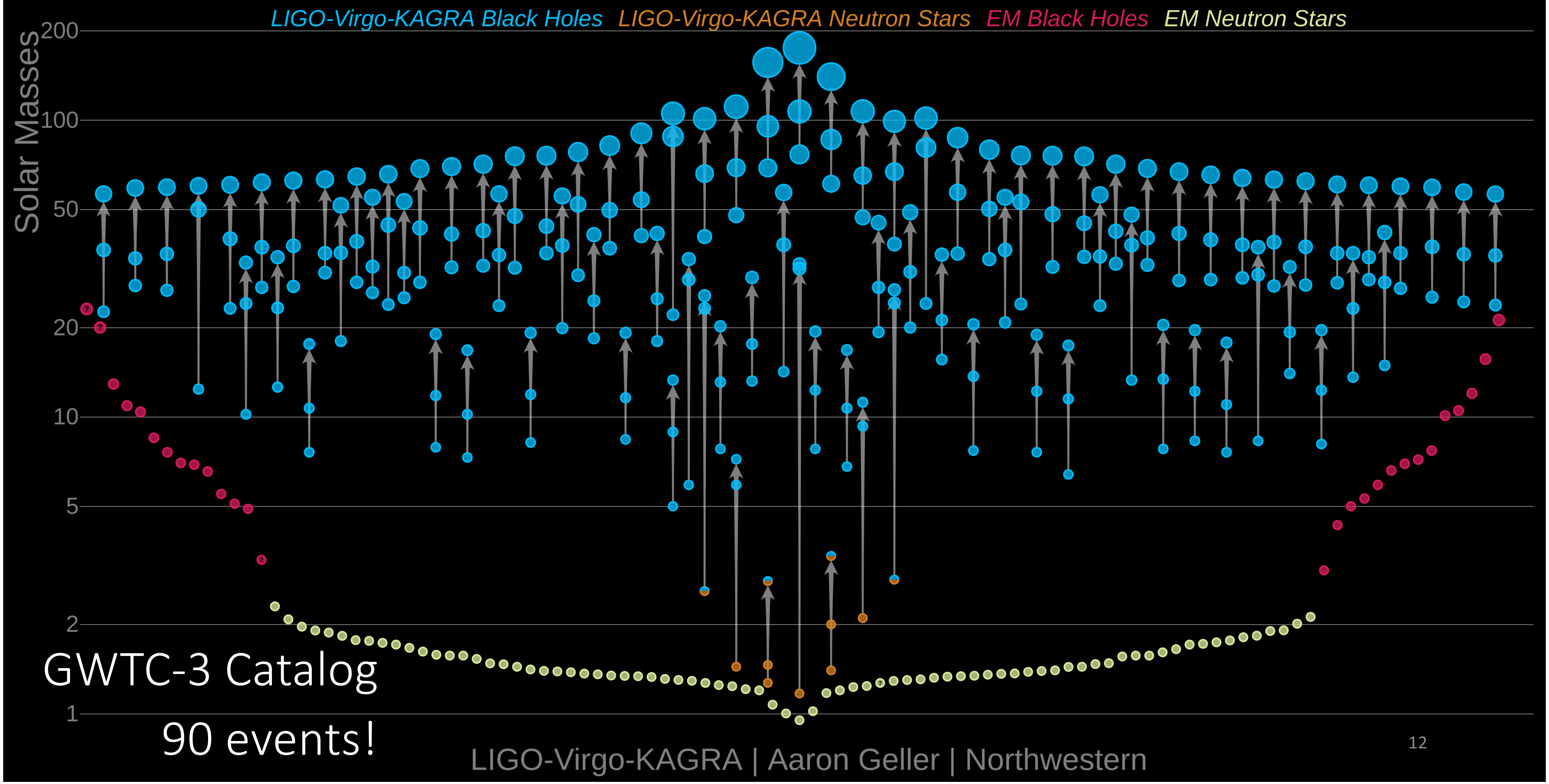


Milestones reached by Advanced detectors (LVK)

- First detection of GWs from a BBH system (GW150914)
  - Physics of BHs
- First three-detectors (LIGO-Virgo) detection of BBH (GW170814)
  - Localization: 30x thanks to Virgo, from 70 to 2 Mpc^3
- First detection of GWs from a BNS system (GW170817)
  - Birth of the multimessenger astronomy with GWs
  - Costraining EOS of NS
- LVK network: localisation capabilities of a GW source
- Measurement of the GW propagation speed
- Test of GR
- Alternative measurement of H_0
- GW polarisations
- Intermediate mass black hole (GW190521)

Masses in the Stellar Graveyard

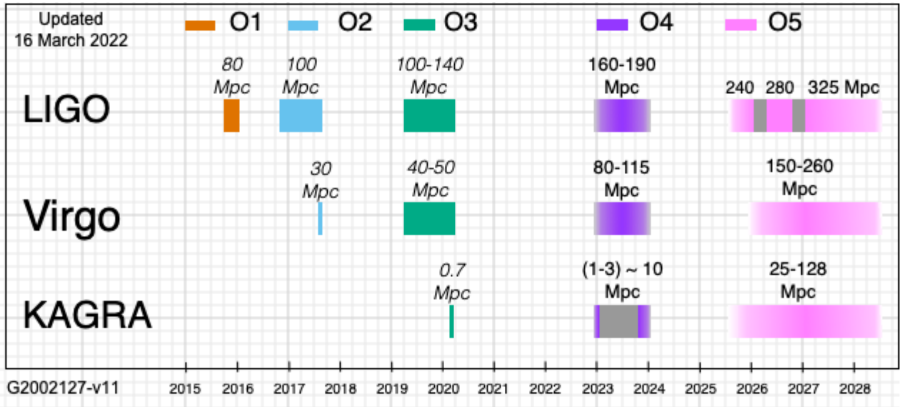


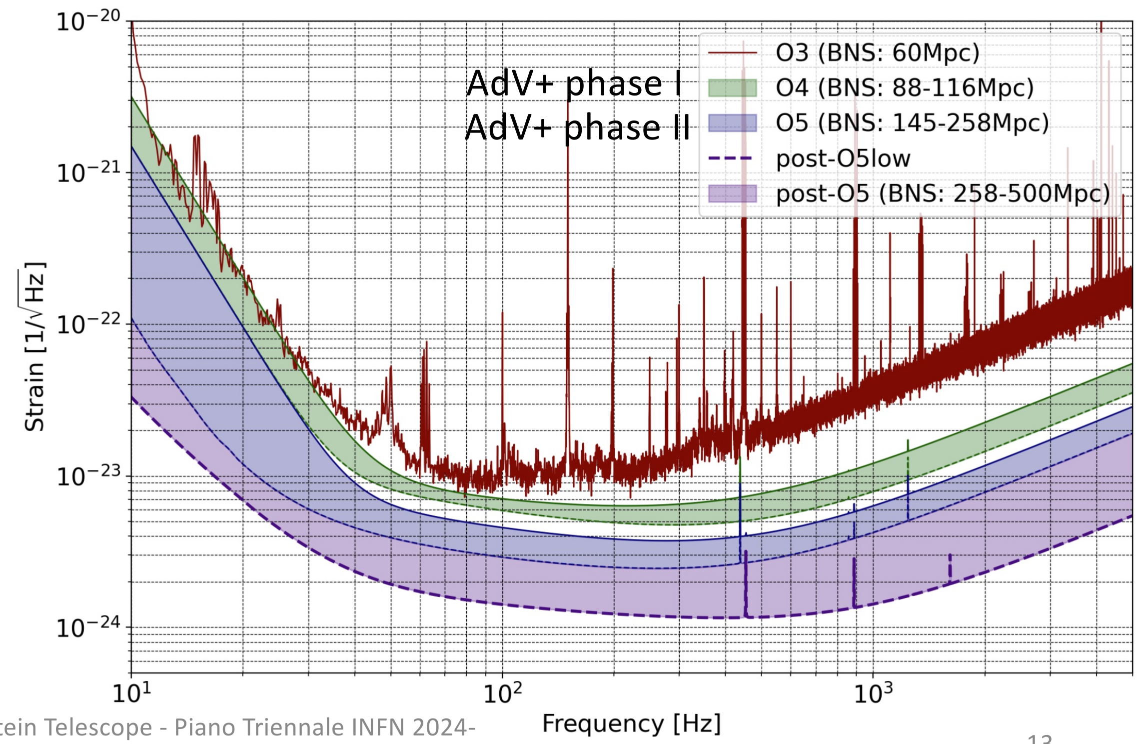
GWTC-3 Catalog

90 events!

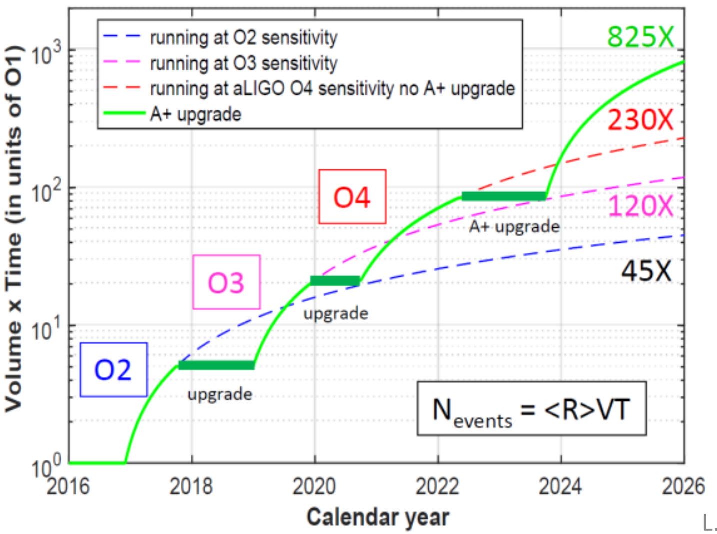
Near future

- **O4 run started on May 24th** (LIGO);
- Virgo will join in autumn ’23;
- Current detectors have a well-defined plan of upgrades and science runs in the next years.



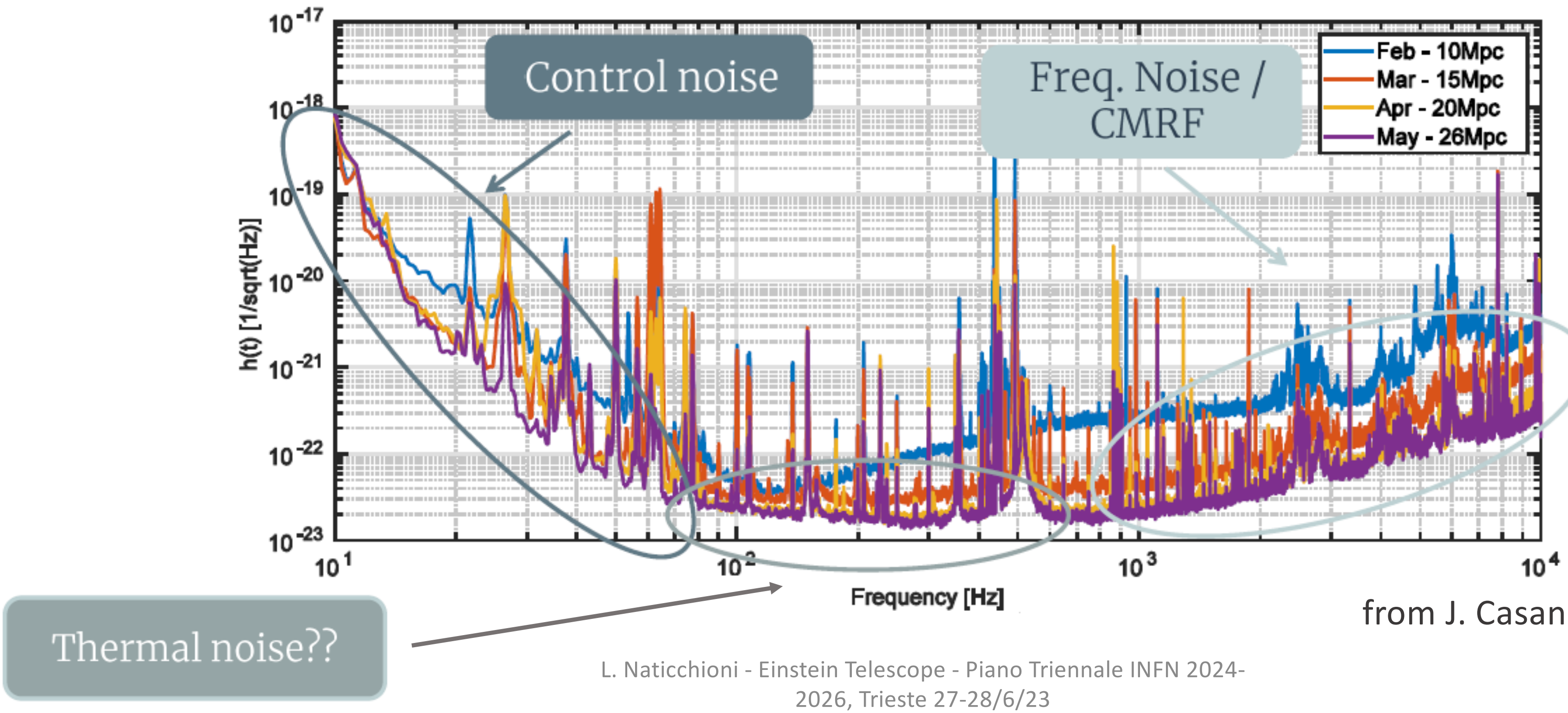


Binary Neutron Stars Events



Near future

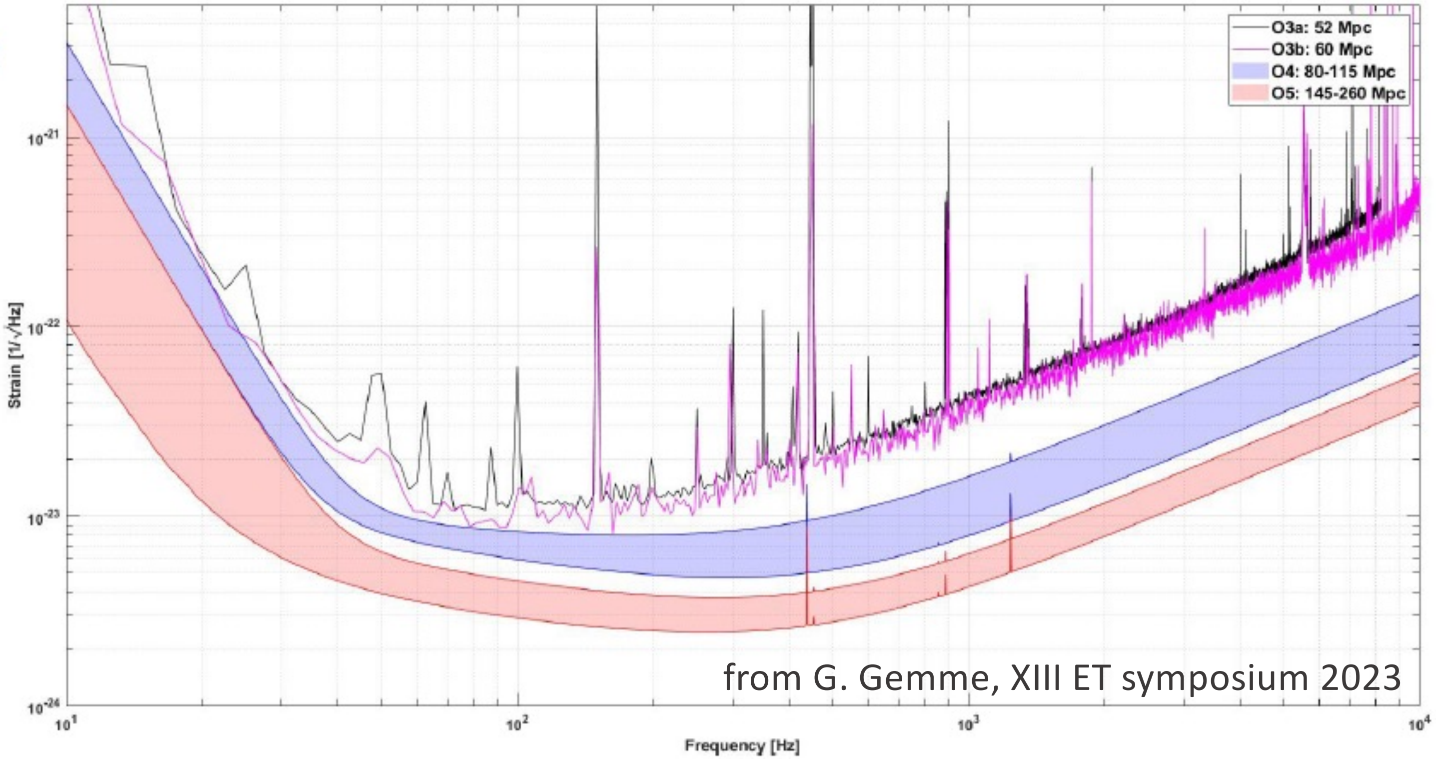
- Virgo collaboration decided to postpone joining O4 in order to improve the detector sensitivity.
- Many important technical issues faced (work in progress), but to reach the nominal sensitivity to enter O4 a longer commissioning is now required.



from J. Casanueva, GWADW23

Near future Advanced Virgo+

- Phase I: reduce quantum noise, hit against thermal noise
  - BNS range ~ 100 Mpc
- Phase II: lower thermal noise wall
  - BNS range ~ 200 Mpc

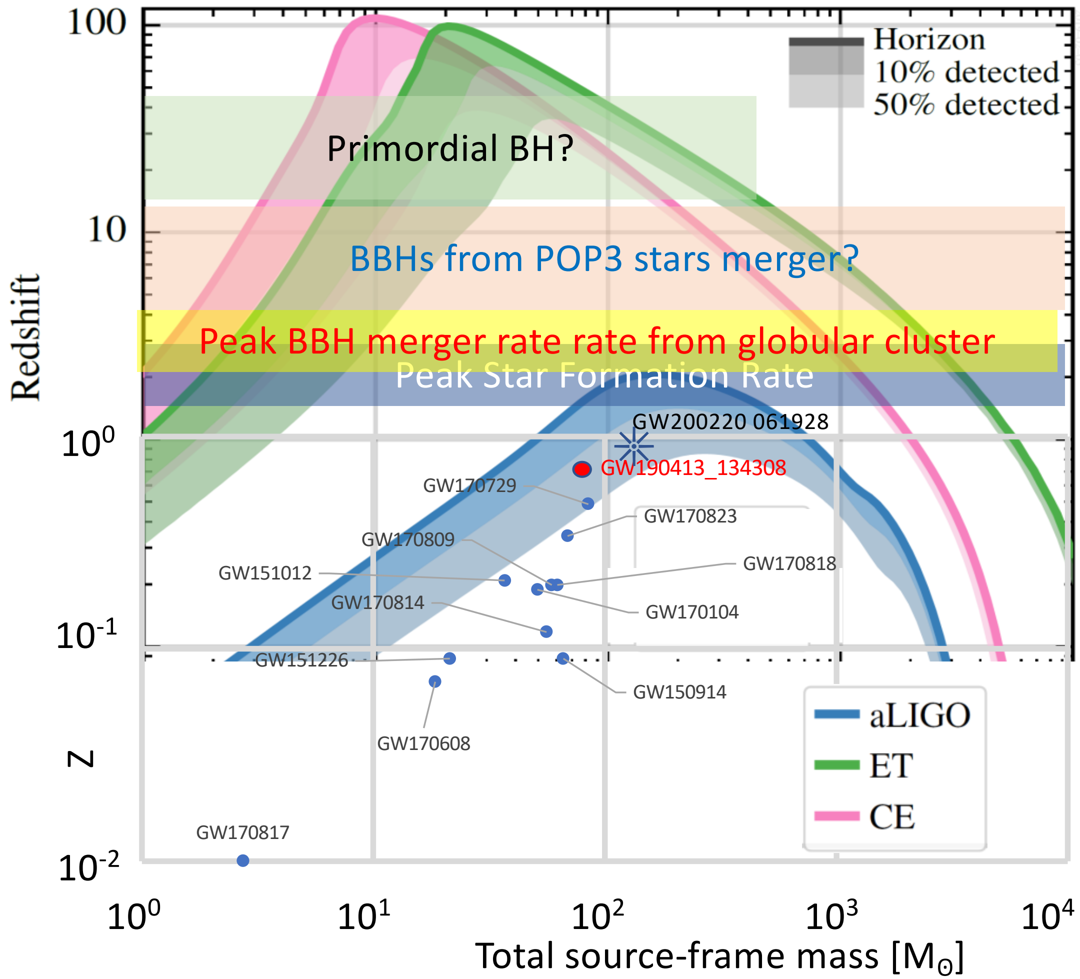


from G. Gemme, XIII ET symposium 2023

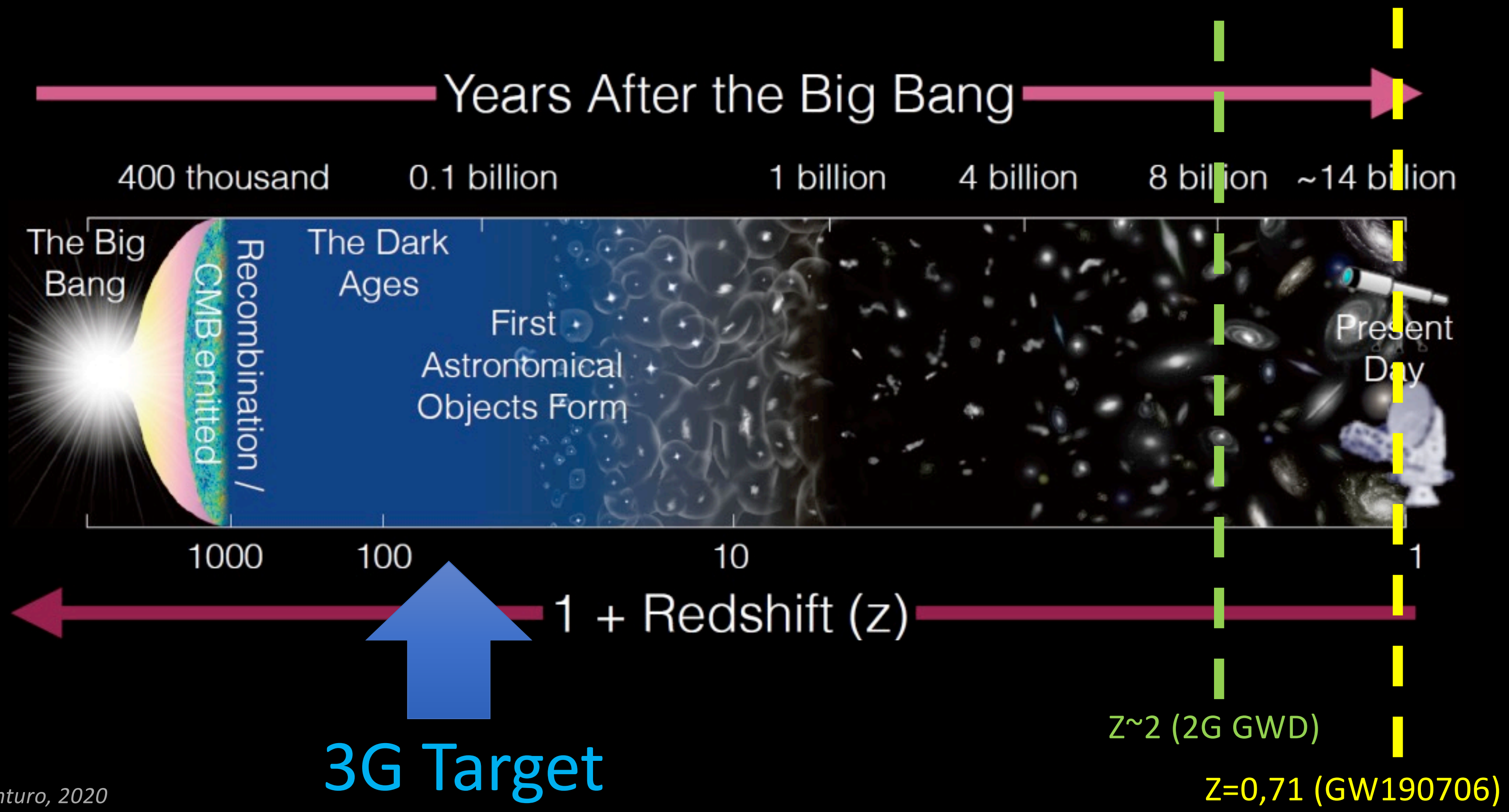
A successful Virgo operation during the next observing runs is **crucial**, also for ET!

Near future

- 2nd generation GW detectors are exploring the *local Universe*, initiating the precision GW astronomy, but to have *cosmological* investigations **a factor of 10 improvement in terms detection distance is needed**.
- Great results achieved even though with a sensitivity below the nominal one.
- Post-O5 Advanced detector will be able to expand the observation horizon, but still local universe!
- **3G ground-based detectors will be required to access the high redshift Universe!**



Detection distance of GWD



Adapted from M.Punturo, 2020
Image credit: NAOJ/ALMA
http://alma.mtk.nao.ac.jp/

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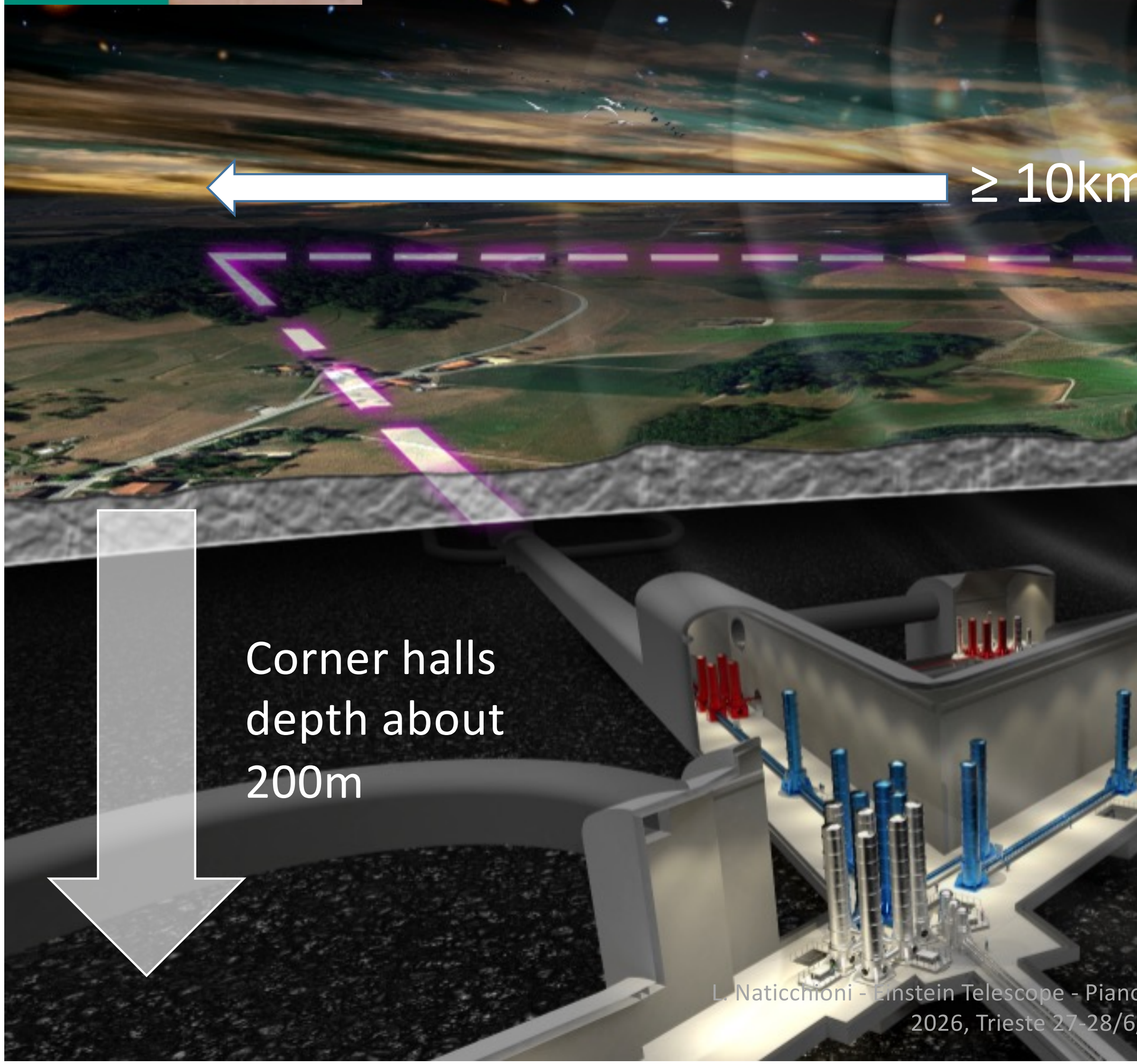
A 3G GW Observatory



ET pioneered the idea of a 3rd generation GW observatory:

- A new infrastructure capable to host future upgrades for decades without limiting the observation capabilities.
- A sensitivity at least 10 times better than the (nominal) advanced detectors on a large fraction of the (detection) frequency band.
- A dramatic improvement in sensitivity in the low frequency (2Hz – 10Hz) range.
- High reliability and improved observation capability .
- Polarisation disentanglement, localization, duty cycle.

ET will be not alone…

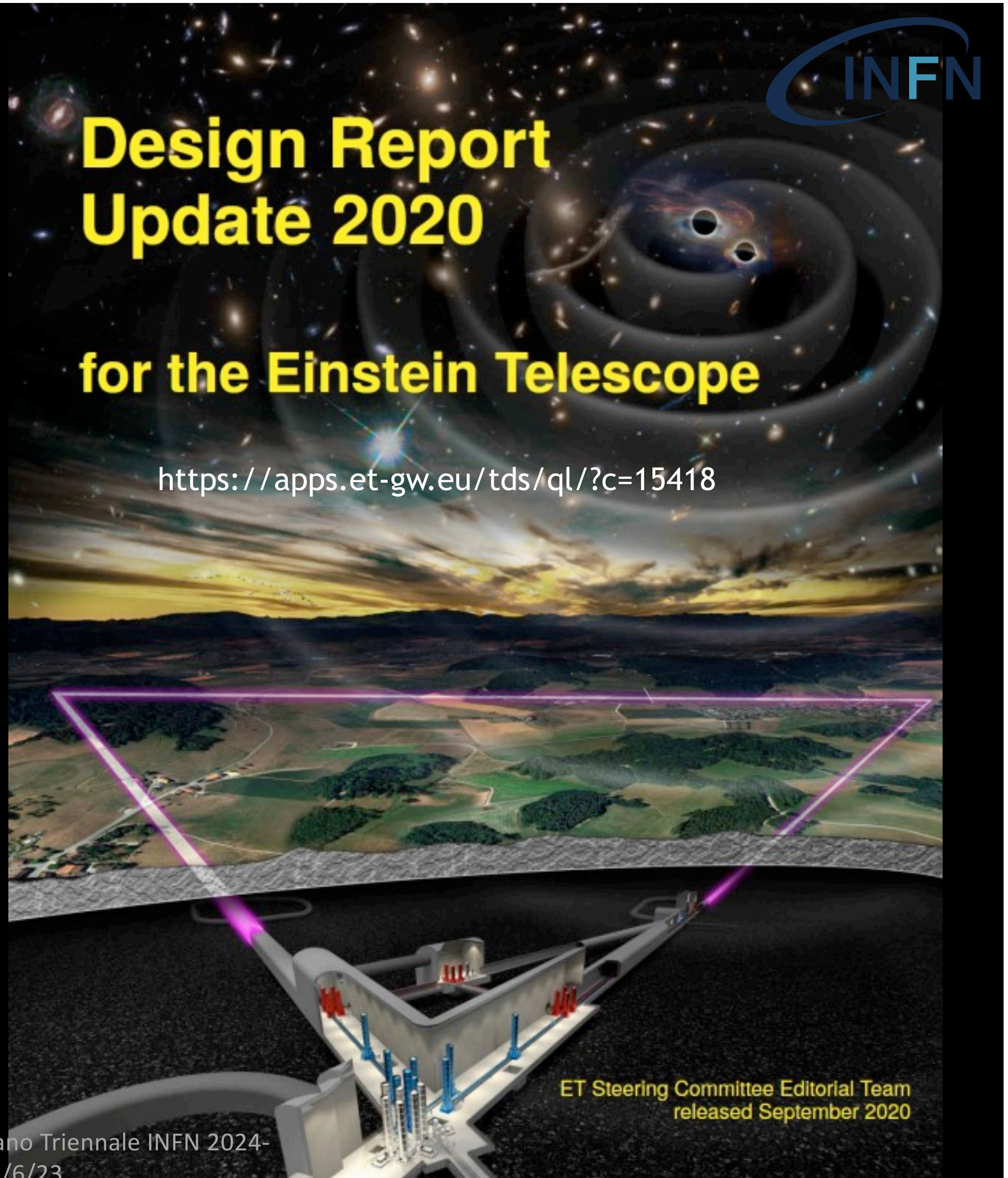
40 km and 20 km L-shaped surface observatories
10x sensitivity of today's observatories (Advanced LIGO+)
Global network together with Einstein Telescope

Artist: Eddie Anaya (Cal State Fullerton)

Design of ET

- 2004-3G idea
- 2005-ET idea
- 2007-ET CDR proposal
- 2011-ET CDR
- 2012-2018 Tech development (in background)
- 2020-ESFRI ET proposal

ESFRI



European Strategy Forum on Research Infrastructures

ESFRI Roadmap

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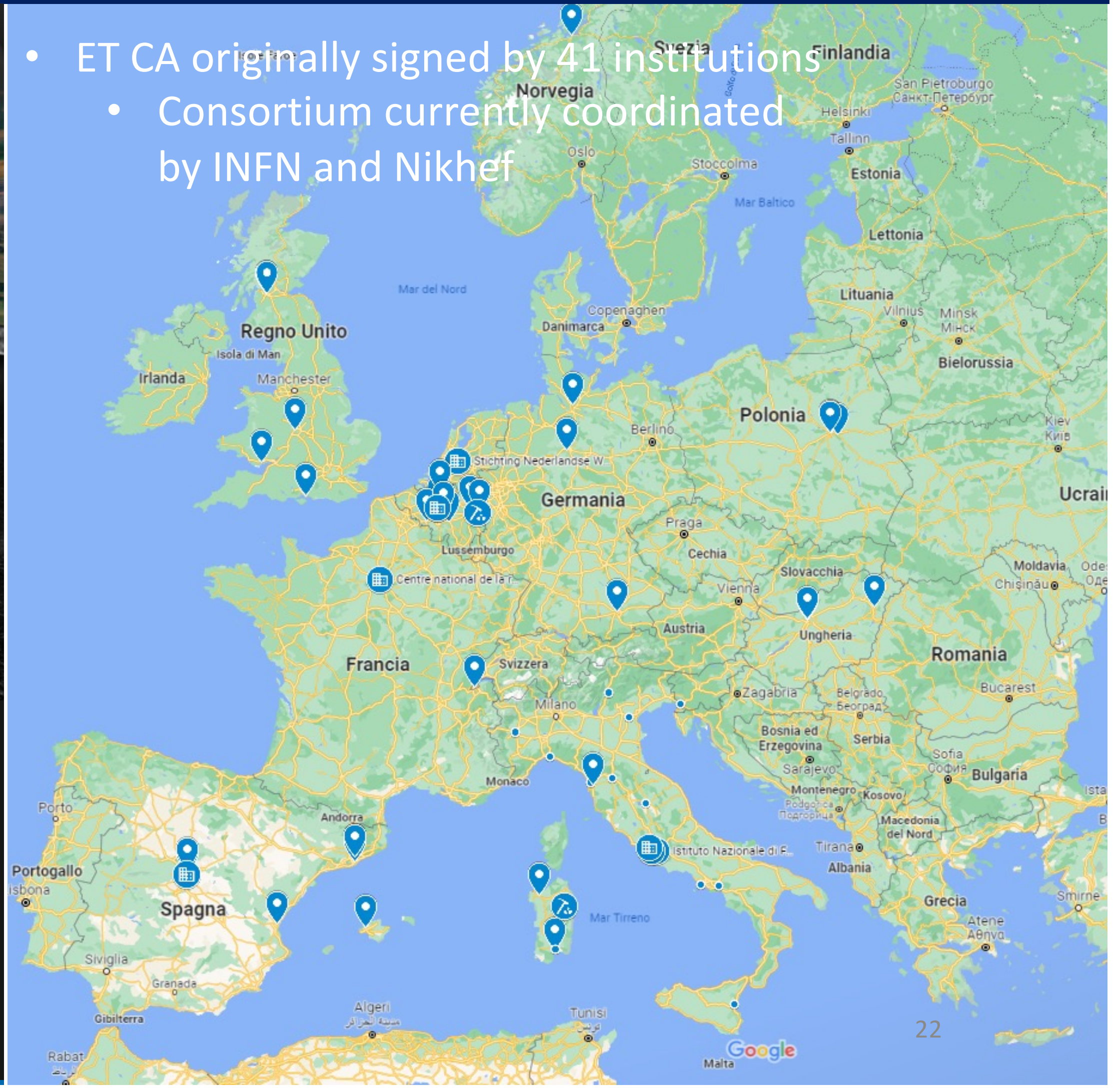
ESFRI partners:

- **Italy** (Lead Country)
- Belgium
- Netherlands
- Poland
- Spain

The ET-PP (preparatory phase) funded by EU commission with 3.45M€: t_0=01/09/2022

It includes also agencies and institutions belonging to:

- **Austria**
- **France**
- **Germany**
- **Hungary**
- **Switzerland**
- **UK**

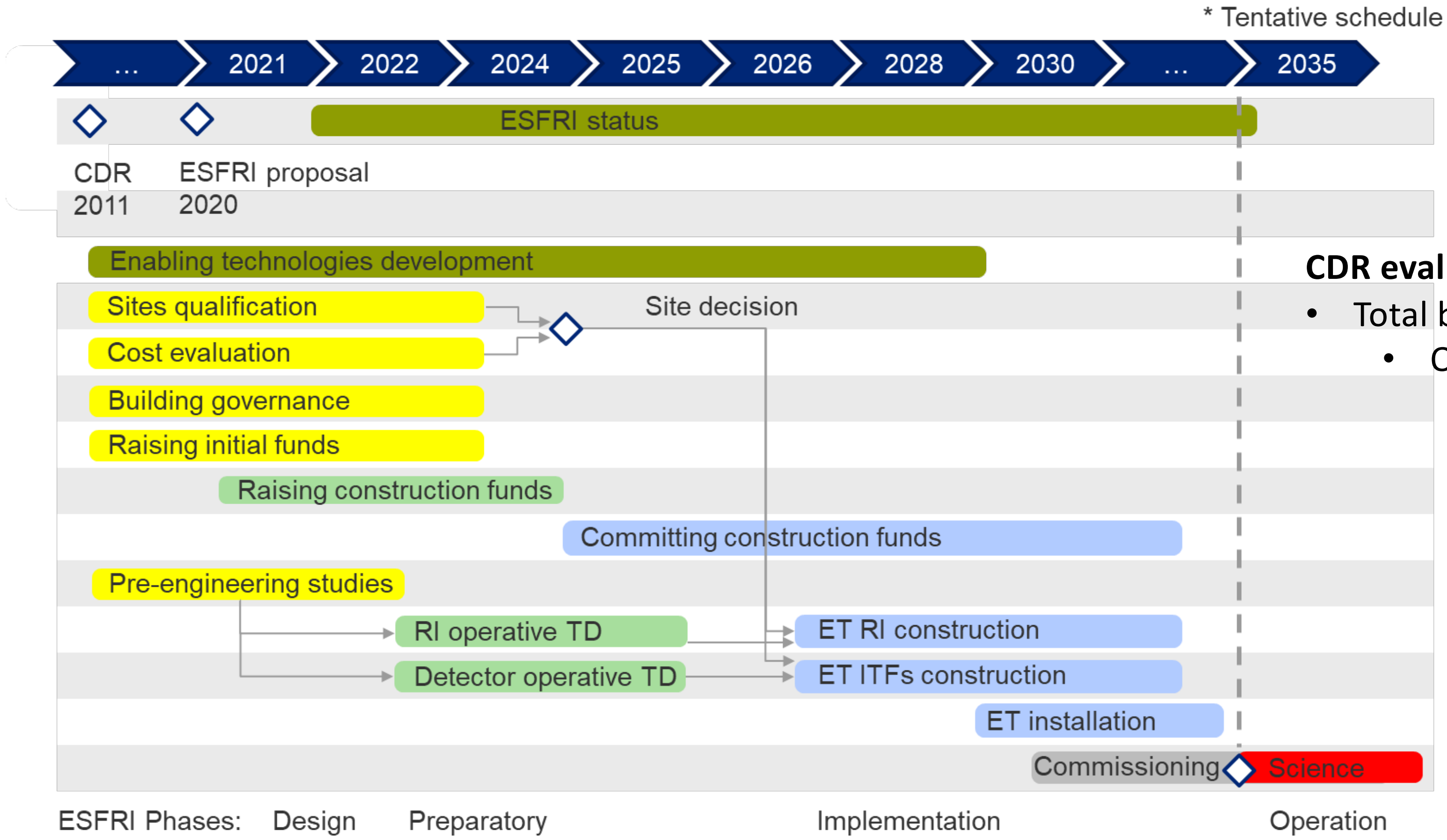


- ET CA originally signed by 41 institutions
  - Consortium currently coordinated by INFN and Nikhef

ET timeline presented to ESFRI

As expected, the ESFRI approval boosted the activities at all the levels:

- Scientists
- Agencies
- Governments



CDR evaluations:

- Total budget ~ 2G€
  - Observatory budget ~ 1.7G€
    - Infrastructure Budget:
      - Civil infrastructure: ~930M€
      - Vacuum system: ~570M€

ET: Key elements

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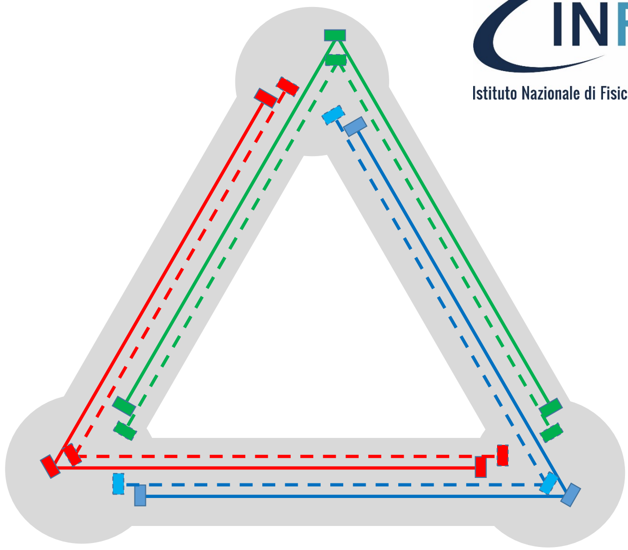
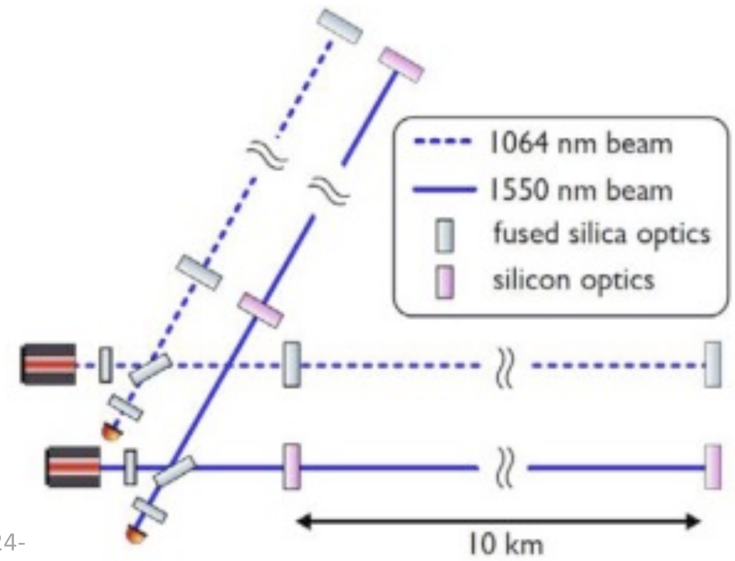
Requirements

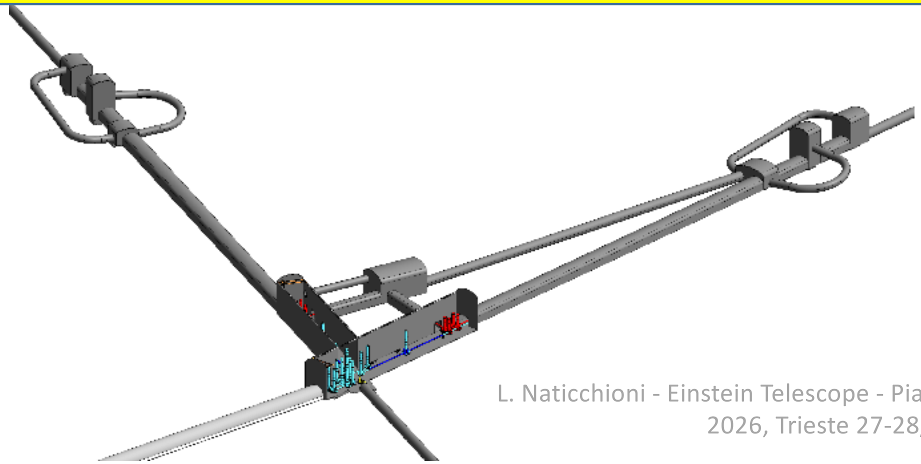
- Wide frequency range
- Massive black holes (LF focus)
- Localisation capability
- (more) Uniform sky coverage
- Polarisation disentanglement
- High Reliability (high duty cycle)
- High SNR

Design Specifications

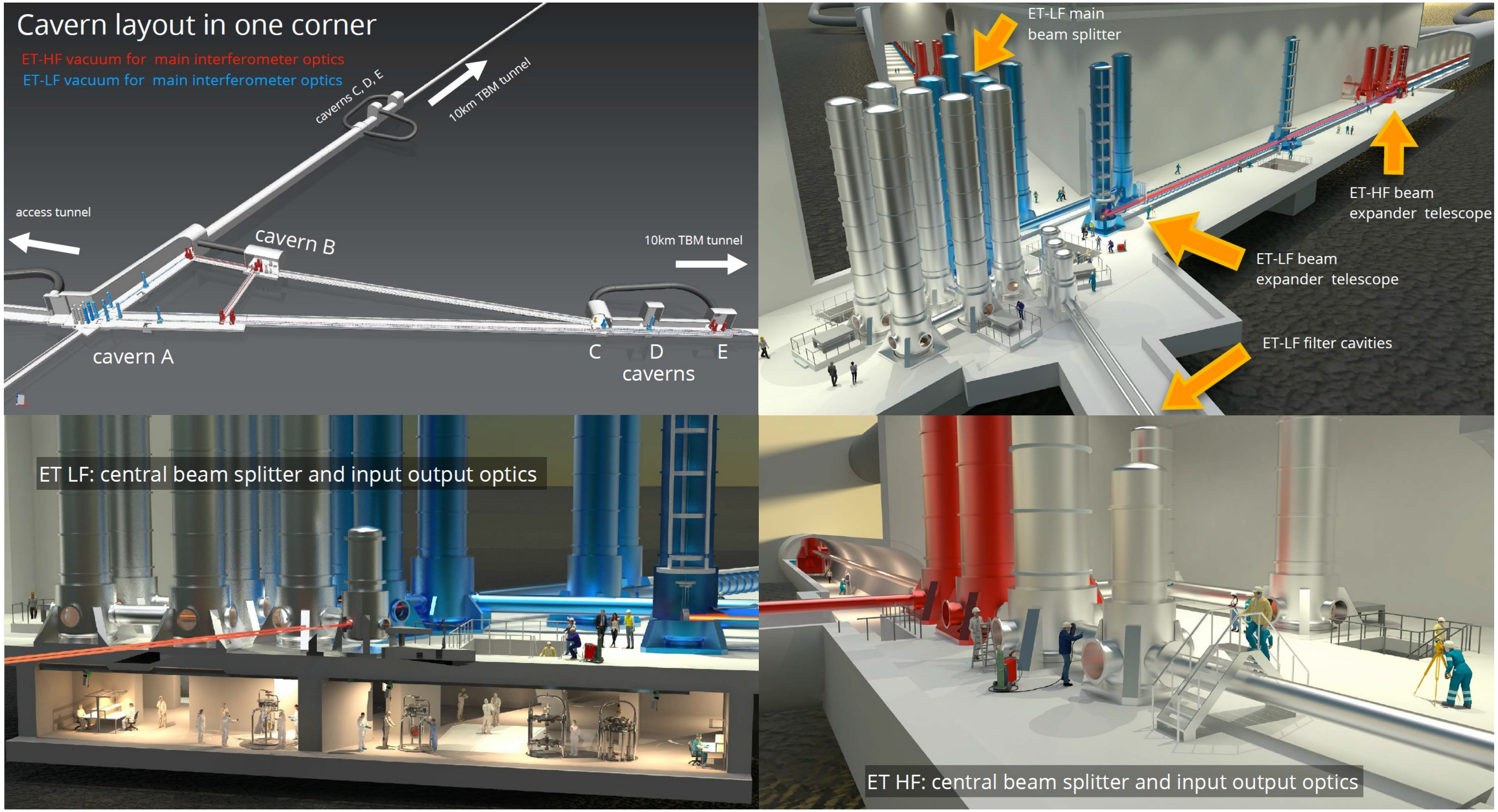
- Xylophone (multi-interferometer HF+LF) Design
- Underground
- Cryogenic (LF)
- Triangular shape
- Multi-detector design
- Longer arms







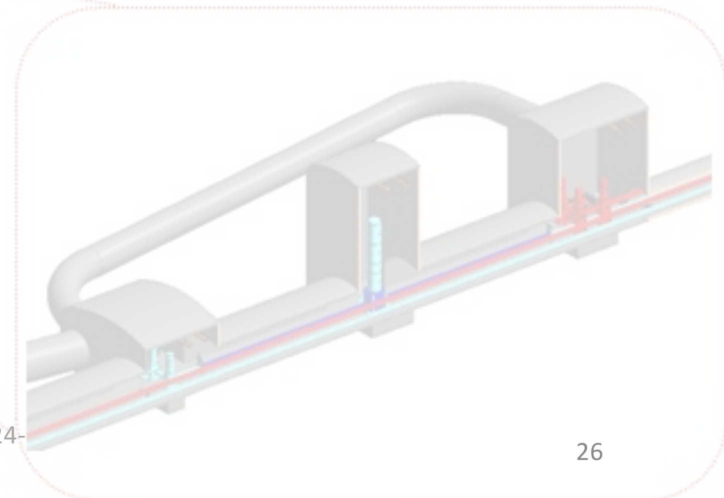
ET: large scale and complex infrastructure



Credit: A.Freise, 2020 XI ET Symposium

Challenging Engineering: key points

- **~30km of underground tunnels**
  - Safety (fire, cryogenic gasses, escape lanes, heat handling during the vacuum pipe backing)
  - Noise (creeping, acoustic noise, seismic noise, Newtonian noise)
  - Minimisation of the volumes, but preservation of future potential)
  - Water handling, hydro-geology and tunnels inclination
  - Cost!
- **Large caverns**
  - In addition to the previous points:
  - Stability
  - Cleanliness
  - Thermal stability
  - Ventilation and acoustic noise



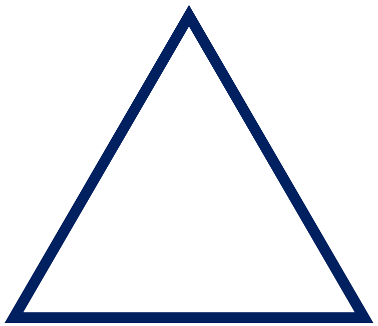
ET design: Δ or (two) L

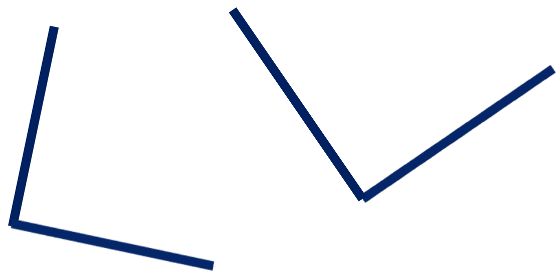
In the last couple of years, the collaboration started the evaluation of the best configuration for ET, considering the alternative of two L configuration (as LIGO, Cosmic Explorer) to maximize the science return and reduce risks.

Since 2011 (CDS, triangle configuration) the situation drastically changed:

- ❑ First detections, GTWC-3 catalog → BH population → new SF and evolution models;
- ❑ Science case developed;
- ❑ Know-how with advanced (L) detectors;
- ❑ International scenario (+ Cosmic Explorer in US);
- ❑ Two candidate sites strongly supported (and a potential third site…).

The collaboration is analyzing both configurations: **science case**, **risk assessment**.





ET design: Δ or (two) L

- **COst Benefit Analysis committee (COBA)** *several independent codes used, same results*
  - Triangle (10,15 km) vs 2L (15-20 km, parallel or 45°), keeping xylophone.
  - 2L (15km, 45° oriented) give better science return with respect to 10km triangle and similar to 15km triangle.
  - L configuration ↔ two sites.
  - 2L only High Frequency (HF) is better than single 10km triangle full xylophone (HF+LF)!
    - Two stage approach possible: commissioning of HF with a good science return, then moving to full HF-LF at room temperature and then cryogenic.
  - 200-pages document and a publication submitted: *2L configuration is generally favoured*.

    ET-0084A-23: https://apps.et-gw.eu/tds/ql/?c=16584
- **ET Risk Assessment committee (ETRAC)** *experts in commissioning, led by L. Barsotti (LIGO)*
  - Identified risk categories*, defined a risk metric, applied risk metric to risk categories ranked the possible configurations, focusing on two of them: **10km-triangle vs 15km-2L**.
  - First report under evaluation/review for further steps of the analysis (e.g. risk mitigation).
  - *2L configuration seems strongly favoured*.

*excluded: political, financial

ET Enabling Technologies

- The multi-interferometer approach asks for two parallel technology developments:

Parameter	ET-HF	ET-LF
Arm length	10 km	10 km
Input power (after IMC)	500 W	3 W
Arm power	3 MW	18 kW
Temperature	290 K	10-20 K
Mirror material	fused silica	silicon
Mirror diameter / thickness	62 cm / 30 cm	45 cm/ 57 cm
Mirror masses	200 kg	211 kg
Laser wavelength	1064 nm	1550 nm
SR-phase (rad)	tuned (0.0)	detuned (0.6)
SR transmittance	10 %	20 %
Quantum noise suppression	freq. dep. squeez.	freq. dep. squeez.
Filter cavities	1×300 m	2×1.0 km
Squeezing level	10 dB (effective)	10 dB (effective)
Beam shape	TEM_{00}	TEM_{00}
Beam radius	12.0 cm	9 cm
Scatter loss per surface	37 ppm	37 ppm
Seismic isolation	SA, 8 m tall	mod SA, 17 m tall
Seismic (for $f > 1$ Hz)	$5 \cdot 10^{-10}\,\mathrm{m}/f^2$	$5 \cdot 10^{-10}\,\mathrm{m}/f^2$
Gravity gradient subtraction	none	factor of a few

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- **ET-LF:**
  - Underground
  - Cryogenics
  - Silicon (Sapphire) test masses
  - Large test masses
  - New coatings
  - New laser wavelength
  - Seismic suspensions
  - Frequency dependent squeezing

- **ET-HF:**
  - High power laser
  - Large test masses
  - New coatings
  - Thermal compensation
  - Frequency dependent squeezing

Challenging engineering

New technology in cryo-cooling

New technology in optics

New laser technology

High precision mechanics and low noise controls

High quality opto-electronics and new controls

Evolved laser technology

Evolved technology in optics

Highly innovative adaptive optics

High quality opto-electronics and new controls

Credit: M. Punturo 2023

Cryo-cooling

Credit: M. Punturo 2023

ET operative temperature ~10K

Key issues

- Acoustic and vibration noises
- Laser absorption and heat extraction
- Cleanliness and contamination
- Cooling time (large masses, commissioning time, …)
- Infrastructures
- Technology (gasses or cryo-coolers)
- Materials
- Safety

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Low Frequency special focus

Credit: M. Punturo 2023

- Underground infrastructure
- 17m tall seismic filtering suspensions
  - Large impact on cavern engineering and costs
- R&D in active-passive filtering systems and seismic sensors

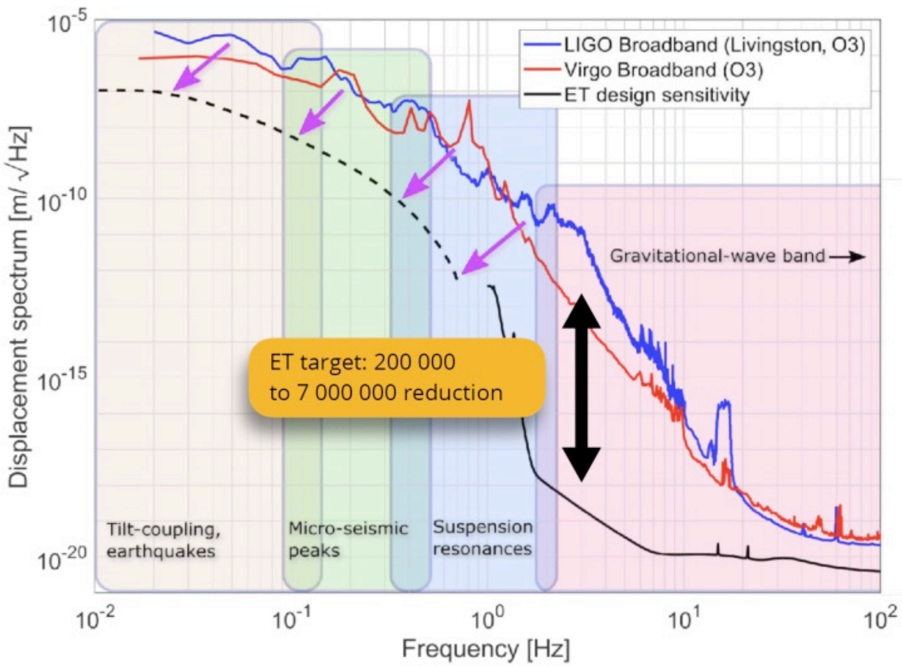
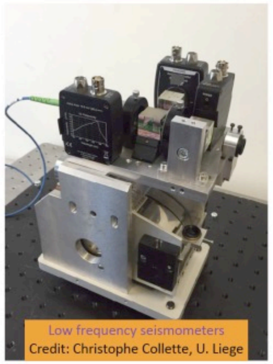
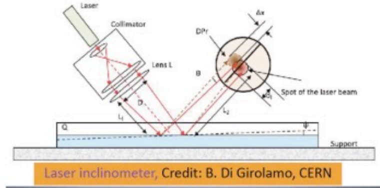


Image: Conor Mow-Lowry

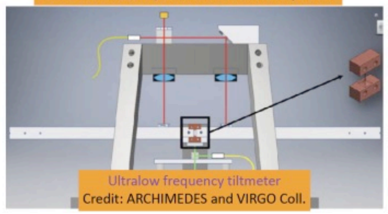
6-D interferometric readout inertial sensor
Credit: Conor Mow-Lowry, VU Amsterdam



Low frequency seismometers
Credit: Christophe Collette, U. Liege



Laser inclinometer, Credit: B. Di Girolamo, CERN



Ultralow frequency tiltmeter
Credit: ARCHIMEDES and VIRGO Coll.

Credits: A.Freise

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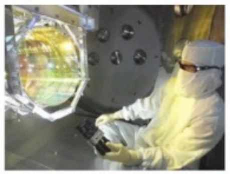
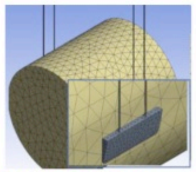
New Optics

Credit: M. Punturo 2023

- **Substrates Challenge:**
  - Substrate (ET-HF silica / ET-LF silicon) of 200 kg-scale, diam≥45cm, with required purity and optical homogeneity/abs.

- **Coating Challenge:**
  - major challenge over recent years:
    - Amorphous dielectric coating solutions often either satisfy thermal noise requirement (3.2 times better than the current coatings) **or** optical performance requirement (less than 0.5ppm) – not both
    - AlGaAs Crystalline coatings could satisfy ET-LF requirements, but currently limited to 200mm diameter.



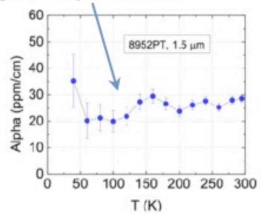


Advanced LIGO – 40 kg / ET 200 kg

Nikon SiO_2

Absorption of "best 45 cm" MCZ Si: 1.5um

Stanford/Glasgow/Berkeley/Caltech 2019



ET EINSTEIN TELESCOPE

New Laser and Opto-Electronic Technology

Credit: M. Punturo 2023

INFN Istituto Nazionale di Fisica Nucleare

Virgo and LIGO developed CW low noise lasers at 1064nm

- In ET-HF their evolution toward higher power will be investigated

In ET-LF we will use a different wavelength because of the Silicon test masses:

- λ=1.55μm or 2μm?

New electro-optic components:

- High quantum efficiency photodiodes
- Low absorption e.o.m.
- Low dissipation faraday isolators

Other relevant challenges

Credit: M. Punturo 2023

- Auxiliary optics, adaptive optics and thermal compensation of optical aberrations
- Precision mechanics, alignment and positioning
- **Vacuum** (*the largest volume under UHV in the World*):
  - More than 120km of vacuum pipes
    - ~1 m diameter, total volume 9.4×10^4 m^3
    - 10^{-10} mbar for H_2, 10^{-11} mbar for N_2 and less than 10^{-14} mbar for Hydrocarbons
  - Joint development with CERN involving ET and CE
- Low noise controls
- Computing
  - Computation intensive, not data intensive
- Governance & Organisation

Summary

- ❑ GW science with ET
- ❑ From Virgo to ET
- ❑ ET: Infrastructure, detector, technologies
- ❑ **The ET collaboration & management**
- ❑ Towards ET in Italy
- ❑ Conclusions

ET Collaboration formed

EINSTEIN TELESCOPE

https://indico.ego-gw.it/event/411/

XII Einstein Telescope Symposium

Official Birth of the ET Collaboration

XII ET Symposium, Budapest on June 7th - 8th

More than 400 scientists,

out of >1200 members of the Collaboration,

attended the meeting in person or remotely.

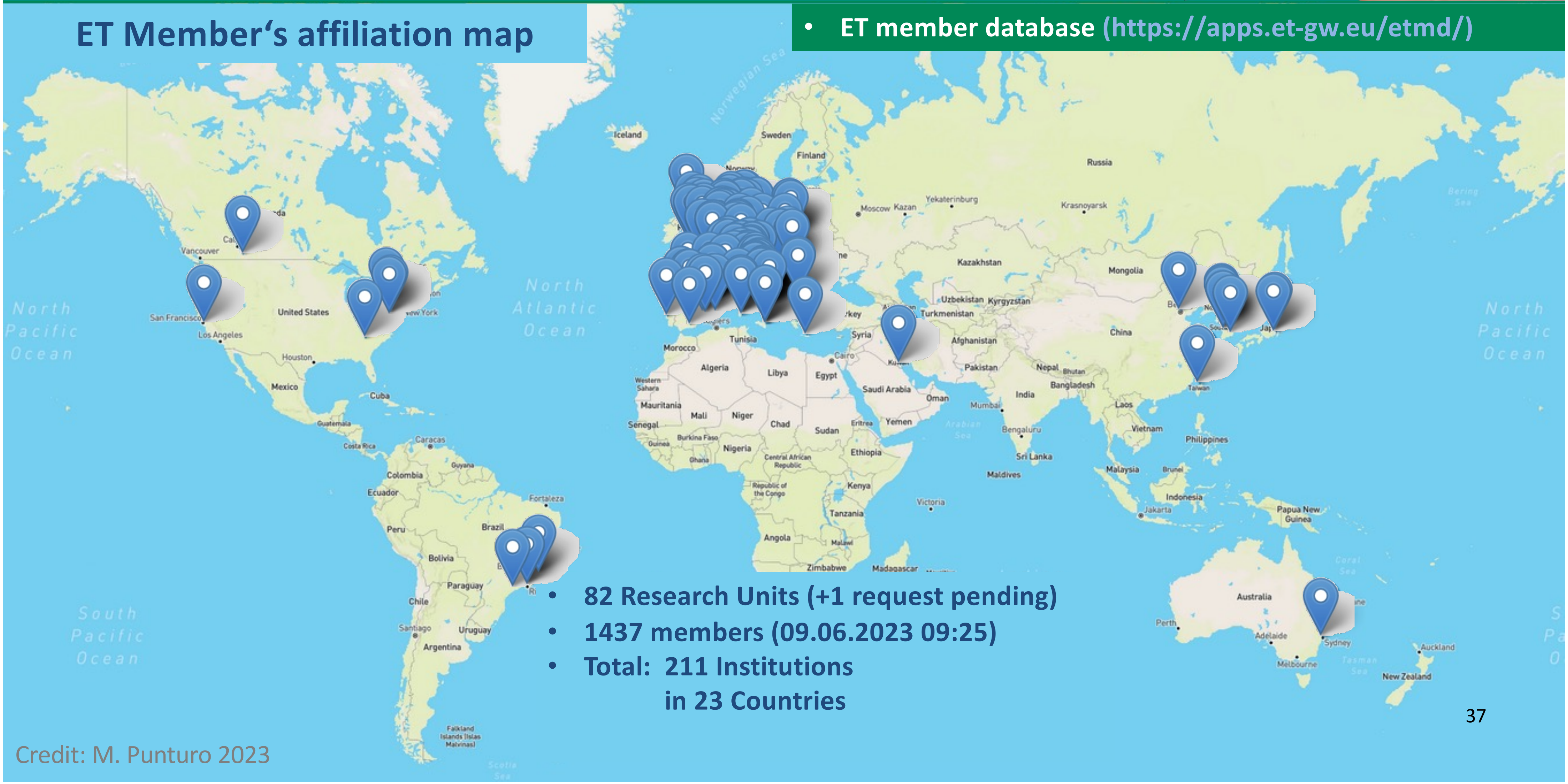
One year ago

The Einstein Telescope Collaboration

EINSTEIN TELESCOPE

ET Member‘s affiliation map

- **ET member database (https://apps.et-gw.eu/etmd/)**

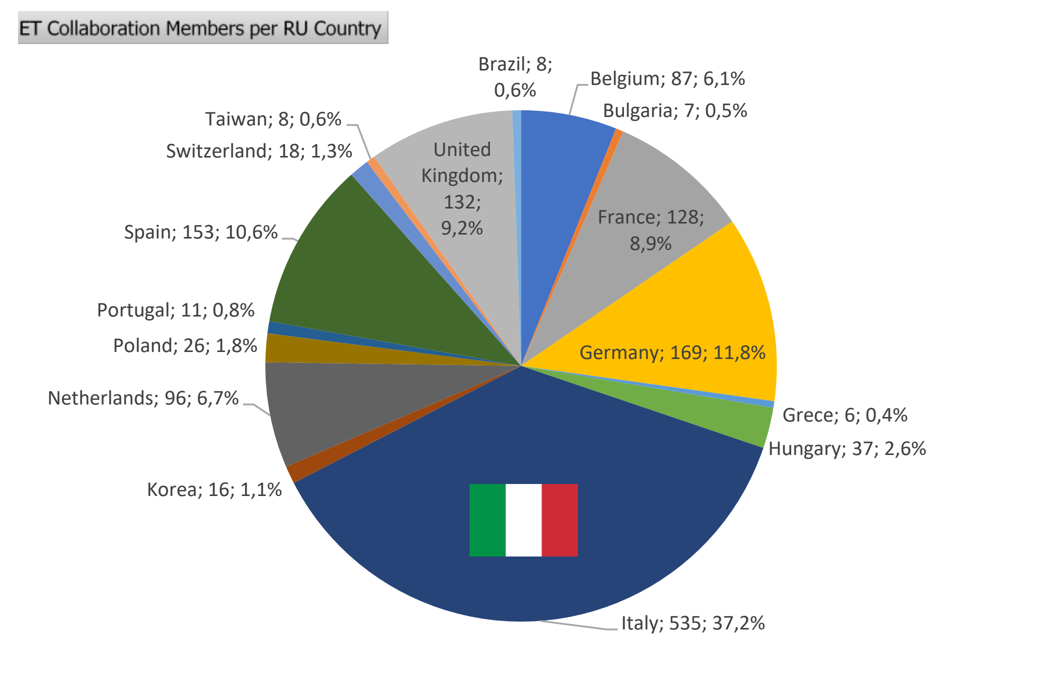


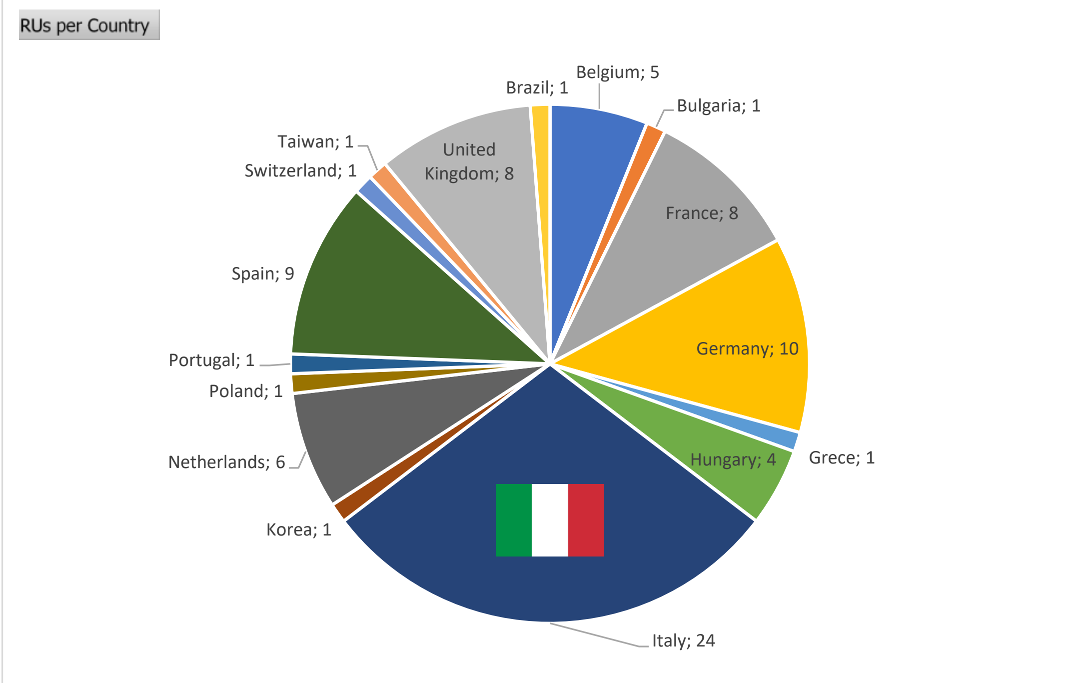
- **82 Research Units (+1 request pending)**
- **1437 members (09.06.2023 09:25)**
- **Total: 211 Institutions in 23 Countries**

Credit: M. Punturo 2023

ET Collaboration Demography

EINSTEIN TELESCOPE





- The data in the ETMD suffer a certain level of inaccuracy:
  - Some RU leaders have not inserted their RU members
  - A few ET members are not updating their information

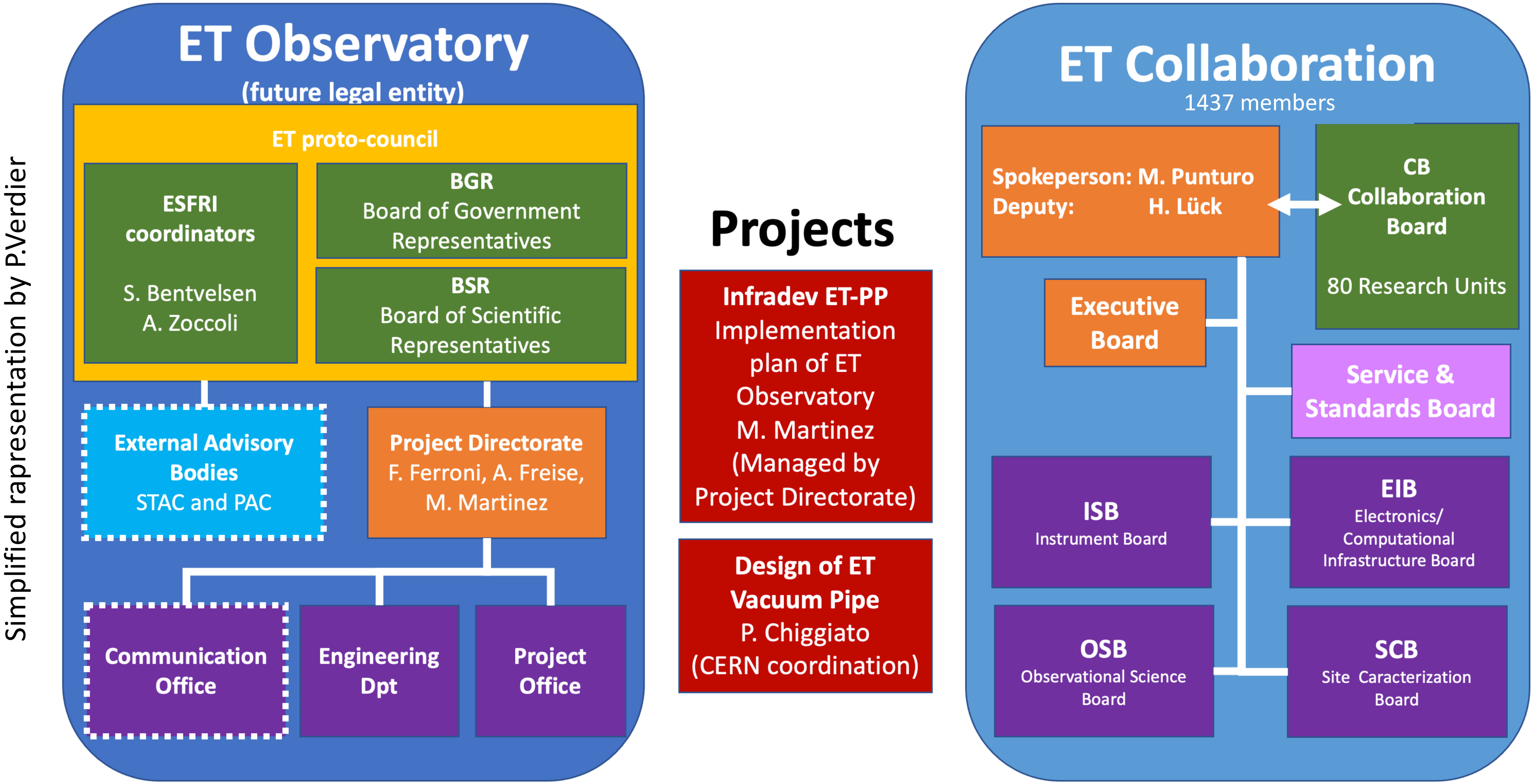
Data from the ET Member Database (ETMDB), tool based in EGO, governing the Authorization and Authentication to the ET collaboration resources: https://apps.et-gw.eu/etmd

Credit: M. Punturo 2023

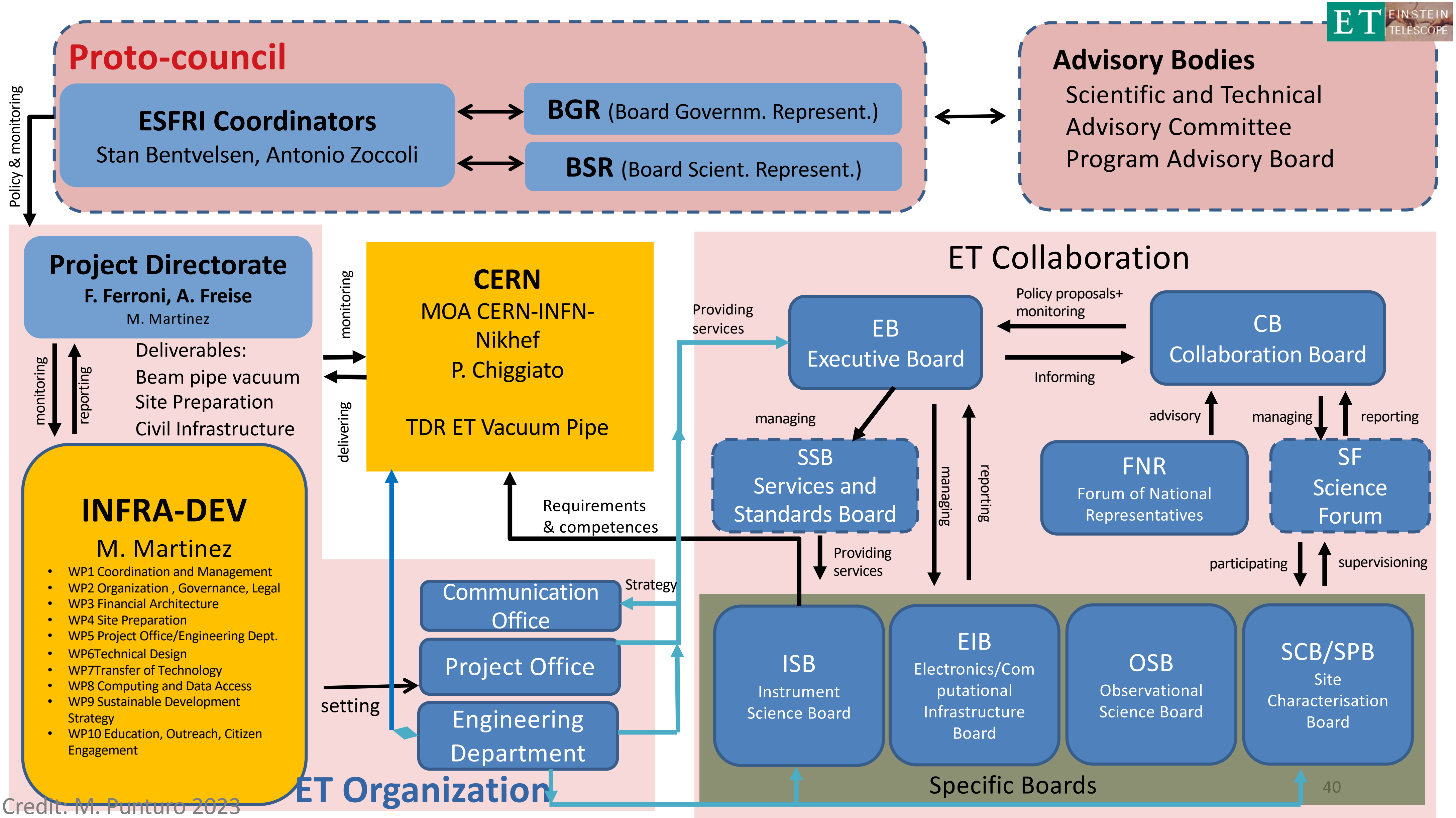
We adopted a "particular" flavor of FTE: FRTE (full research time equivalent)

- The declared FRTE need to be matched to an effective activity
  - This will be a major effort in the next years and we should find a realistic method in the Bylaws
- Currently we have about 295 FrTE →24% on average per member - quite low

ET Current Organization

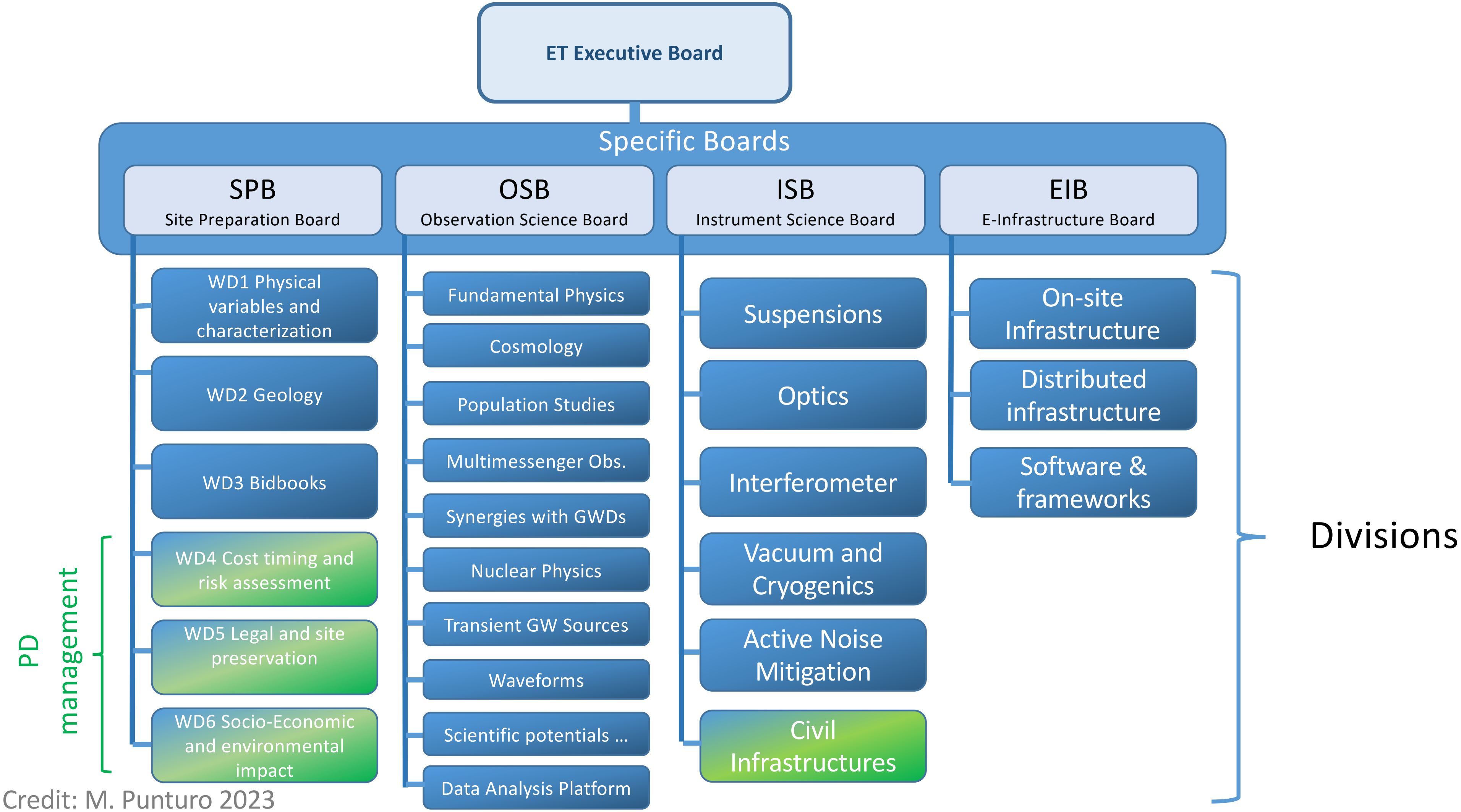


Credit: M. Punturo 2023



Proto-council
ESFRI Coordinators
Stan Bentvelsen, Antonio Zoccoli
BGR (Board Governm. Represent.)
BSR (Board Scient. Represent.)
Advisory Bodies
Scientific and Technical
Advisory Committee
Program Advisory Board
EINSTEIN TELESCOPE
Policy & monitoring
Project Directorate
F. Ferroni, A. Freise
M. Martinez
monitoring
reporting
Deliverables:
Beam pipe vacuum
Site Preparation
Civil Infrastructure
monitoring
delivering
CERN
MOA CERN-INFN-Nikhef
P. Chiggiato
TDR ET Vacuum Pipe
INFRA-DEV
M. Martinez
WP1 Coordination and Management
WP2 Organization , Governance, Legal
WP3 Financial Architecture
WP4 Site Preparation
WP5 Project Office/Engineering Dept.
WP6Technical Design
WP7Transfer of Technology
WP8 Computing and Data Access
WP9 Sustainable Development Strategy
WP10 Education, Outreach, Citizen Engagement
Requirements
& competences
Communication Office
Strategy
Project Office
setting
Engineering Department
ET Organization
Credit: M. Punturo 2023
ET Collaboration
Providing services
EB
Executive Board
Policy proposals+ monitoring
Informing
CB
Collaboration Board
managing
SSB
Services and Standards Board
managing
reporting
advisory
managing
reporting
FNR
Forum of National Representatives
SF
Science Forum
Providing services
participating
supervisioning
ISB
Instrument Science Board
EIB
Electronics/Computational Infrastructure Board
OSB
Observational Science Board
SCB/SPB
Site Characterisation Board
Specific Boards

ET Specific Boards



Credit: M. Punturo 2023

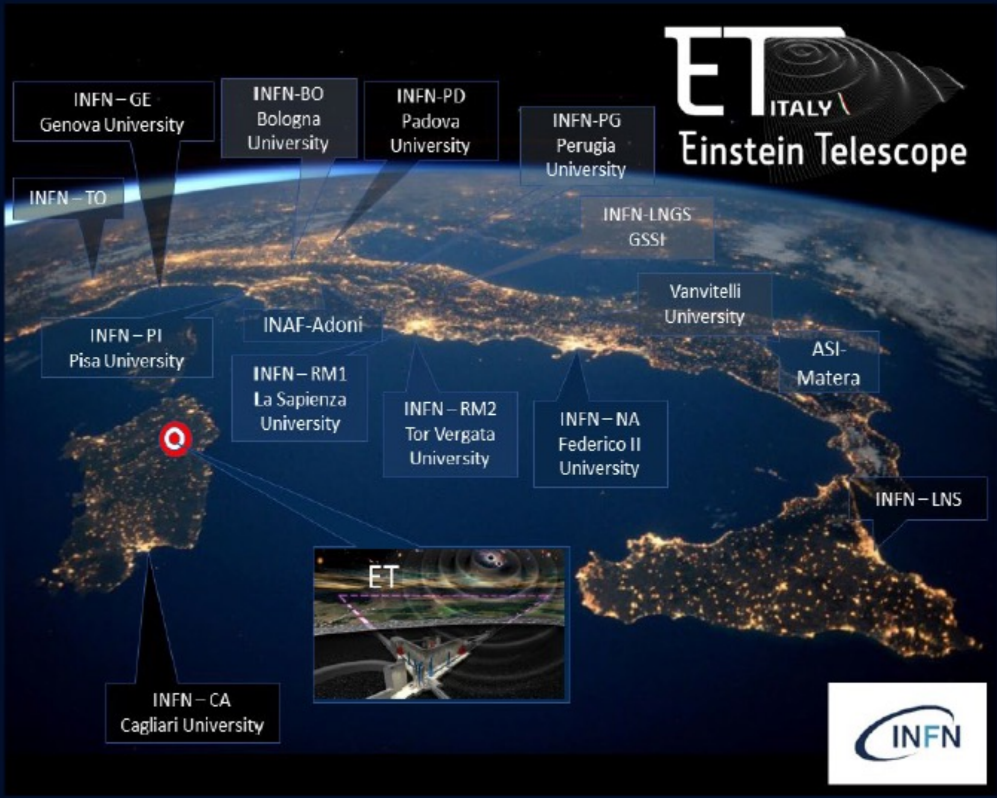
Summary

- ❑ GW science with ET
- ❑ From Virgo to ET
- ❑ ET: Infrastructure, detector, technologies
- ❑ The ET collaboration & management
- ❑ **Towards ET in Italy**
- ❑ Conclusions

ETIC Project

- ETIC is a Project funded by the Italian Ministry for University and Research (MUR) with 50M€ for 30 (36) months within the PNRR (NRRP National Recovery and Resilience Plan)
- It started the 1st of January 2023
- ETIC is lead by INFN, it involves other 2 national research institutions:
  - INAF (Italian institute for Astrophysics)
  - ASI (Italian Space Agency)
- and 11 Italian universities for a total of 27 operating units (INFN and INAF Units, Department of physics, civil engineering, architecture)

ETIC
Einstein Telescope Infrastructure Consortium

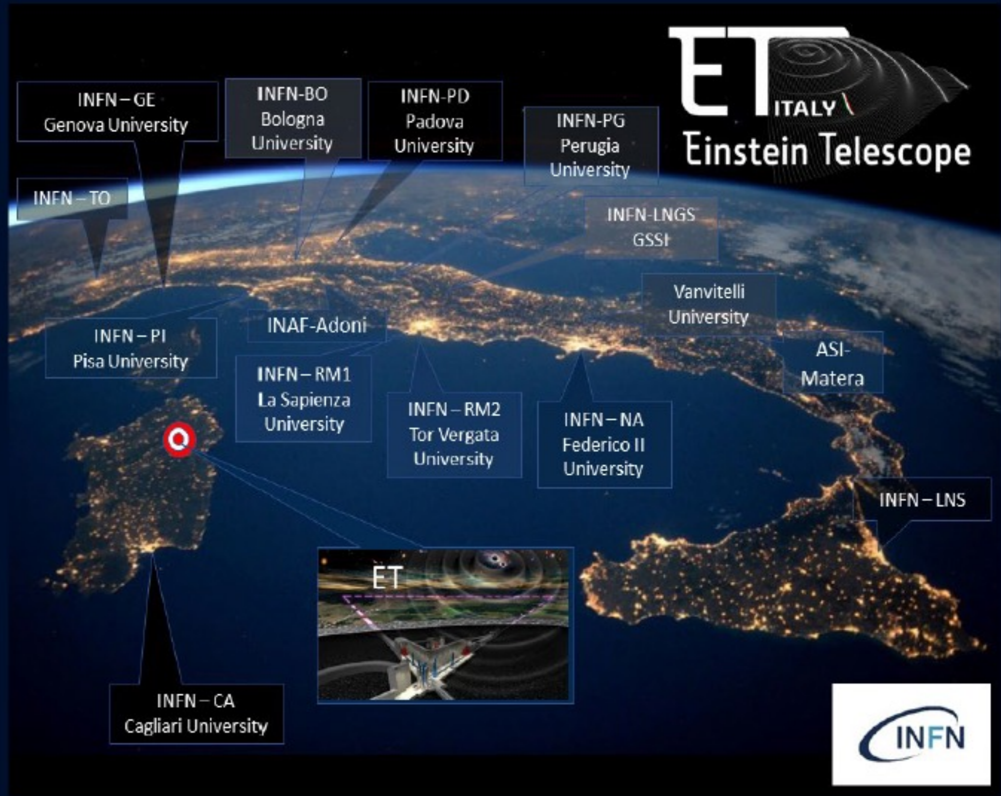


ETIC targets

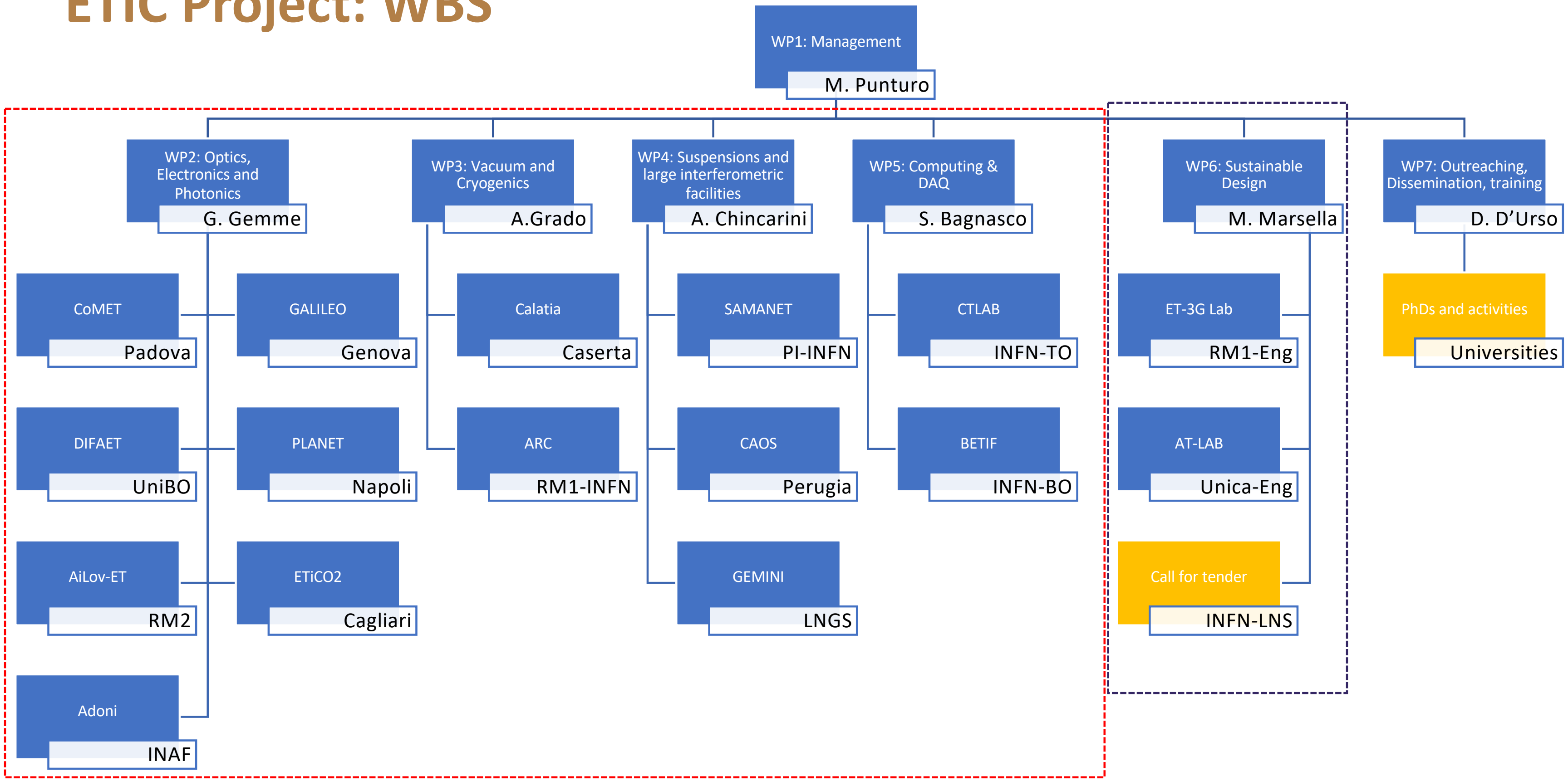
https://web.infn.it/einsteintelescope/index.php/it/home-it-it/infrastrutture-e-labs

- The ETIC aim is twice:
  - Realize a network of research infrastructures located in the participating laboratories or universities addressed to the ET enabling technologies
  - Realize a feasibility study of ET in Sardinia, key element of the Italian bidbook, including geotechnical and engineering studies

ETIC
Einstein Telescope Infrastructure Consortium



ETIC Project: WBS



ETIC: Budget distribution

ETIC is organized in 7 Work Packages and hundreds of tasks

- WP1: Management — 417.942€
  - WP2: Optics, Electronics and Photonics — 12.266.676€
  - WP3: Vacuum and Cryogenics — 5.228.165€
  - WP4: Suspensions and large interferometric facilities — 10.511.601€
  - WP5: Computing & DAQ — 1.108.177€
  - WP6: Sustainable Design — 19.843.048€
  - WP7: Outreaching, Dissemination, training — 623.320€

INFN	UniBO	UniCA	UniGE	UniNA	UniVanvitelli	UniPD
33.867.823.25 €	186.574.23 €	1.624.578.86 €	989.113.35 €	1.400.259.10 €	281.035.50 €	1.947.255.55 €

UniPG	UniPI	UniSapienza	UniRM2	INAF	ASI	GSSI
5.079.557.50 €	599.649.40 €	1.550.135.75 €	1.348.432.40 €	407.316.90 €	312.525.60 €	404.674.00 €

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INFN

Human Resources

- ETIC aims to training a new generation of young scientists and engineers for ET
- The majority of these positions have been allocated and contracts are starting in May/June/July

Months	ETIC	INFN
Tecnici laureati cat D	108	0
RTDA	432	0
CTER	162	150
Tecnologo III	492	438
Manager	30	30
Positions	**ETIC**	**INFN**
Tecnici laureati cat D	4	0
RTDA	16	0
CTER	7	6
Tecnologo III	21	18
Manager	1	1

Feasibility study (Δ and L)

- The Italian candidature of the site in Sardinia passes through the WP6 of ETIC
  - **European call for tender of about 17.5M€ + IVA** already opened weeks ago, and it is approaching its closure.
  - Engineering studies, geotechnical studies, cost evaluation.
  - Call for tender managed by INFN LNS (G. Schillaci) within the WP6 coordinated by the Civil Engineering department (DICEA) of Sapienza – University of Rome (M. Marsella)
- **This candidature is supported and surveilled at the highest level of the Italian Government!**

Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA | INFN

Candidatura Italiana

ET Italia: https://www.einstein-telescope.it/

https://www.governo.it/it/media/il-presidente-meloni-alla-presentazione-della-candidatura-italiana-einstein-telescope/22813

6/6/2023

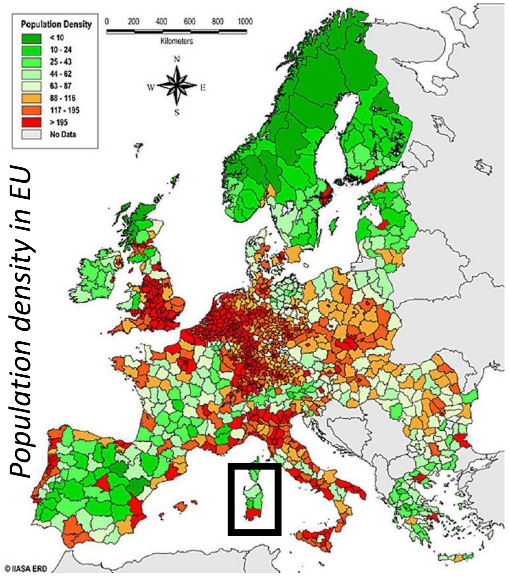
ET candidate sites

- Two sites officially candidate to host ET:
  - EMR EUregio, border region between Nederland, Belgium and Germany
  - Sardinia (Lula area, Barbagia)
- A third potential site is located in Saxony (Lusatia), still not official
- Overall site evaluation is a complex task depending on:
  - Geophysical and environmental quality
  - Financial and organization aspects
  - Services, infrastructures

ET in Sardinia, why?

Sardinia is made of:

- ➢ Quaternary alluvial deposits and minor intra-plate volcanism
- ➢ Tertiary sedimentary basins with volcanic units
- ➢ Deeply eroded Mesozoic sedimentary rocks
- ➢ Metamorphic basement widely intruded by Carboniferous-Permian Granitoids (Variscan orogenesis; 360-290 Ma)

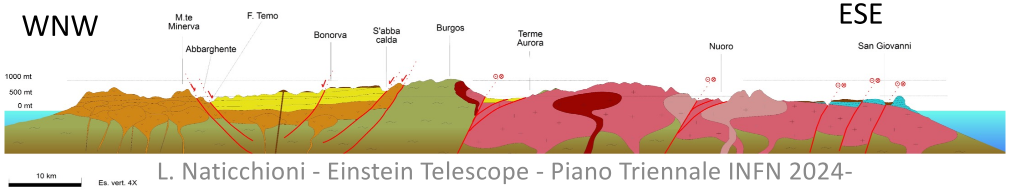


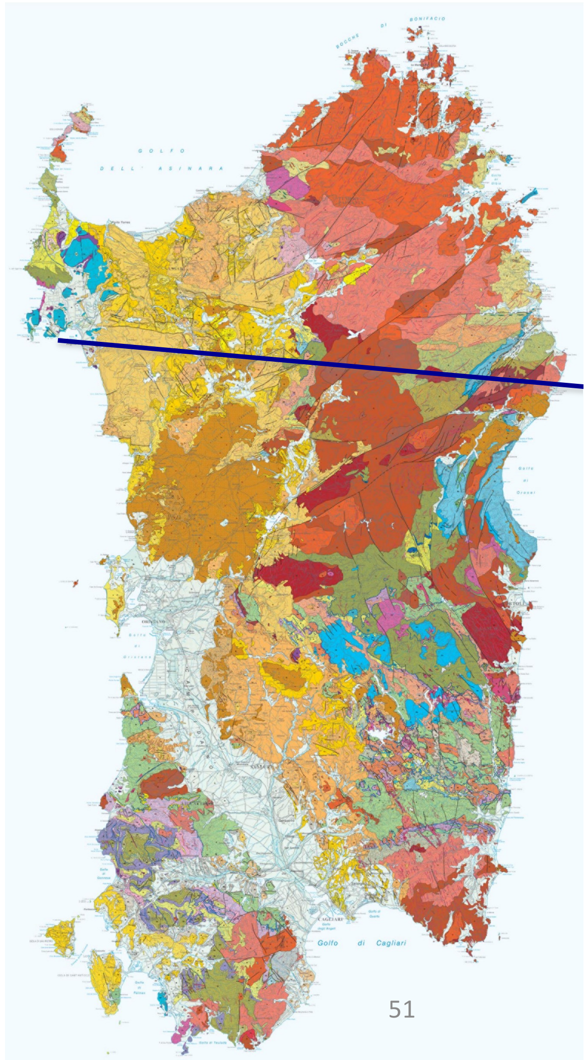
Population density in EU

The ET Italian candidate site is located in the stable Variscan basement of Sardinia.

- Geodynamic quietness
- Low Anthropogenic noise
    - Low E.M. noise

LOW SEISMIC NOISE!

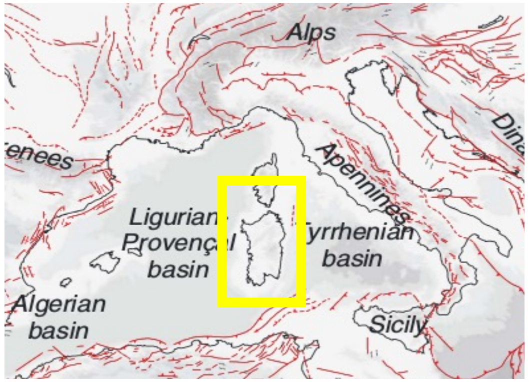


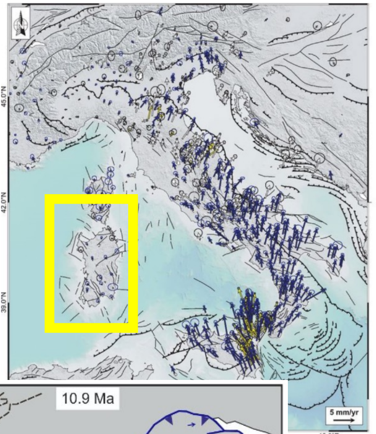


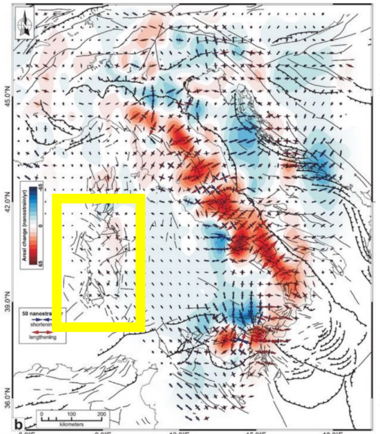
ET in Sardinia, why?

Sardinia, the geological framework

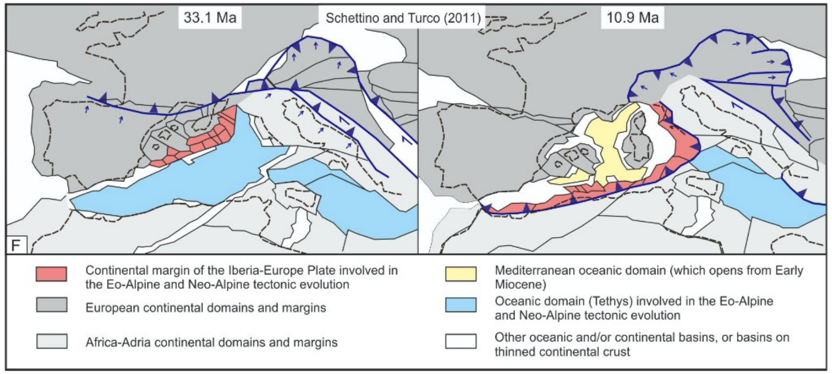
Far from active fault lines, the Corsica-Sardinia microplate is very stable → low crustal deformation.



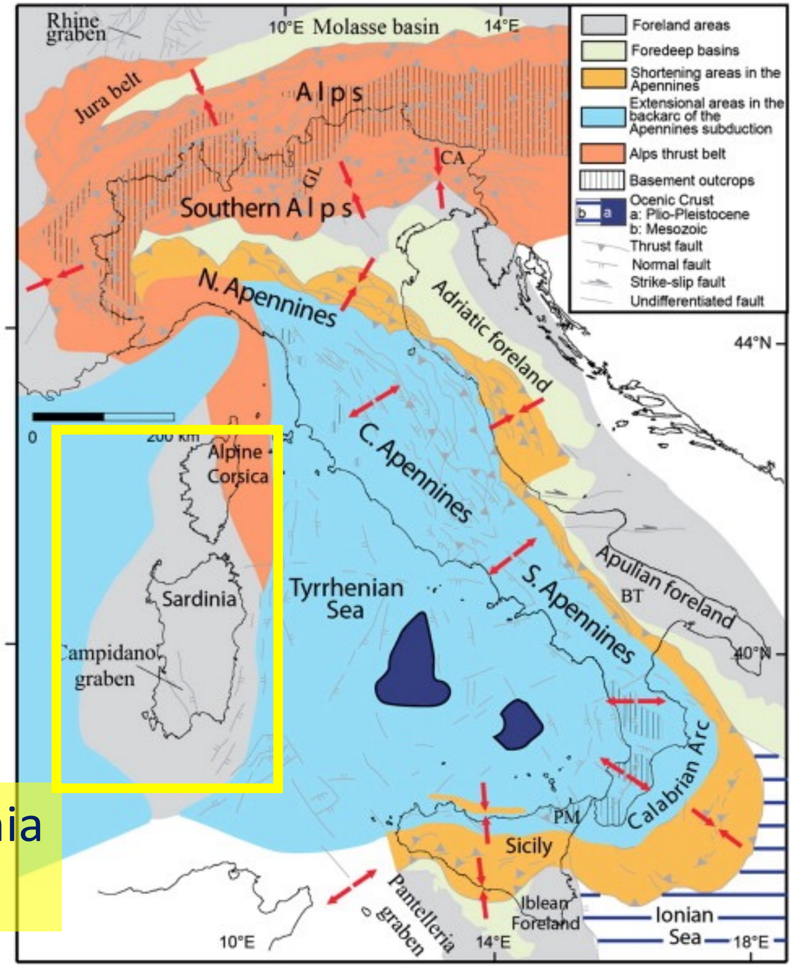




Geosciences 2020, 10, 366;
doi:10.3390/geosciences10090366



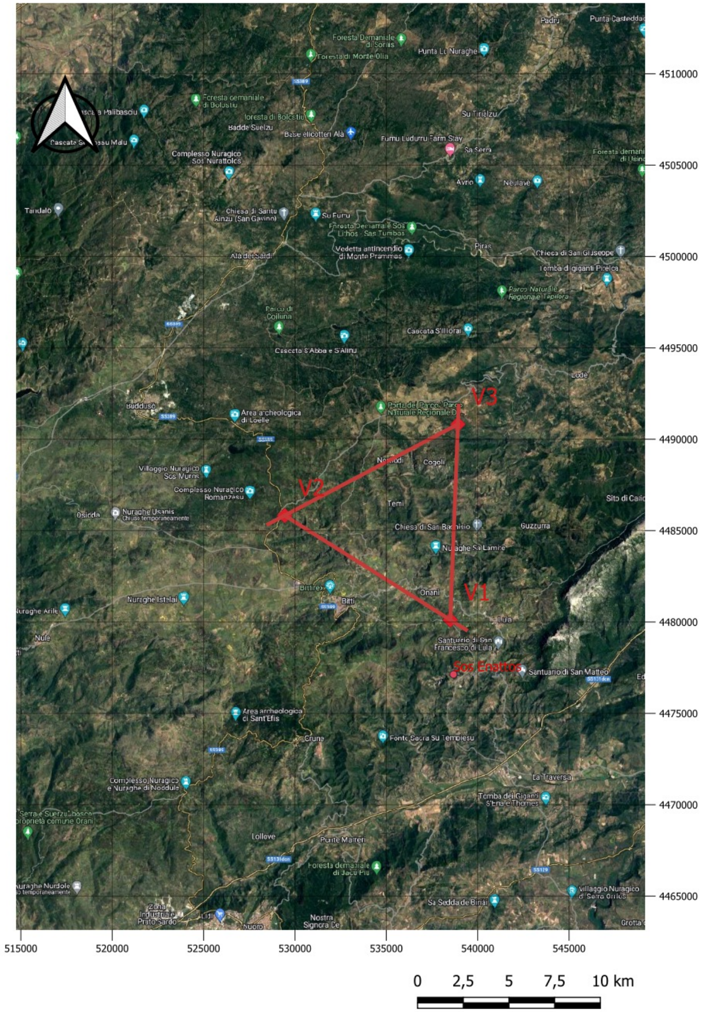
Corsica-Sardinia Microplate

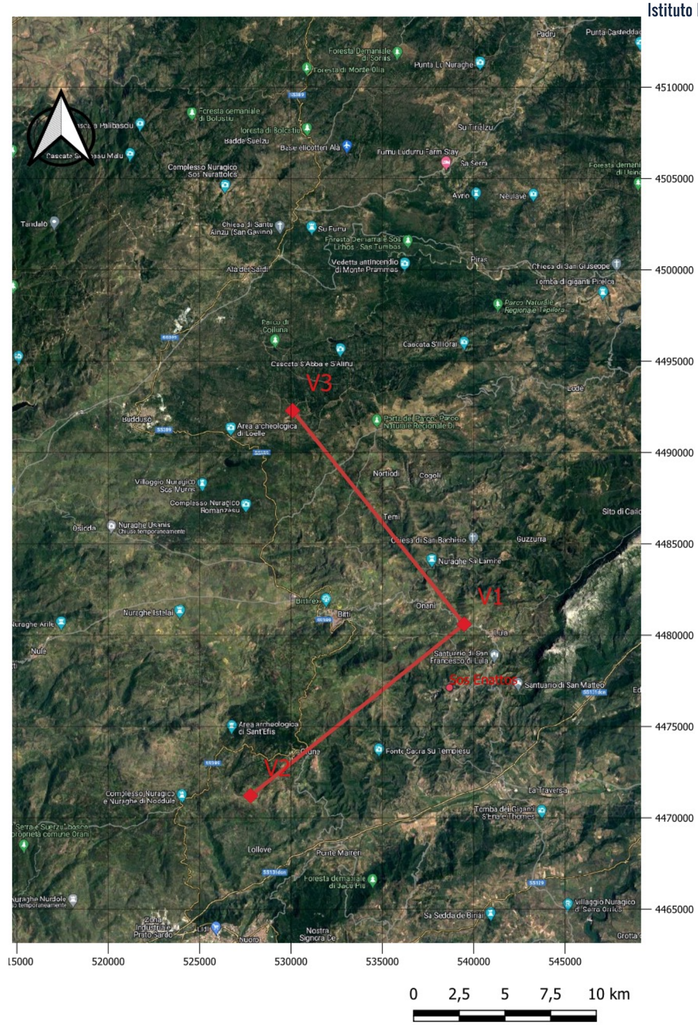


ET in Sardinia, where?

∆ and L layouts

The area of Sos Enattos could easily host a triangle with 10km-long sides (*base design*) and a L with 15-20km-long arms.





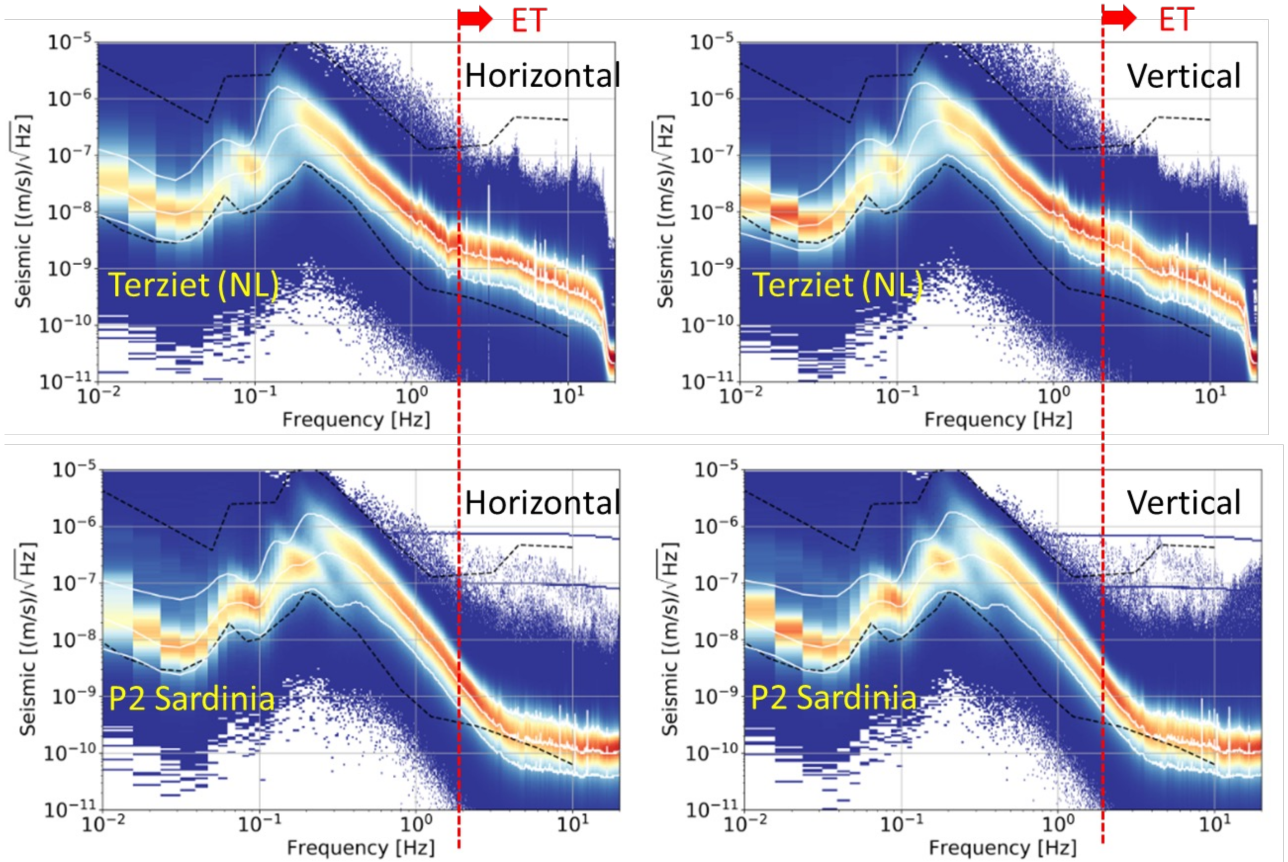
The Sos Enattos site

Sos Enattos former mine

Site comparison with other candidates

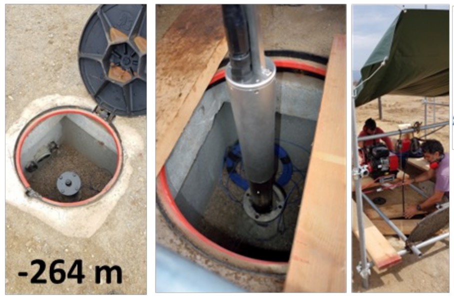
Borehole measurements comparison

In the crucial few Hz band of ET (2-10 Hz), Sos Enattos area is among the quietest sites in the world.



EMR Terziet (NL) borehole

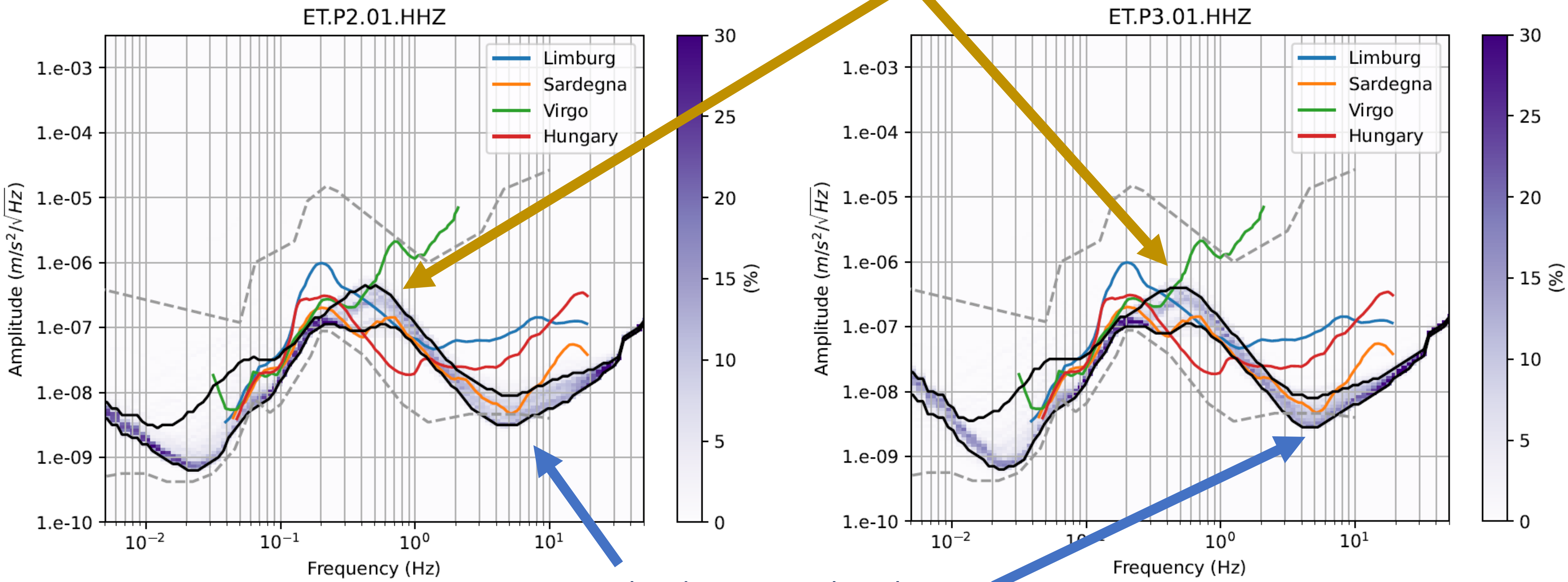
Sardinia P2 borehole



Site comparison with other candidates

Borehole measurements comparison

High amplitudes: Influence of the sea below 2 Hz

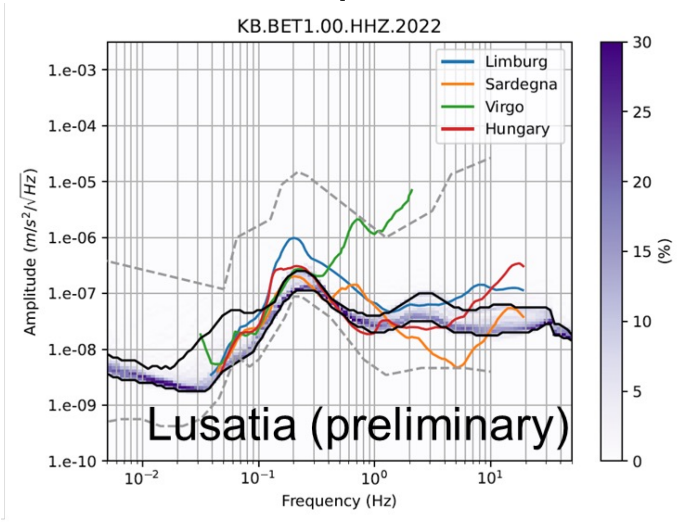


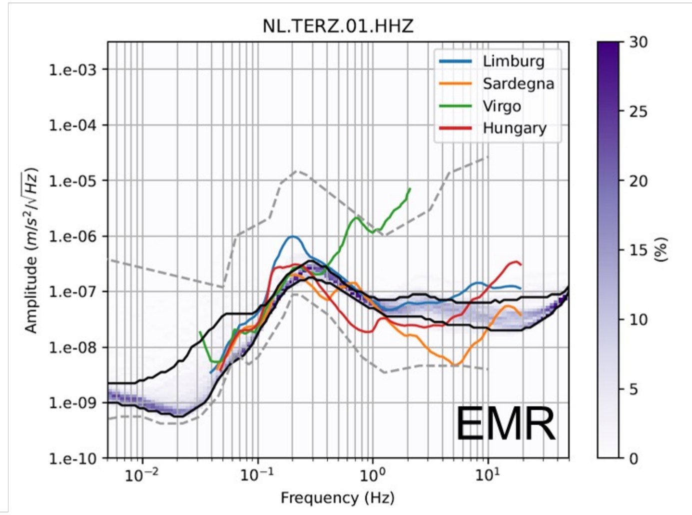
Low amplitudes: Low cultural noise

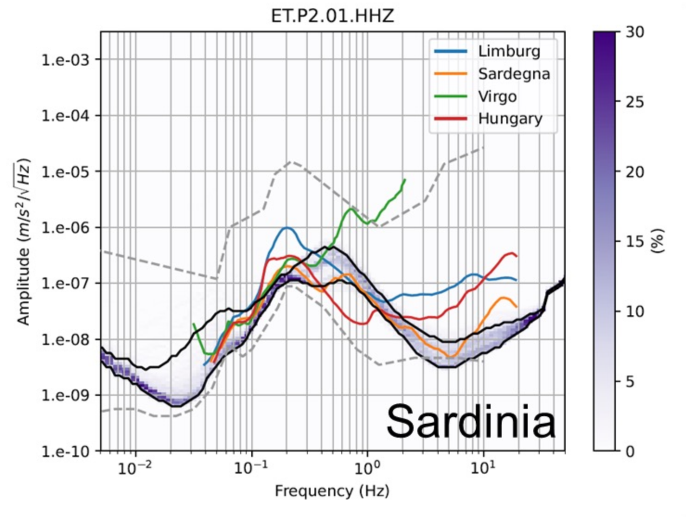
A. Rietbrock et al., SPB Workshop 2023

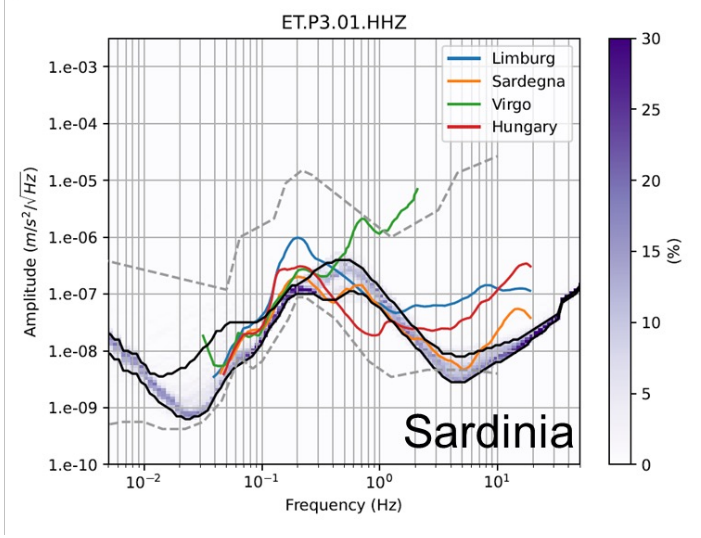
Site comparison with other candidates

Borehole comparison

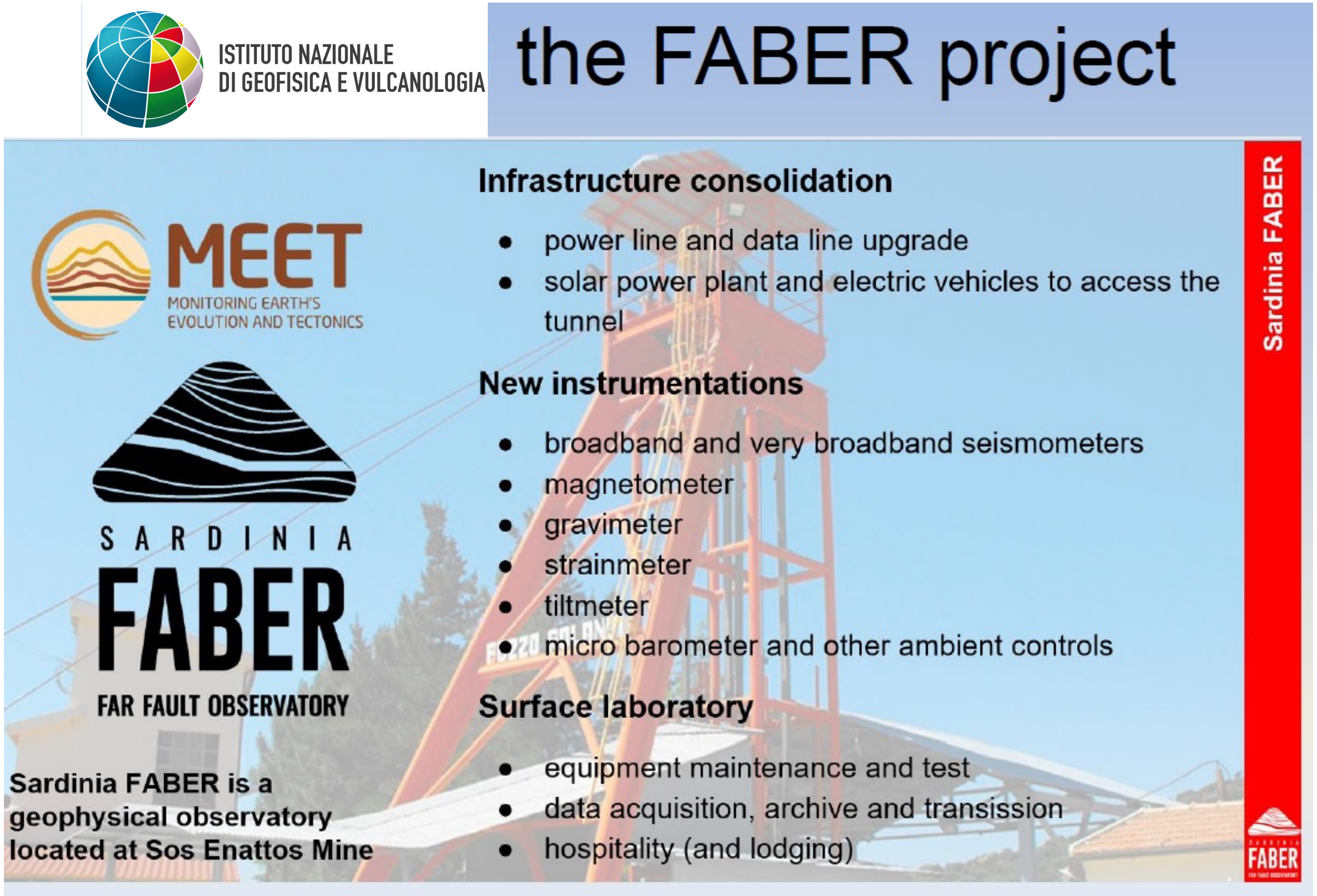








Strong synergy with INGV



INGV is collaborating since 2019 with INFN in the site qualification in Sardina.
Through a dedicated PNRR project INGV will contribute to the site characterization.

Summary

- GW science with ET
- From Virgo to ET
- ET: Infrastructure, detector, technologies
- The ET collaboration
- Towards ET in Italy
- **Conclusions**

Conclusions

- ET will be able to extend the detection horizon to the whole observable universe: routine (Multimessenger) astronomy, cosmology, fundamental physics in extreme conditions.
- ET will be the larger and more complex underground research infrastructure!
- ET will require and push great technological improvements in many fields.
- Two baselines under study: 10km- triangle and 15km- (double) L.
- ET intl. Collaboration: 211+ institutions, 23+ countries, 1437+ members, still growing!
- Italy (INFN) has a great tradition and expertise in GW detectors: larger community within ET coll. and many coordination roles.
- Italy has the best candidate site (Sardinia) and a strong support from local and national government.
- ETIC (PNRR) project is already supporting the Italian candidature: research infrastructure network and feasibility engineering study.
- Strong and fruitful synergy with other EPR in Italy: INGV & INAF.

ET

Einstein Telescope

BACKUP SLIDES

EINSTEIN TELESCOPE

GW Science with ET

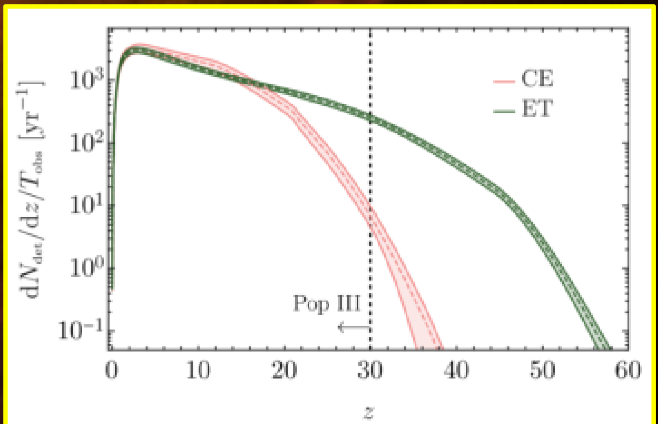
INFN

Extreme Gravity conditions

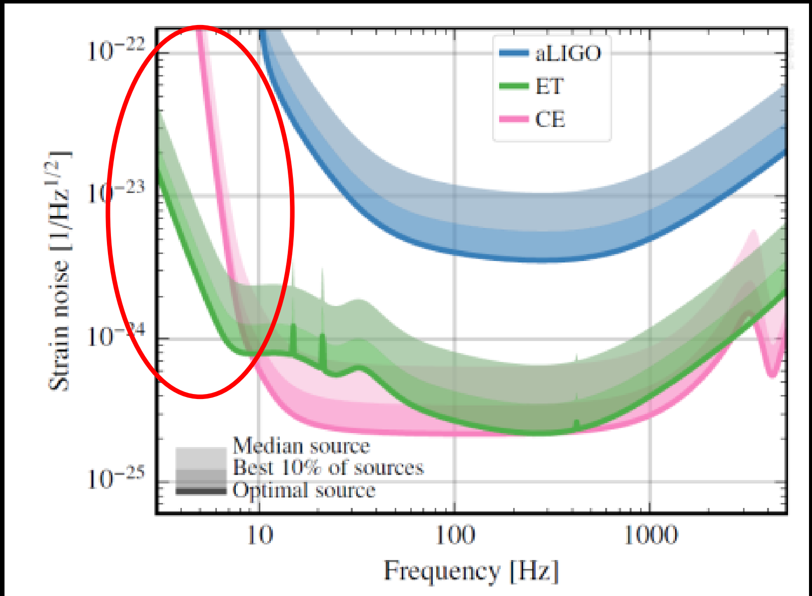
- In GR, no-hair theorem predicts that BHs are described only by their mass and spin (and charge)
  - However, when a BH is perturbed, it reacts (in GR) in a very specific manner, relaxing to its stationary configuration by oscillating in a superpositions of quasi-normal (QN) modes, which are damped by the emission of GWs.
  - A BH, a pure space-time configuration, reacts like an elastic body → Testing the “elasticity” of the space-time fabric
  - Exotic compact bodies could have a different QN emission and have echoes.

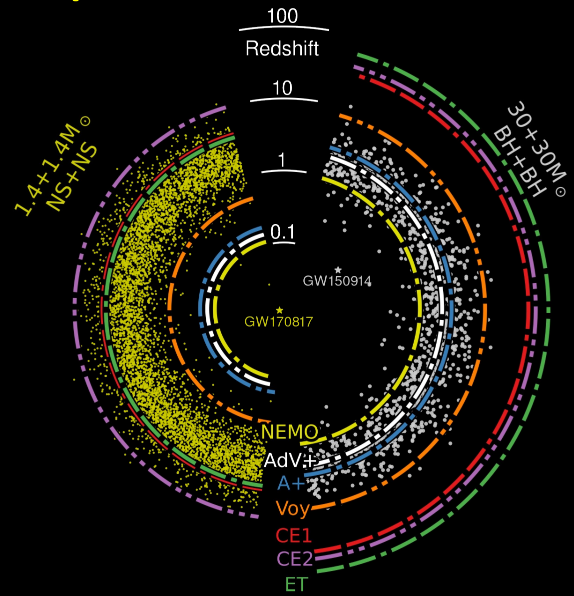
Primordial Black Holes

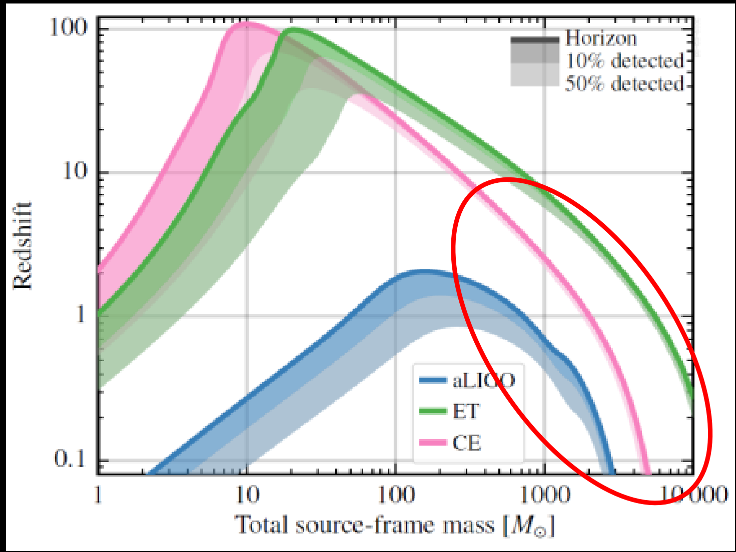
- ET (and CE) will detect BH well beyond the SFR peak z~2
  - comparing the redshift dependence of the BH-BH merger rate with the cosmic star formation rate to disentangle the contribution of BHs of stellar origin from that of possible BHs of primordial origin: any BBH merger at z>30 will be of primordial origin.



Observation performances of ET & CE







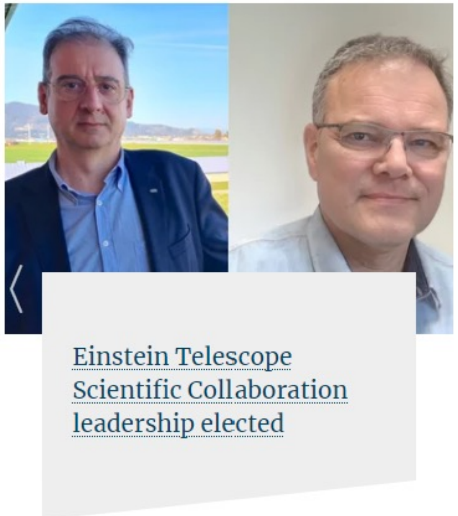
- BNS to z~2
  - 10^5 BNS/year
  - Possibly O(10-100)/year with e.m. counterpart
- High SNR

- BBH up to z~50-100
- 10^5 BBH/year
  - Masses $M_T \gtrsim 10^3\ M_\odot$

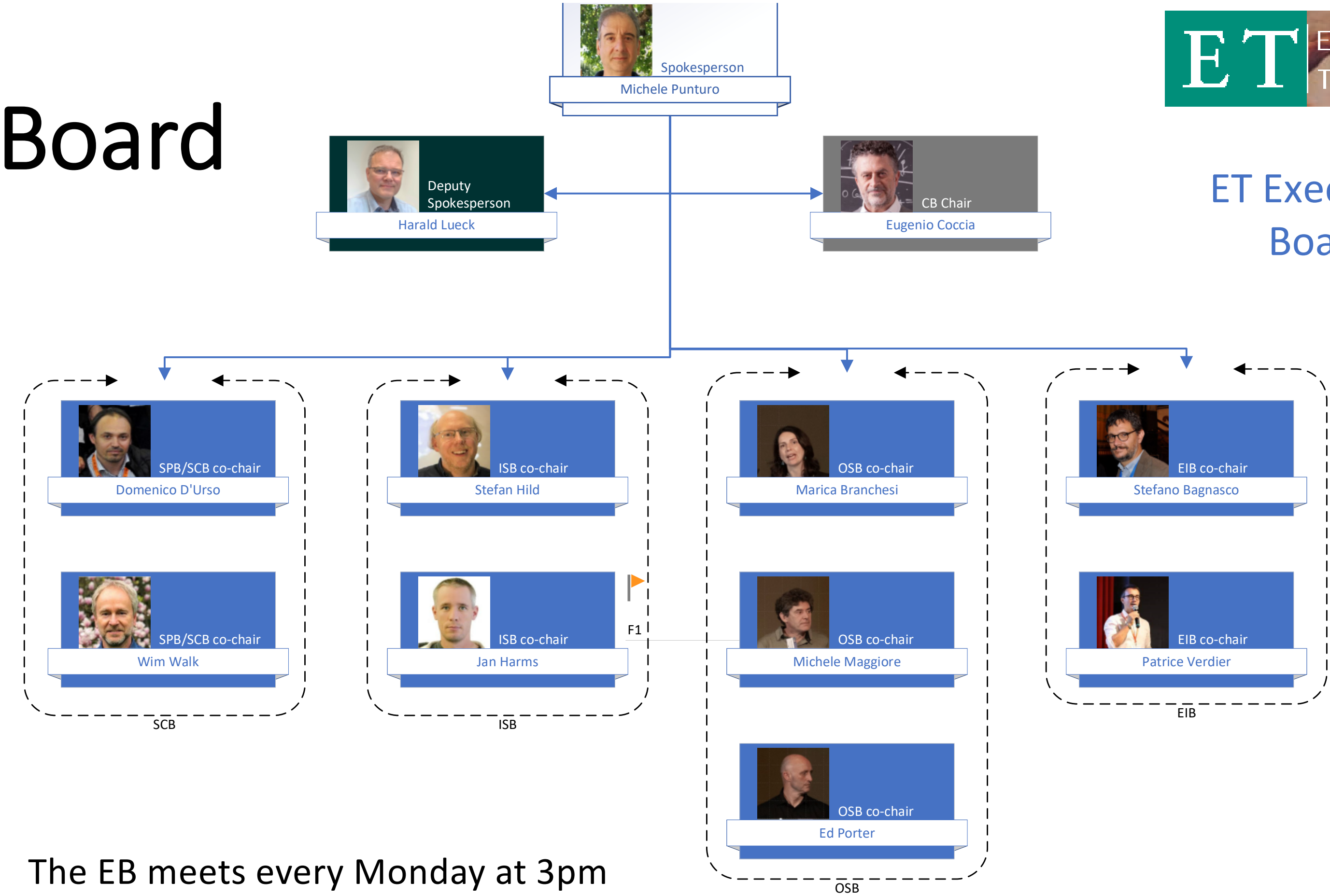
The Executive Board

ET Executive Board

- On the 23rd of March, 2023 the ET Collaboration elected the Spokesperson/Deputy Spokesperson team:
- Michele Punturo
- Harald Lueck



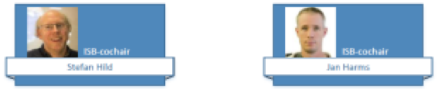
Credit: M. Punturo 2023

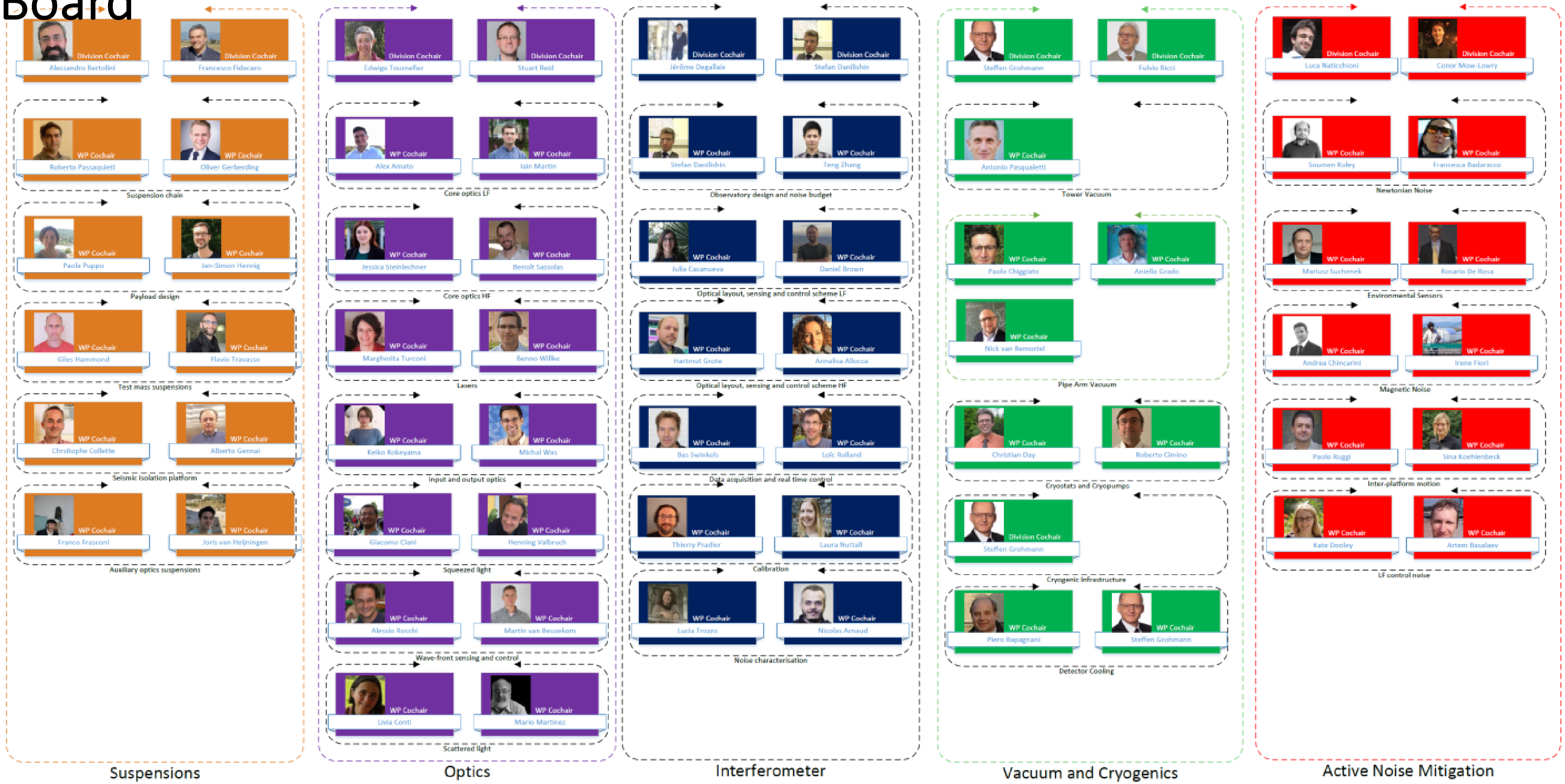


- The EB meets every Monday at 3pm
- You can follow its activities through the meeting minutes on the ET Collaboration Technical Documentation System (TDS): https://apps.et-gw.eu/tds/ *
- More info here: https://wiki.et-gw.eu/EB/WebHome *
- ET Collaboration web site (since 2008): https://www.et-gw.eu/ *
- Indico (all international ET coll. meetings): https://indico.ego-gw.it/category/23/ *

(*) Services provided by EGO, based on the ETMDB service (Active Directory)

The Instrument Science Board





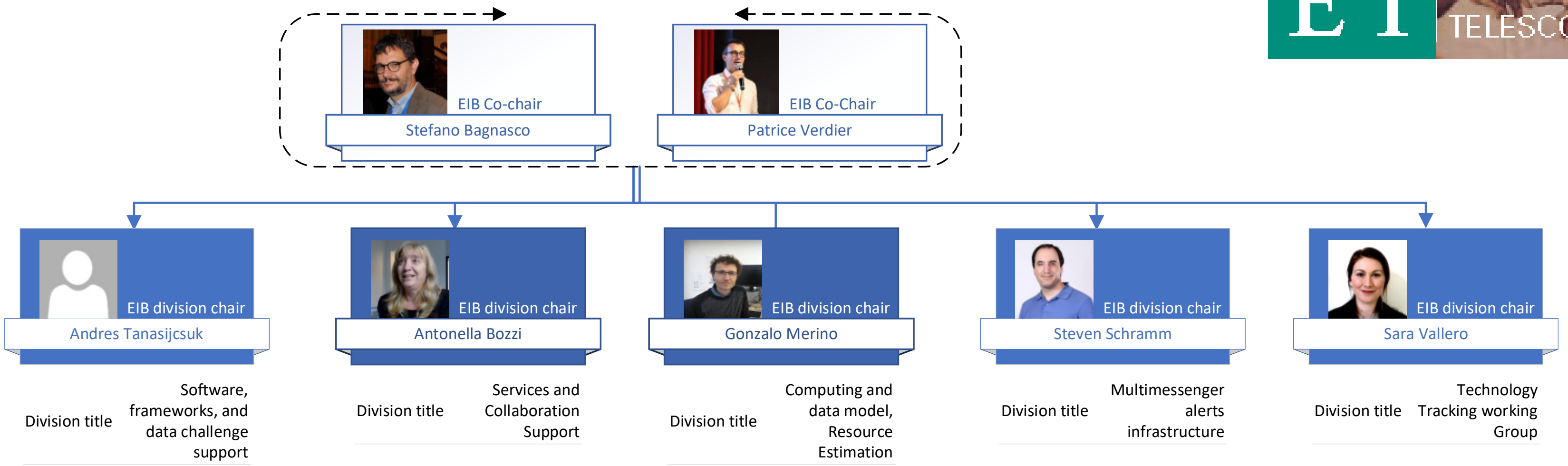
ET EINSTEIN TELESCOPE

Credit: M. Punturo 2023

The Observational Science Board OSB

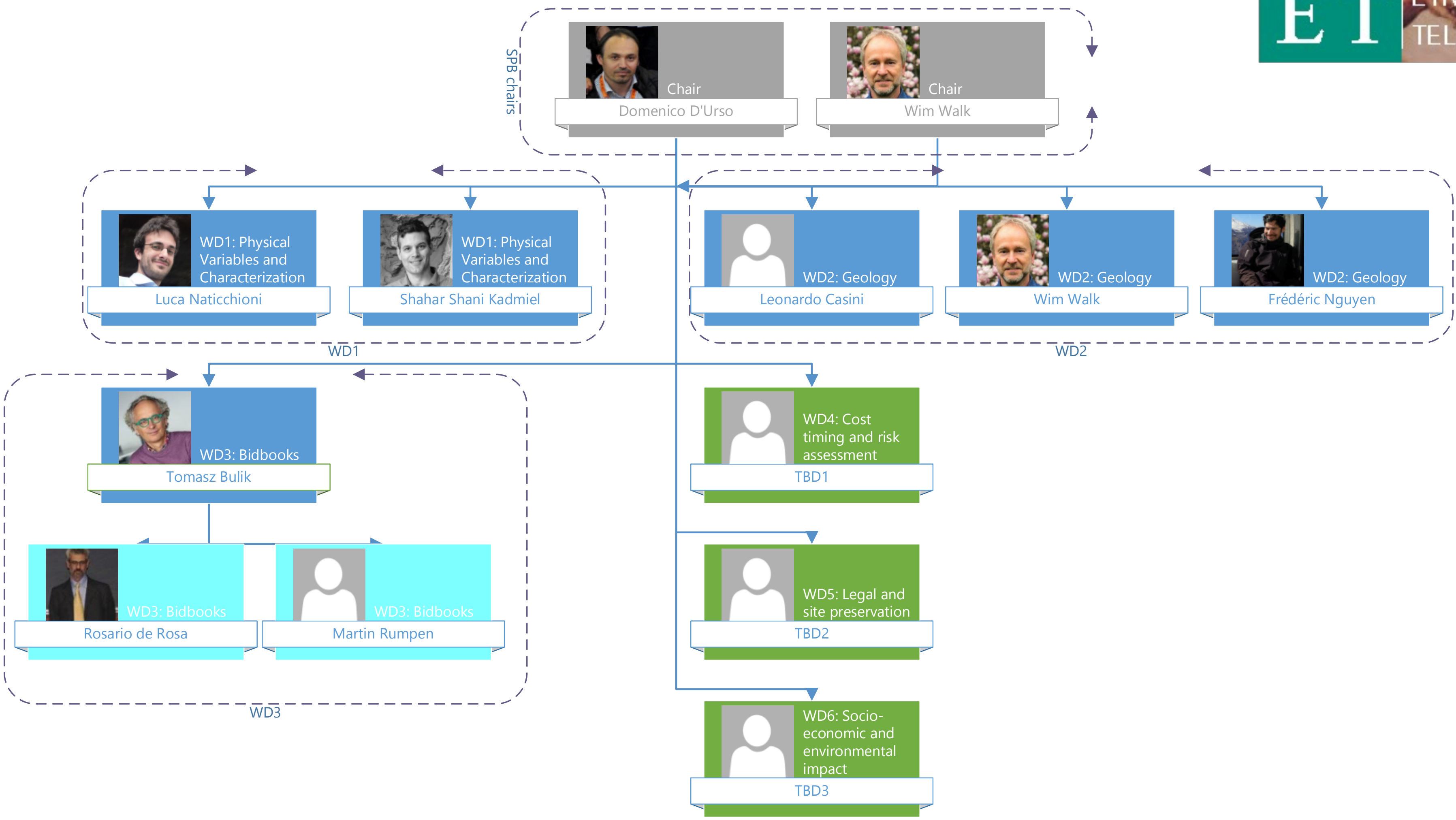
Credit: M. Punturo 2023

The E-Infrastructure Board



Credit: M. Punturo 2023

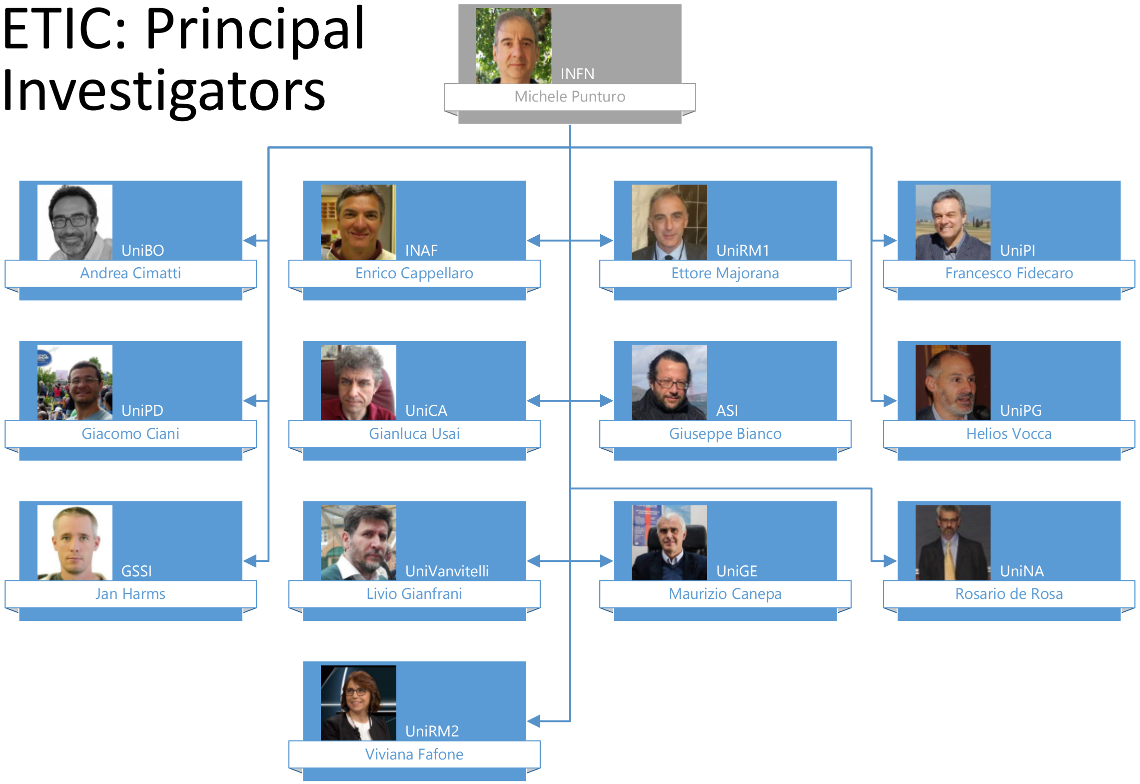
The Site Preparation Board



Credit: M. Punturo 2023

ETIC Project: OBS

ETIC: Principal Investigators

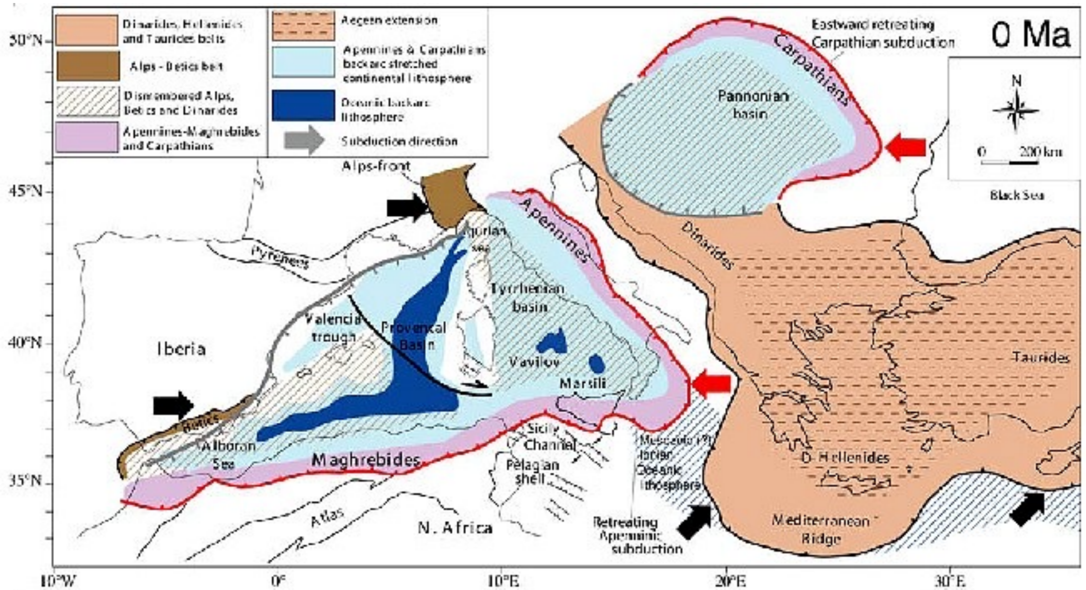


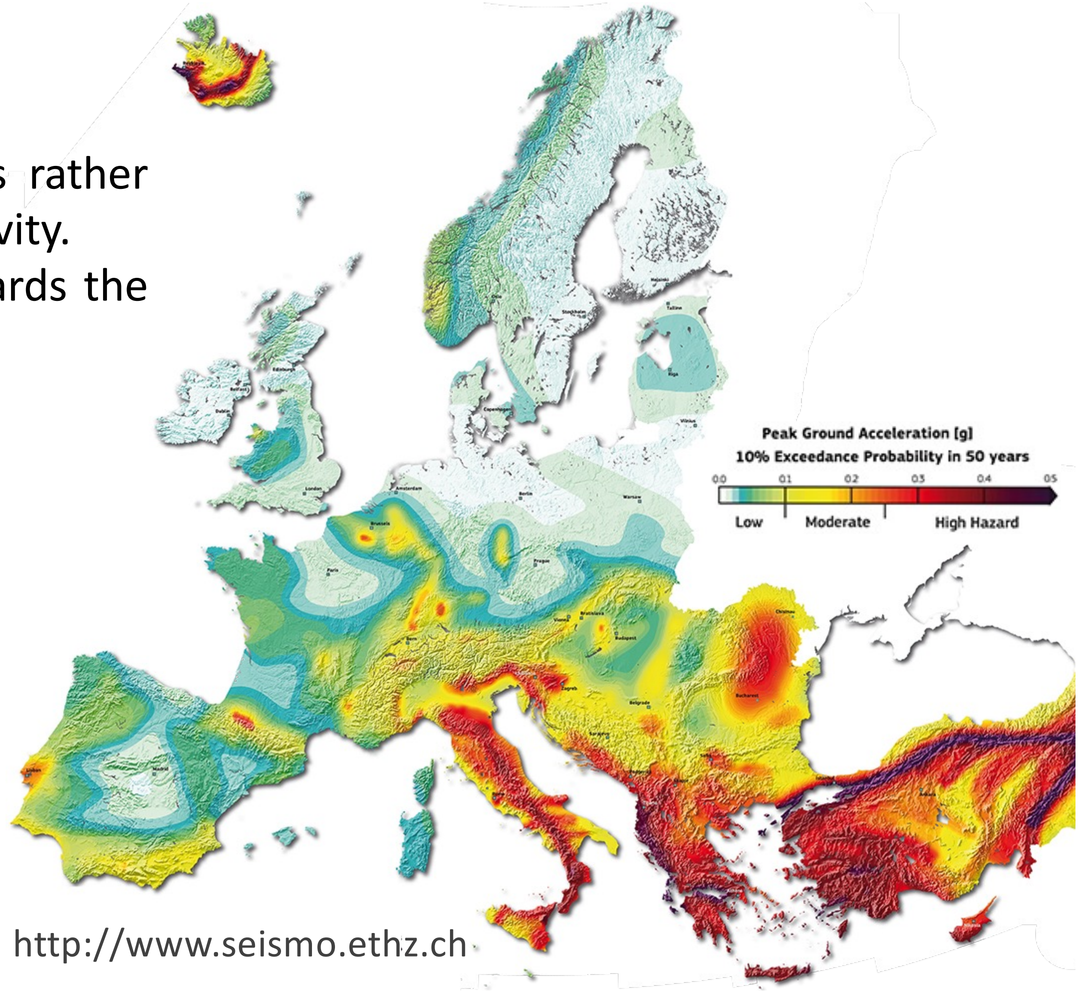
ETIC: OU Board

ET in Sardinia, why?

Sardinia, the geological framework

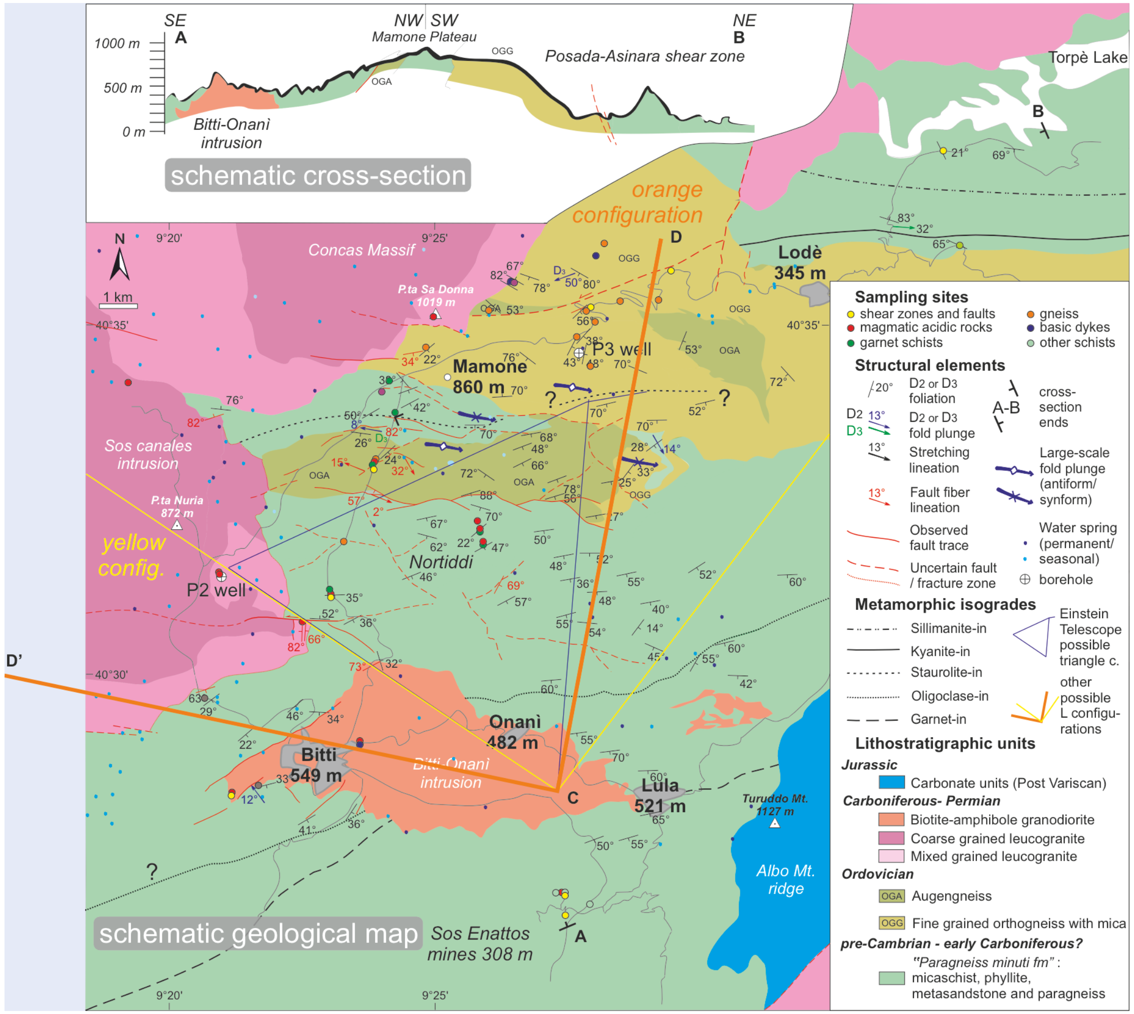
In the last million years, the Sardo-Corsican block is rather stable and quite unaffected by significative seismic activity.
This is due to localization of active geodynamics towards the east of Italy.





http://www.seismo.ethz.ch

ET in Sardinia, why?



Good rock quality

Lithologies: Orthogneiss, granitoids, micaschists. The red triangle represents the hypothetic Δ underground trace of ET. One of the possible L traces is also shown. P2 and P3 are the borehole locations. Ongoing geological survey of the area and review of the geological maps.