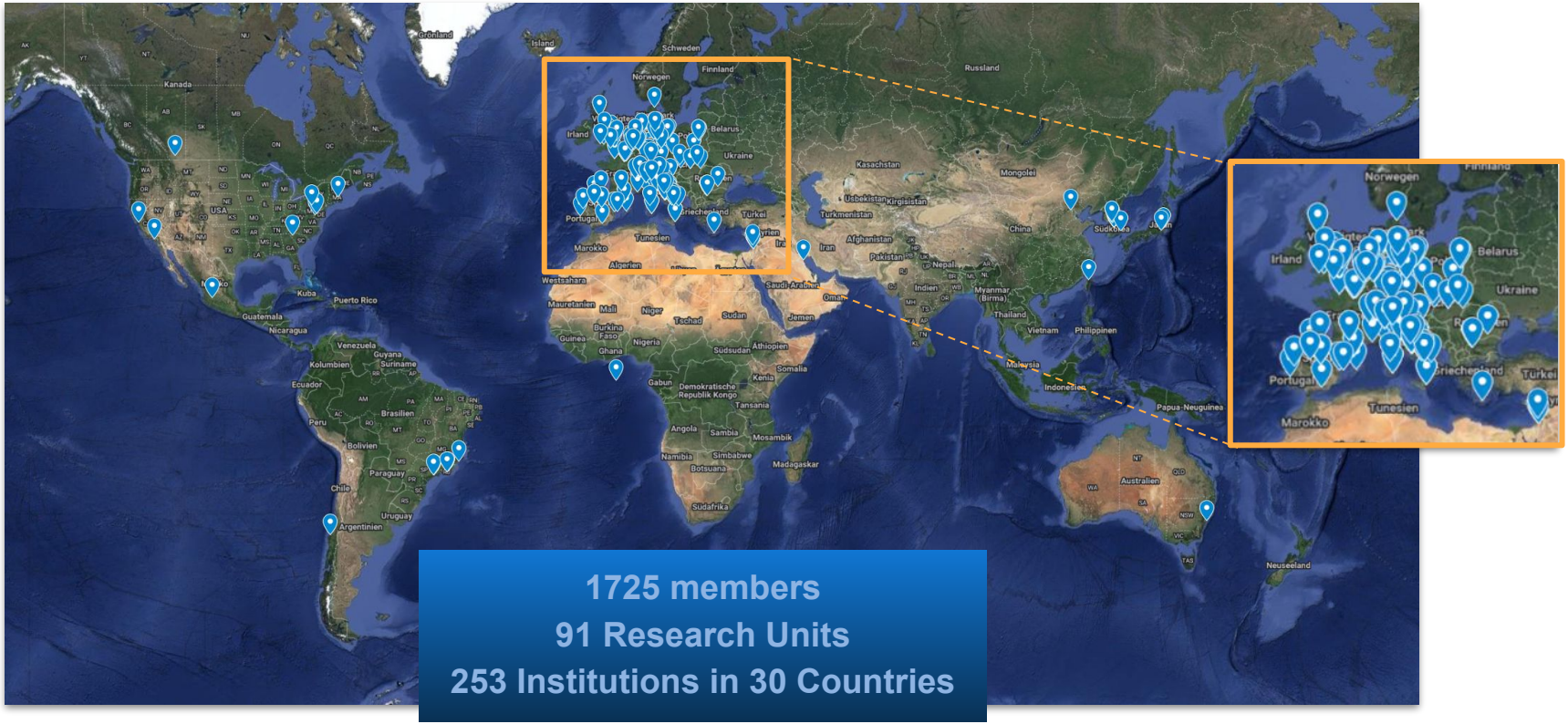
Einstein Telescope
Status and Overview

Giuseppe Greco - INFN Perugia
ET Collaboration

Data analysis for Multi-messenger Astrophysics - AHEAD2020 Final WP3 workshop

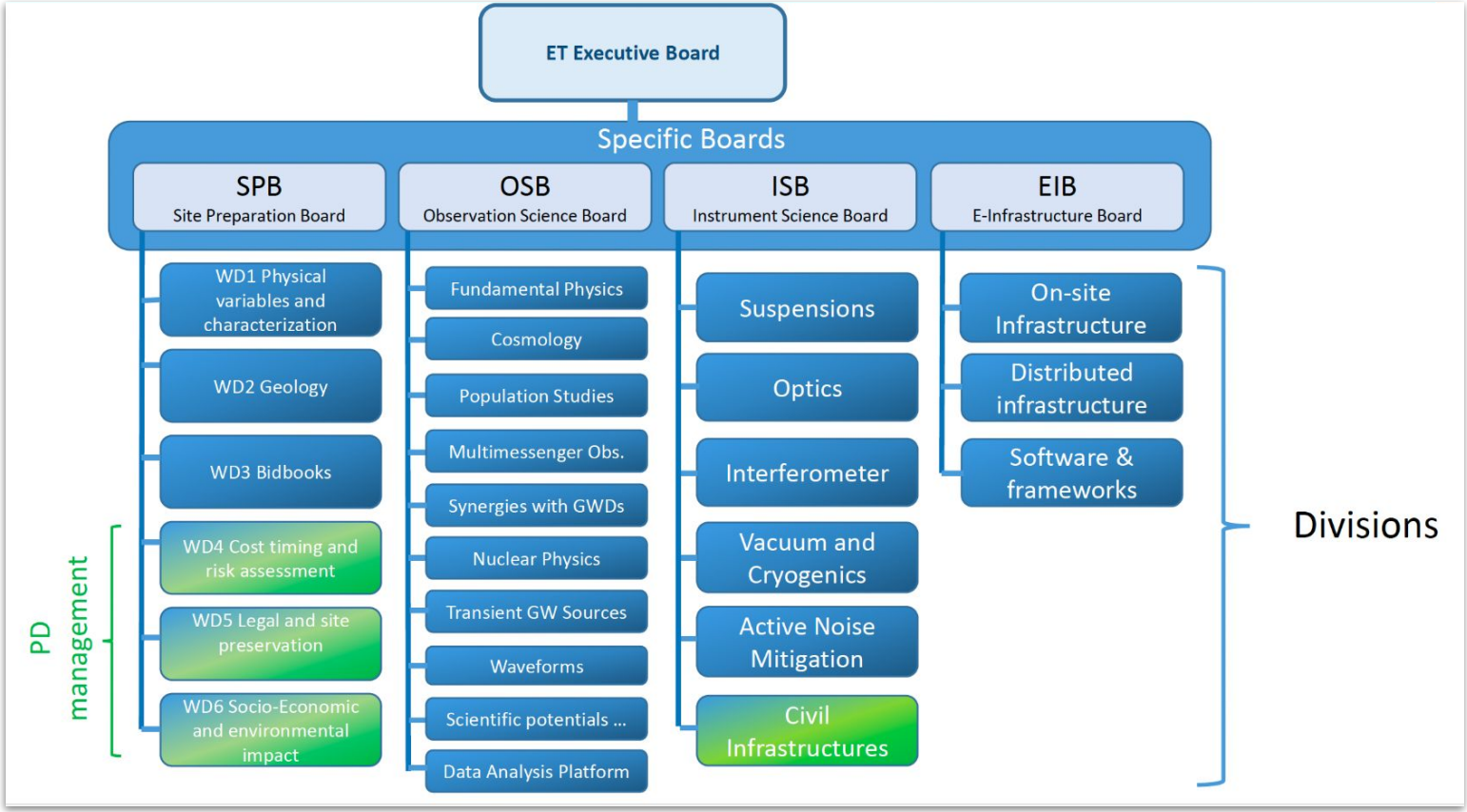
21–23 Oct 2024
European Gravitational Observatory

Worldwide Network of ET Member Affiliations

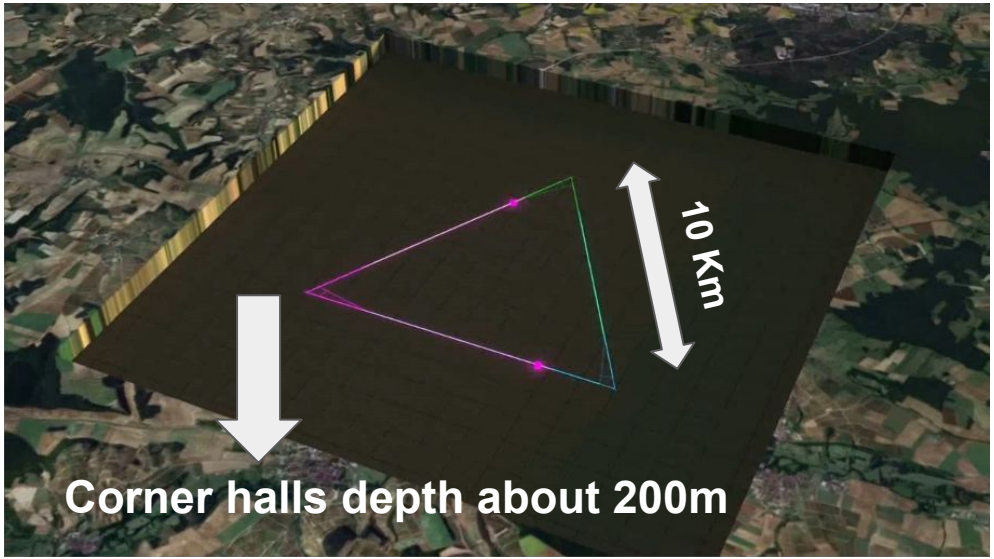


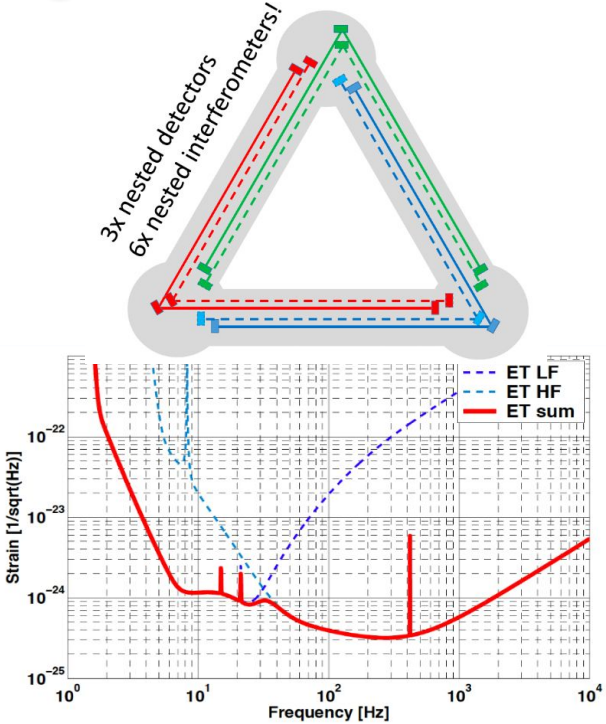
From ET Monthly Meeting - Last Updated: October 2024

ET Specific Boards



ET original configuration (2011): triangular geometry

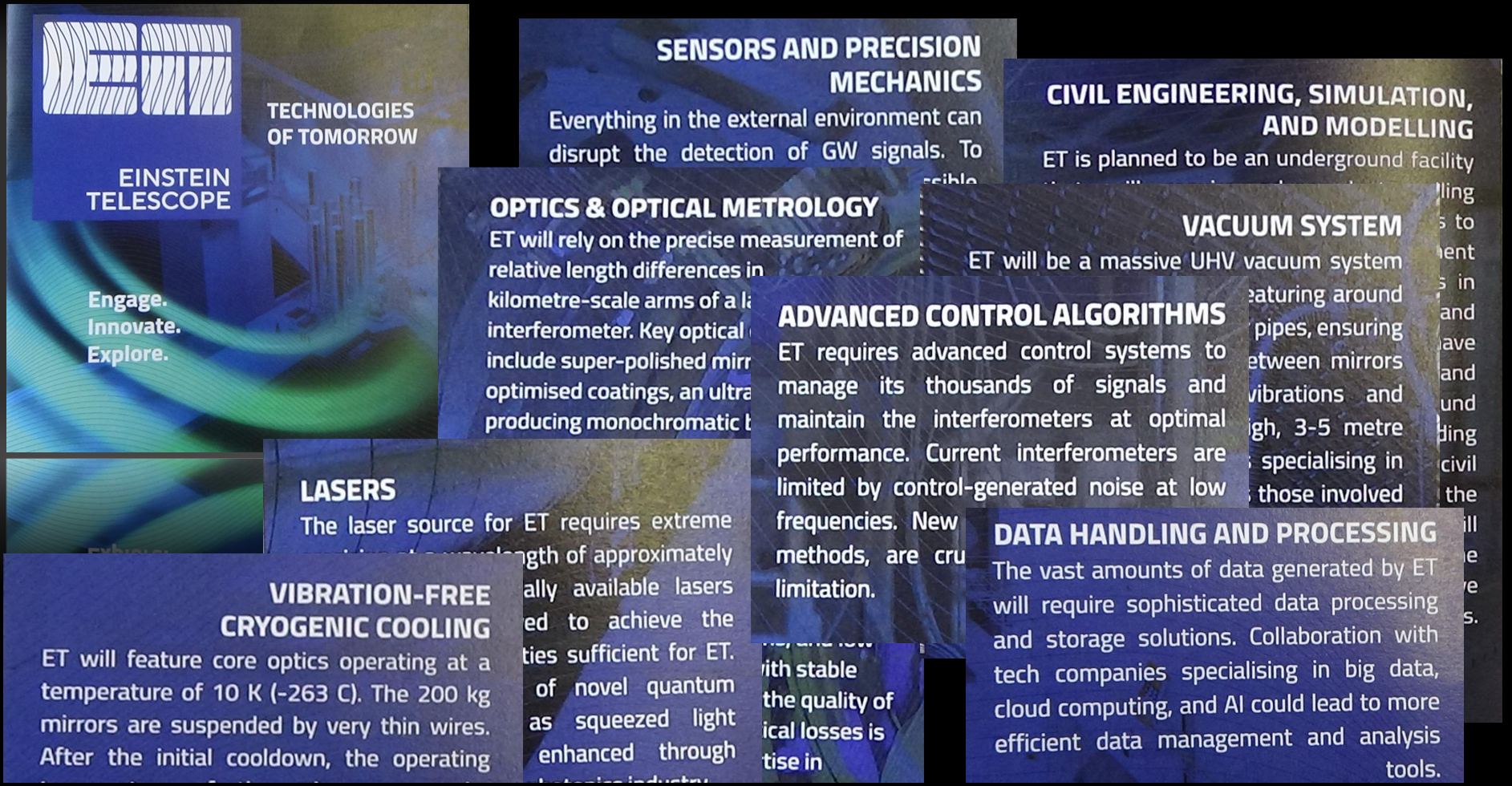




Three Nested Detectors: Arranged in a triangular layout, represented in **blue, green, and red**.Each detector comprises **two interferometers**:

- One optimized for **low-frequency sensitivity** (solid lines).
- One optimized for **high-frequency sensitivity** (dashed lines).

ET Pioneered the 3rd-Generation GW Observatory, enabling advanced technologies.
Future-Proof Design, built for decades of upgrades.



Big Science Business Forum - Trieste 1-4 October 2024

Candidate Sites for Hosting ET

- **Two official candidate sites**:
  - **EMR Euregio**: Border region between the Netherlands, Belgium, and Germany
  - **Sardinia**: Sos Enattos, Lula area in Barbagia
- **A third potential site**:
  - **Saxony (Lusatia)**: Not yet officially confirmed
- **Site evaluation** involves multiple factors:
  - **Geophysical and environmental quality**
  - **Financial and organizational aspects**
  - **Availability of services and infrastructure**
- **Ongoing measurements** focus on:
  - **Seismic noise**
  - **Magnetic**
  - **acoustic noise**

Einstein Telescope 😃 emozionato/a.
18 luglio ·

Both candidate sites for the ET are making great strides in exploring undergro
📌 EMR site: A drilling campaign is halfway through to study the subsurface c
stability. The deepest drilling at Aubel has reached 400 m. The total length of
from the six completed sites, if laid end-to-end, is approximately 2000 m. Fas
about the materials' age and origin have been revealed during the analysis of
Read more: https://buff.ly/3ScxTOY
📌 Italian site: Soon, at the Sos Enattos mine in Italy, researchers will use muo
perform muon tomography. This technique, similar to X-ray radiography, creat
the rock mass above the detectors by measuring muon flux. It will provide det
into the rock's internal structure and density, crucial for the ET stability. Read
https://buff.ly/3LtX7Vn

These efforts are paving the way for the ET, ensuring we select the best site f
observatory 🌠

#EinsteinTelescope #GravitationalWaves #Geology #MuonTomography

Photos:
📷Dezső Varga, László Oláh e Gergely Surányi (HUN-REN Wigner Research C
Physics) at Sos Enattos (INFN/Andrea Contu)
📷One of the ET drilling sites (Obsinnich) (ET-PP/Yuliya Hoika)

Einstein Telescope
29 agosto ·

🌍 Recently, the area around the former Sos Enattos mine in Nuoro has become a point f
several scientific activities, crucial for the future of the Einstein Telescope.
🎙 At the end of July, researchers from the GSSI - Gran Sasso Science Institute installed
microphone stations to study atmospheric acoustic noise, which can impact the sensitivi
#gravitationalwave detectors.
🎙 Simultaneously, a team from SAR-GRAV installed seismometers to evaluate seismic n
one of the potential sites for ET.
🌟 These studies are essential in determining the optimal location and depth for the futu
observatory.

Università di Sassari University of Milan-Bicocca INFN - Istituto Nazionale di Fisica Nu
Photo: Einstein Telescope Italy

Einstein Telescope
5 g ·

News on the ET technologies🛠✨
The Einstein Telescope EMR project office, in collaboration with University of Liège and KNMI - Koninklijk Nederlands Meteorologisch Instituut, is making strides in the German, Belgian, and Dutch border region 🇩🇪🇧🇪🇳🇱: Around 250 seismometers, called geophones, are being deployed to measure ground vibrations and acoustic waves. This will help scientists understand how noise penetrates deep underground and reduce its impact on the ET's ultra-sensitive detectors.
Meanwhile, in Sardinia 🇮🇹, the Agenzia Spaziale Italiana (ASI) is moving full speed ahead 🚀at the Sos Enattos mining site, another potential ET location: GNSS and weather stations are being installed to support the design of surface and underground structures, playing a key role in setting up the geodetic reference network. The project is expected to wrap up by mid-2025.

📖 To read more about:
✨ GNSS and weather stations: https://buff.ly/3YiAqdP
✨ geophones: https://buff.ly/3Nsx8OV

Photos: ET_EMR, ET_Italy

Government Support for Hosting ET

Significant financial backing from local and national governments at both candidate sites:

- **€900M** pledged by the Netherlands for the **EMR site**.
- **€950M** pledged by Italy, plus an additional **€300M** from the Sardinian local government, for the **Sardinia site**.

Geotechnical and geophysical evaluations underway at both sites to support the **engineering design** of the ET infrastructure:

- **€2M contract** in the Netherlands (EMR site).
- **€12M contract** in Italy (Sardinia site).

28 DECEMBER 2023

THE ITALIAN GOVERNMENT STRENGTHENS THE EINSTEIN TELESCOPE CANDIDACY

The Italian Government is ready to support the financial commitment required to host the Einstein Telescope (ET), the large research infrastructure dedicated to the study of gravitational waves that Italy has proposed to build in Sardinia, in the area of Sos Enattos, in Lula.

The government has expressed its commitment, both institutional and financial, to strengthen our country's candidacy for ET in a letter addressed to Antonio Zoccoli, the President of the

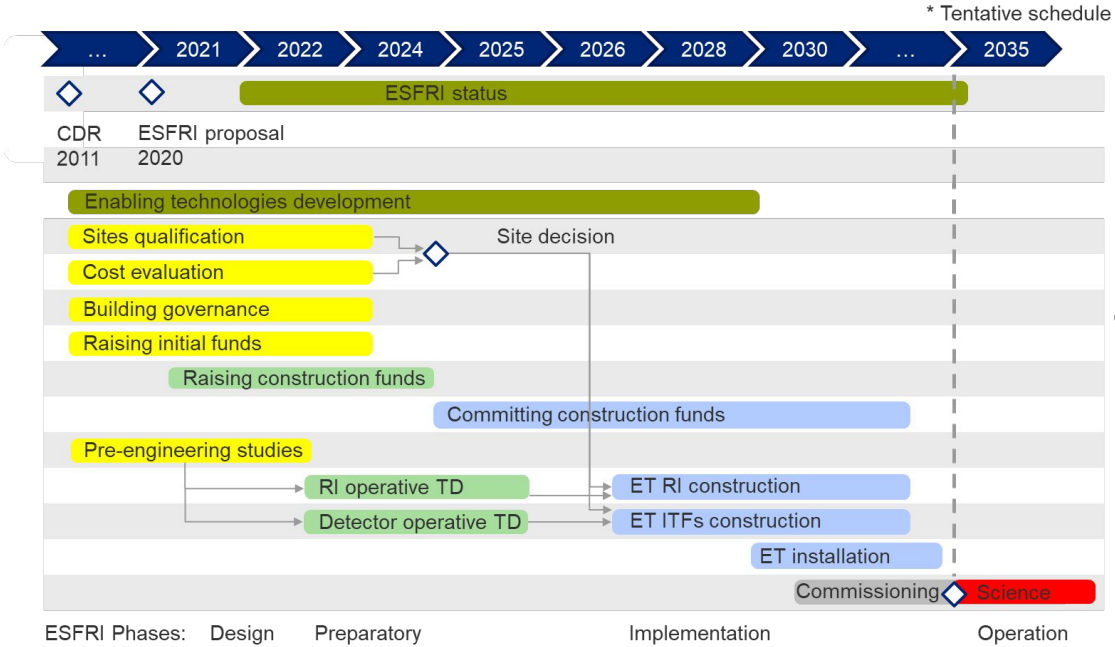
More than 900 million euros for Einstein Telescope

42 million for the preparations and 870 million for when the installation is actually built in Limburg

14-04-2022 · News

MAASTRICHT. The Dutch government is investing in the Einstein Telescope: almost 1 billion. The money, from the National Growth Fund, is partly for the preparations (42 million) and partly a reservation for when the installation is actually built in the Heuvelland (870 million). That is still uncertain; the decision will be made in 2025 whether the gigantic project will be awarded to South Limburg or Sardinia.

ET Project Timeline Presented to ESFRI

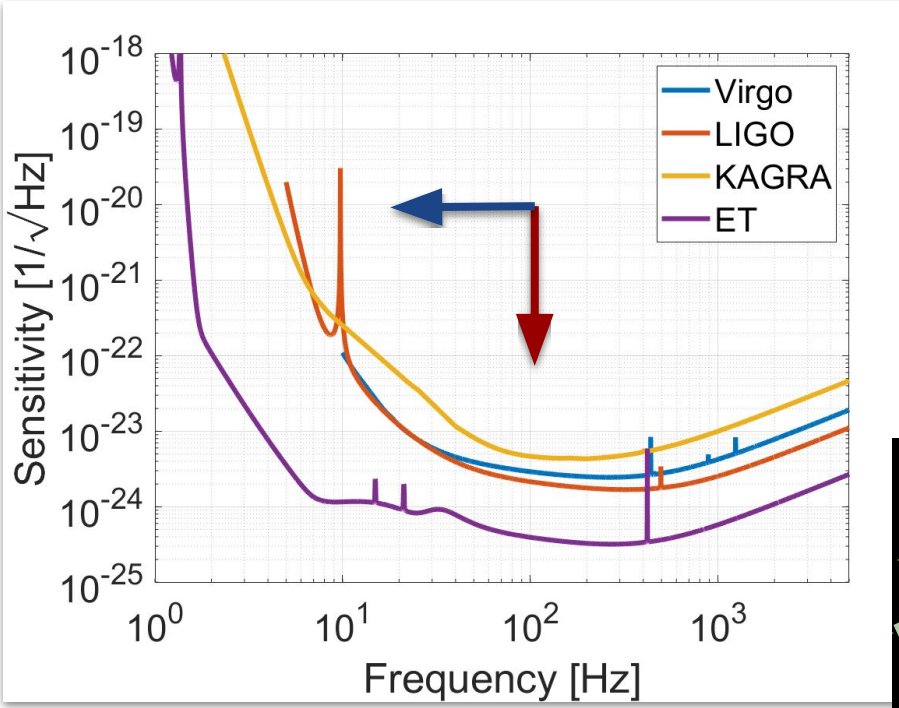


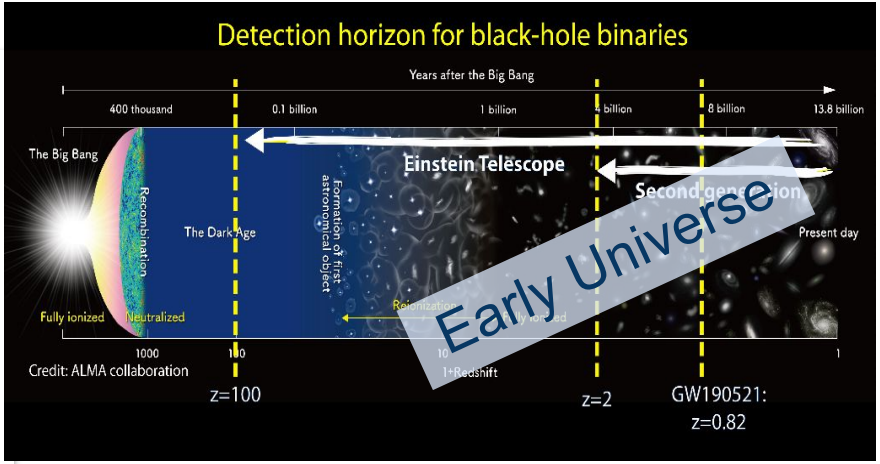
A new timeline is under definition!

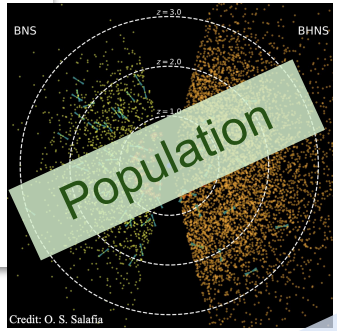
CDR Evaluations: Budget Overview

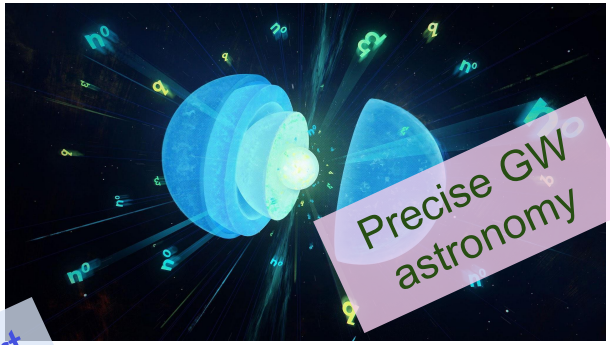
- **Total Budget**: ~€2 billion
  - Excavations and civil engineering: ~€930 million
  - Vacuum system: ~€570 million

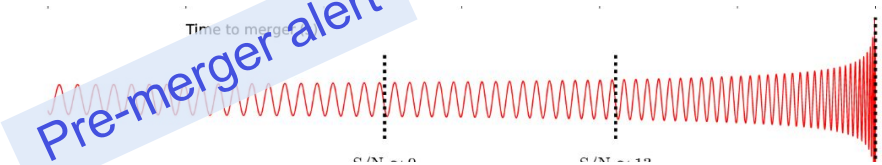
The European Commision included ET in the ESFRI roadmap in 2021 and is currently funding the preparatory phase activities, which are being conducted under the European ET-PP project.











ET will enhance sensitivity by **an order of magnitude** compared to Advanced Virgo and Advanced LIGO, while extending the observation range to **lower frequencies**.

ET Scientific Summary

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

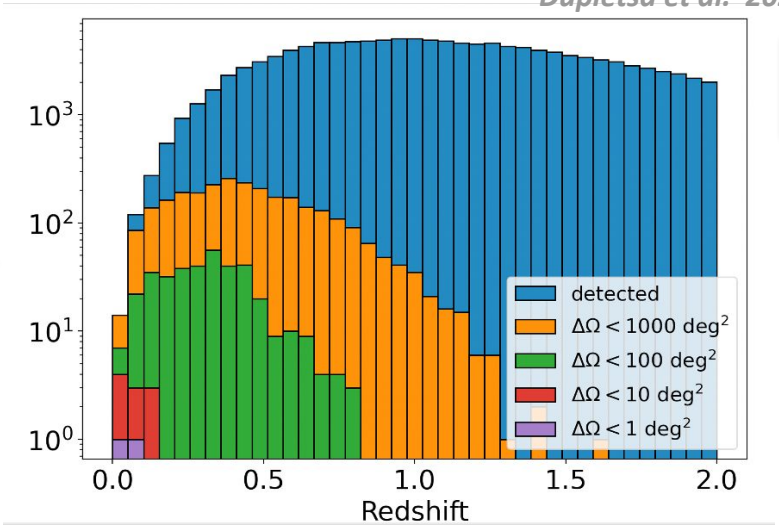
- **The nature of compact objects**
  - near-horizon physics
  - tests of no-hair theorem
  - exotic compact objects
- **Tests of General Relativity**
  - post-Newtonian expansion
  - strong field regime
- **Dark matter**
  - primordial BHs
  - axion clouds, dark matter accreting on compact objects
- **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

Enables routine multimessenger astronomy and advances in cosmology and fundamental physics.

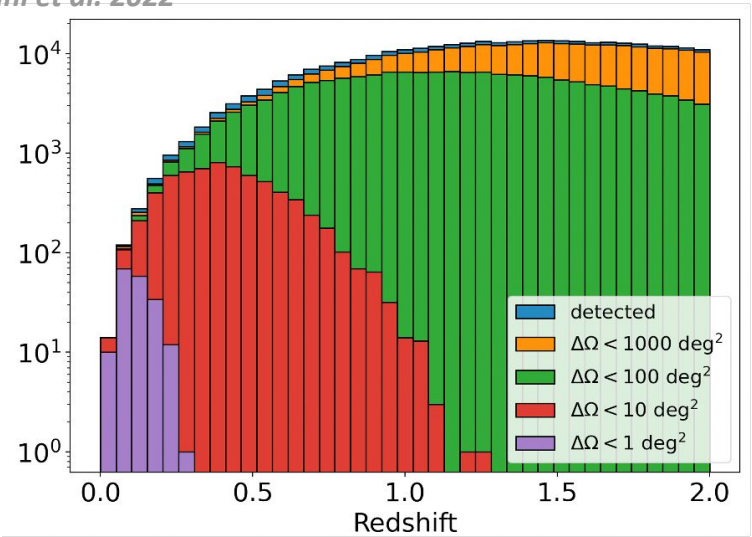
Localization Capabilities: ET Alone vs. ET in a Network

Dupletsa et al. 2023, Ronchini et al. 2022

ET



GWFISH



ET + CE

ET Low-Frequency Sensitivity and BNS Localization

- Enables the localization of **Binary Neutron Star (BNS) mergers**.
- Expect **~100 detections per year** with sky localization accuracy (90% confidence) **under 100 square degrees**.
- Provides **early warning alerts** for timely follow-up observations.

Sky Localization Capability in ET Network

- **~1000 detections per year with sky localization accuracy (90% confidence) under 10 square degrees.**

The Cost and Benefit Analysis (CoBA) process

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Science with the Einstein Telescope: a comparison of different designs

Marica Branchesi,[1,2,*] Michele Maggiore,[3,4,*] David Alonso,[5] Charles Badger,[6] Biswajit Banerjee,[1,2] Freija Beirnaert,[7] Enis Belgacem,[3,4] Swetha Bhagwat,[8,9] Guillaume Boileau,[10,11]

JCAP

The science case for different ET designs **Δ or 2L** has been studied by a dedicated committee (the Cost Benefit Analysis,CoBA).

Will the Einstein Telescope be split in two?

While Italy and the Netherlands prepare their bids to host the next gravitational wave observatory, the collaboration is considering an alternative design that would use both sites.

https://www.nature.com/natitaly

The study concluded that two L-shaped detectors would lead to better results. “For nearly all the science cases we have considered, two L shaped detectors would be able to observe from two to three times the number of events that the triangle would see. That this design would also allow to better locate the source of each gravitational wave in the sky, which is critical for pointing optical telescopes in the right direction and observing the light emitted by merging neutron stars.

AHEAD WP 12 Deliverable

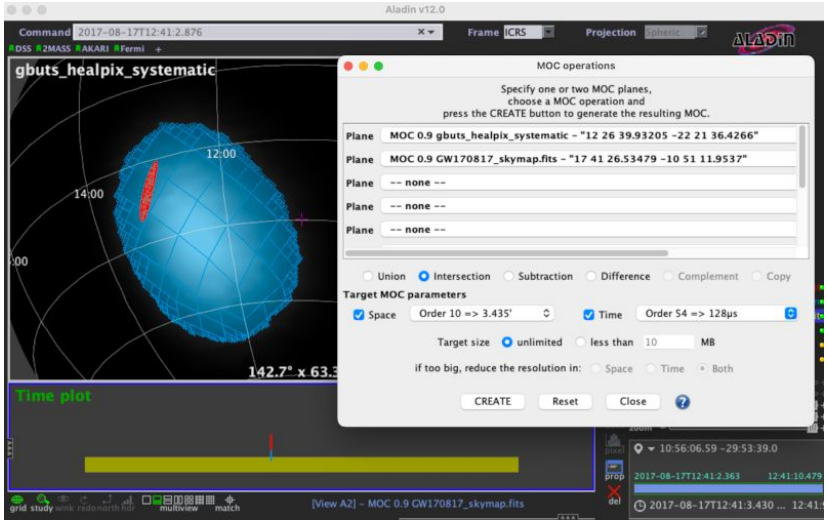
MOC: Multi-Order Coverage map
Version 2.0

IVOA Recommendation 27 July 2022

Interest/Working Group:
http://www.ivoa.net/twiki/bin/view/IVOA/IvoaApplications

IVOA Recommendation

Contents



Space and time MOCs allow for simultaneous spatial and temporal intersections. An example is provided in the **IGWN User Guide** for **GW170817**.

As part of WP 12 of AHEAD, we developed a new standard, recommended by the IVOA, to support the Virtual Observatory (VO) for encoding skymaps, specifically adaptable to future needs in the era of Multimessenger Astronomy (MMA) with ET.

Einstein Telescope (ET) - Key Highlights

- **3rd-generation observatory**: Expands detection horizon to the entire observable universe.
- Enables **routine multimessenger astronomy** and advances in **cosmology** and **fundamental physics**.
- **Largest underground research infrastructure**, driving technological innovation across multiple fields.
- Part of the **European ESFRI roadmap**:
  - Two configurations under study: **10 km triangular** and **15 km dual L-shaped**.
- Backed by the **ET International Collaboration**:
  - Over **1,725 members**, **253 institutions**, across **30 countries**.
- **Two candidate sites** for hosting the ET:
  - **Euregio Meuse-Rhine (NL, BE, DE)**.
  - **Sardinia, Italy**.
- Extensive **site characterization studies** underway, with strong financial backing from host countries.