ET collaboration perspective, a challenge and an opportunity

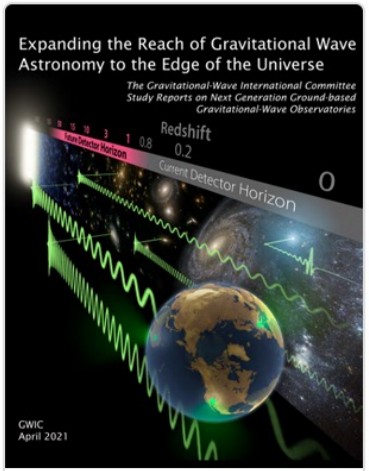
E. Majorana

KAGRA Future Working Group 17/11/2022

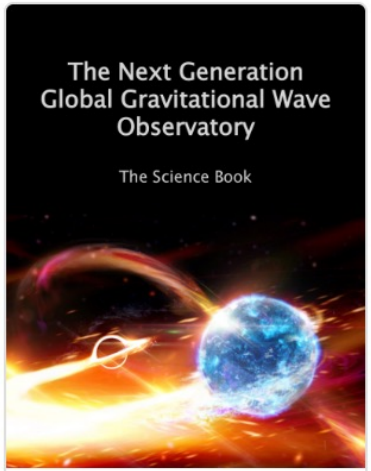
A worldwide community, a prosperous future

GWIC-3G Home Charge Committee Subcommittees Documents Meetings

GWIC Releases the GWIC-3G Subcommittee Reports on Next Generation Ground-based Observatories

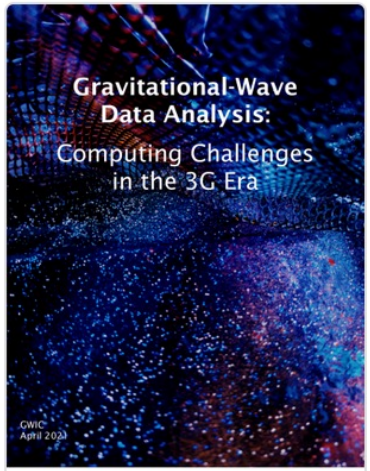


Introduction

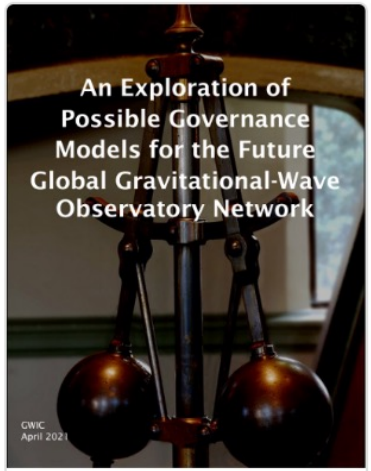


Science

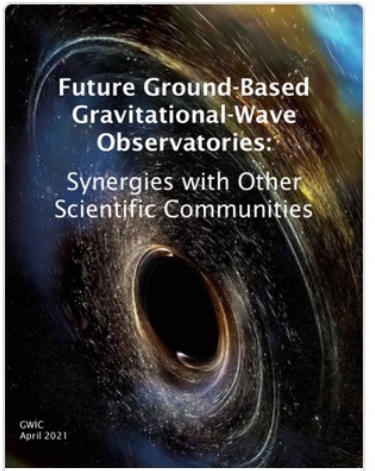
R&D



Computing



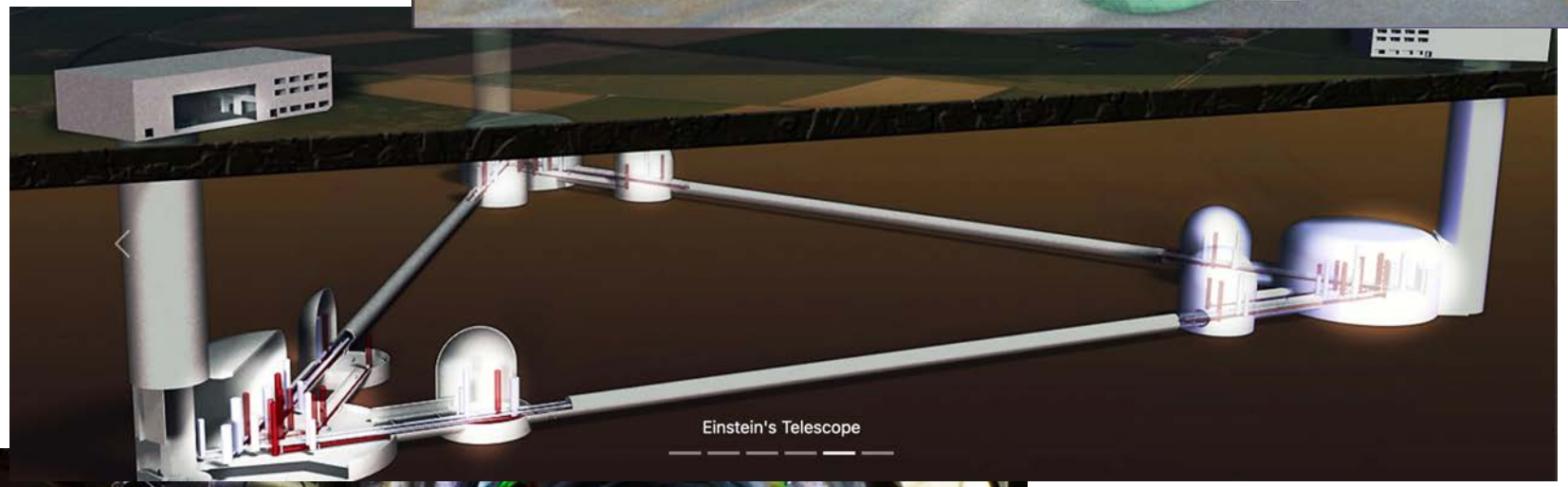
Governance



Communities

https://gwic.ligo.org/3Gsubcomm/

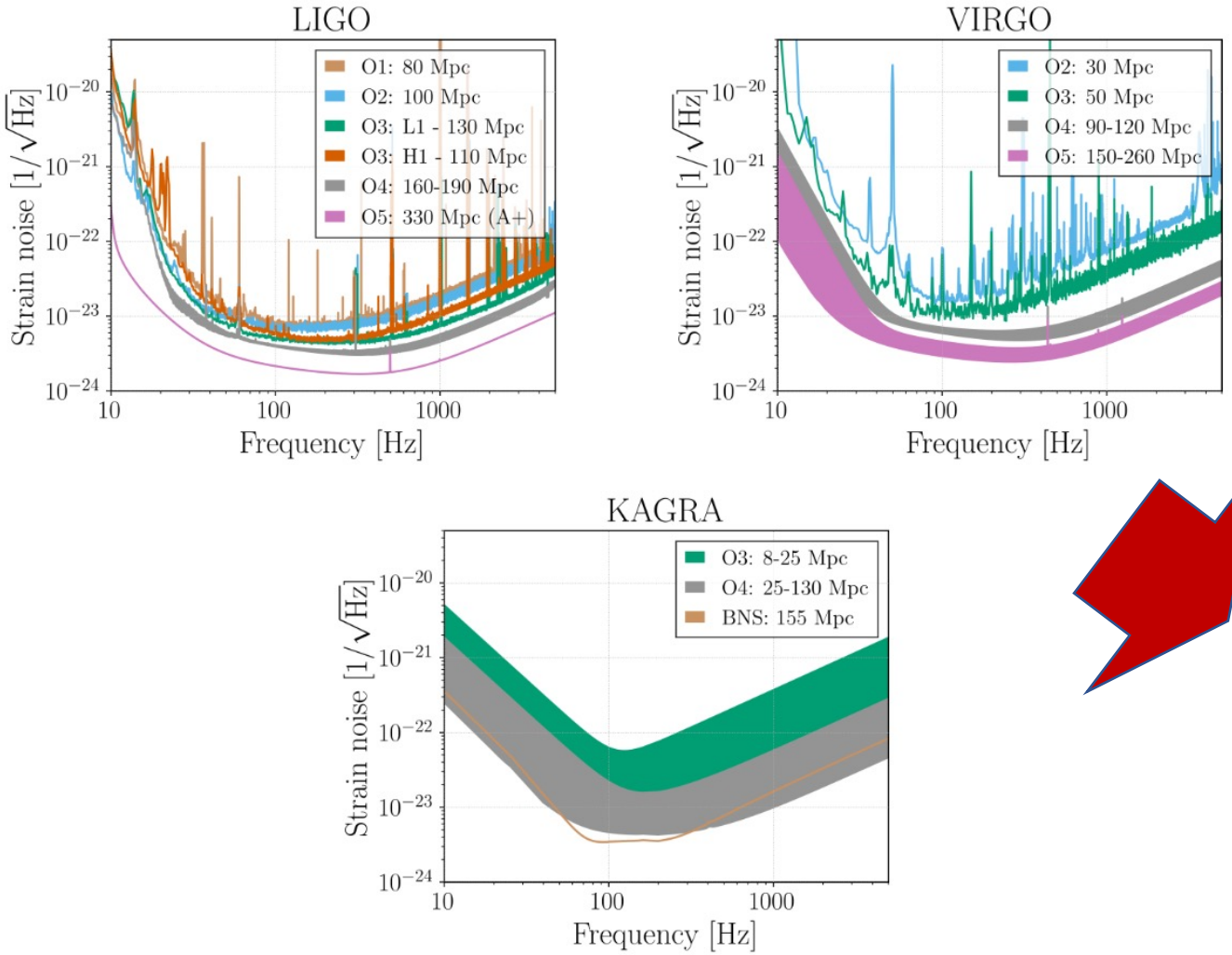
A worldwide community, a prosperous future

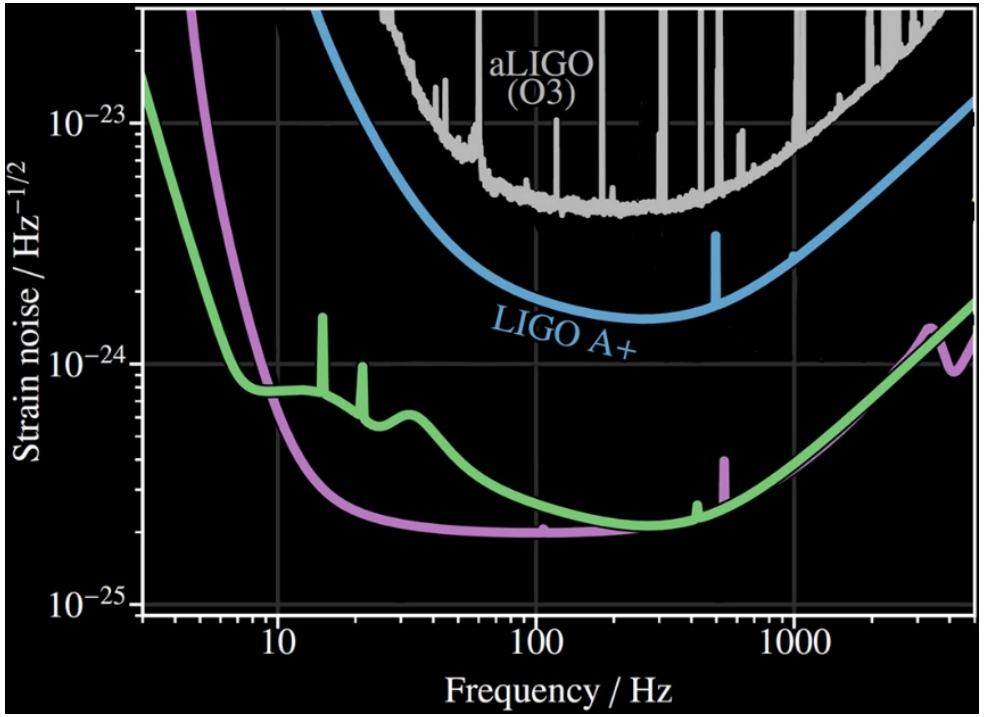


In the path towards 3G detectors KAGRA is commonly set close to ET

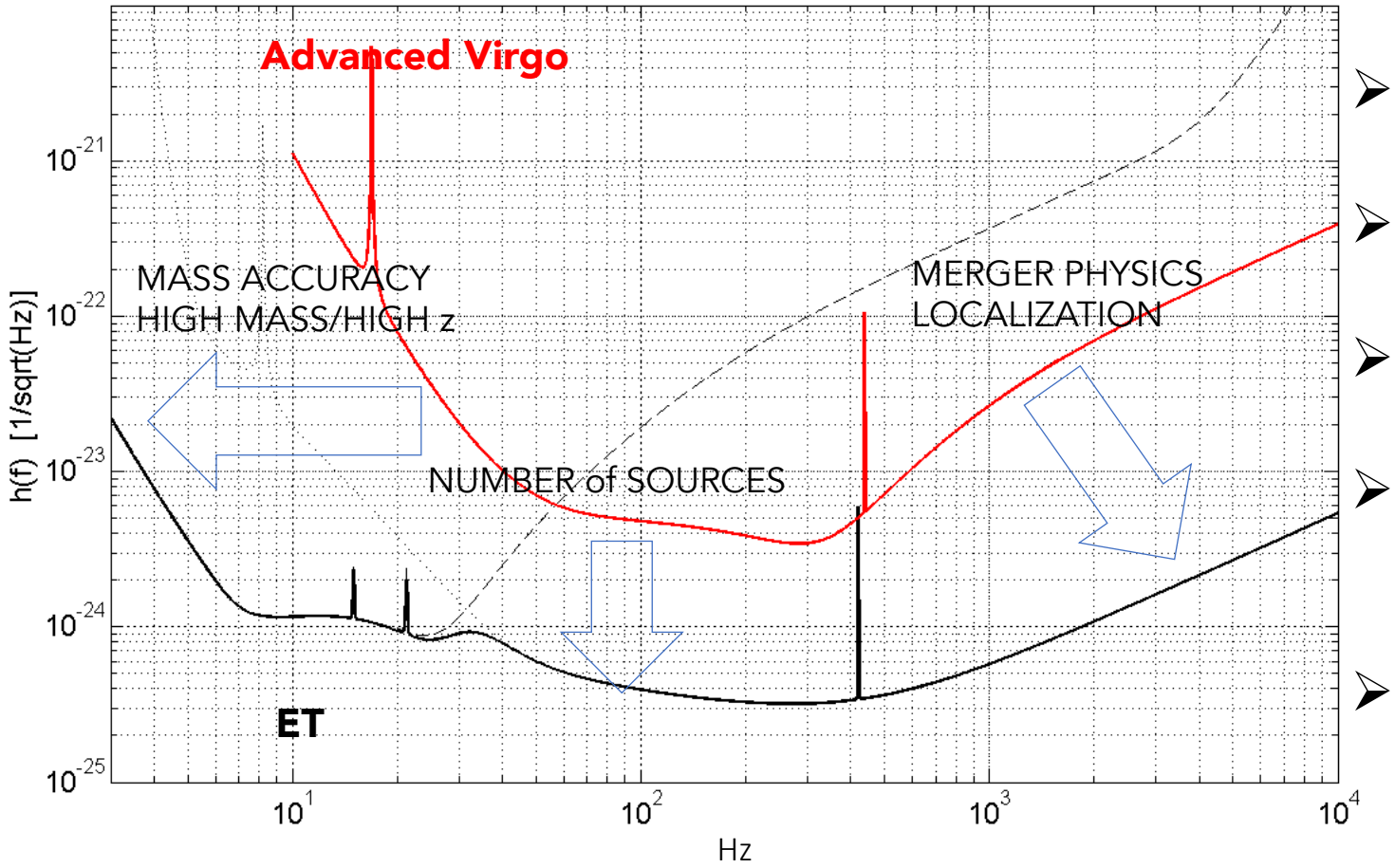
What‘s next (the first detections operaed by KAGRA…)?

Prospects for observing and localizing gravitational-wave transients with Advanced LIGO, Advanced Virgo and KAGRA https://doi.org/10.1007/s41114-020-00026-9





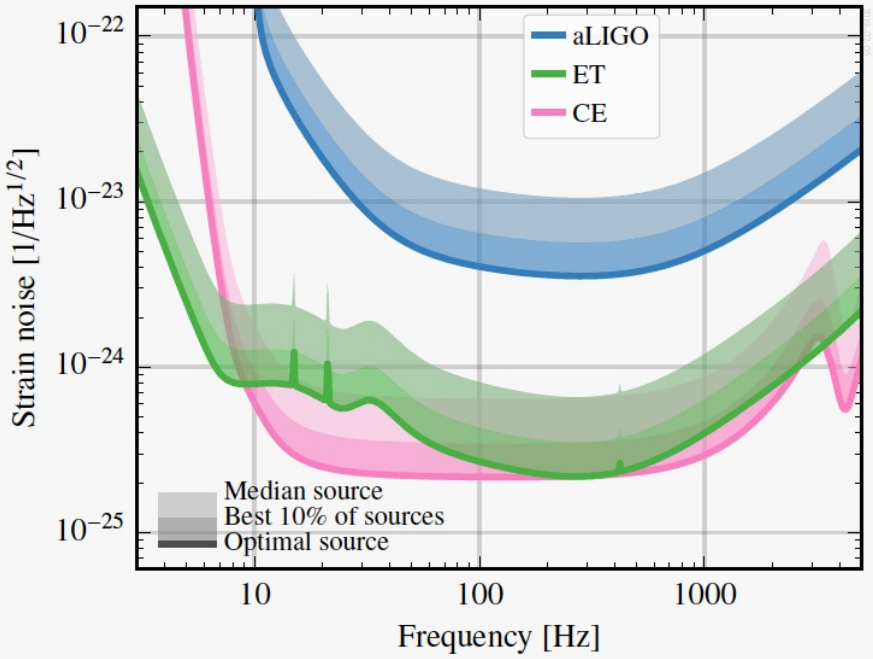
SENSITIVITY GOAL: ~×10-20 better



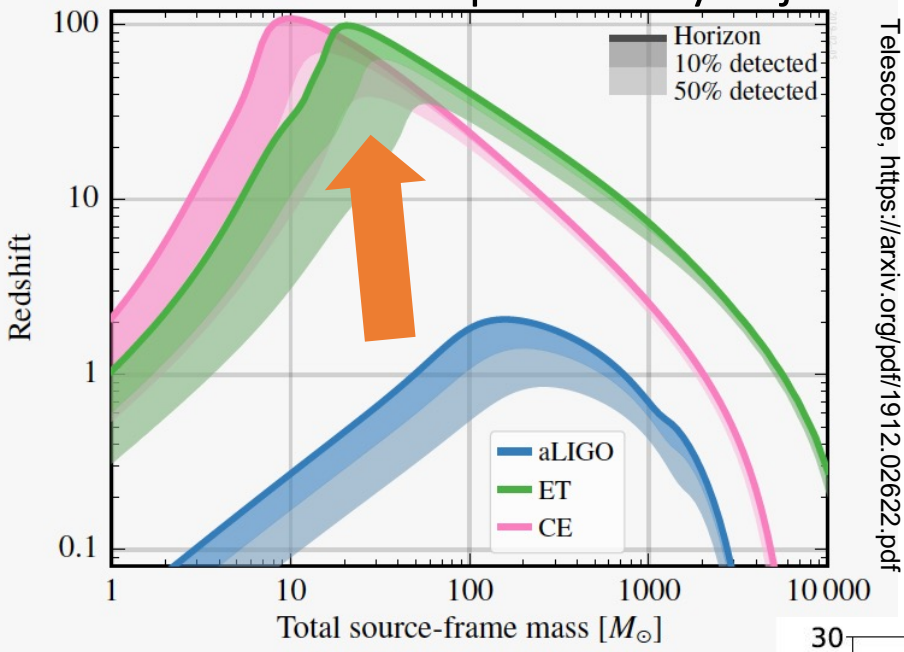
- *Merging Black Holes* ***throughout the whole universe*** and reconstruct BH demography
- Explore *new physics in gravity* and fundamental properties of compact objects
- Study the properties of the *hottest matter* in the universe
- Investigate connection between high *energy processes in radiation/particle VS gravitation*
- *Investigate primeval universe* and connections with particle physics

Our target 10^5 to 10^6 events/year

Strain sensitivity



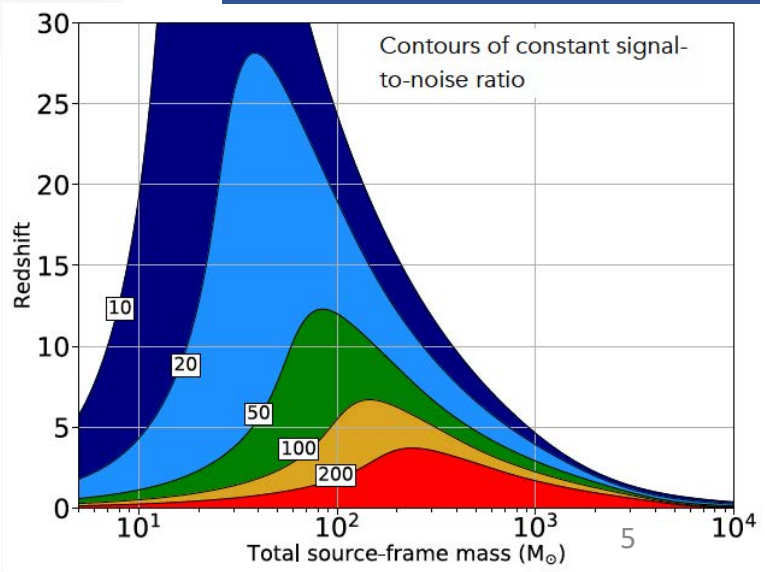
Coalescence of compact binary objects



M. Maggiore et Al. Science Case for the Einstein Telescope, https://arxiv.org/pdf/1912.02622.pdf

Binary Coalescences Overview:

- Census of stellar and intermediate-mass BBH population over full Universe, 10^5-10^6 events per year;
- High SNR events will provide excellent precision to do accurate test of GR, nature of the BH, strong-field dynamics, black hole no-hair theorem etc;
- Extend the range of observed BBH masses towards >1,000M_{sol} and <1M_{sol};
- Observe several 10,000 binary neutron star mergers per year.
- ET will determine NS EOS.



A network of 3 3G detectors (ET+CENorth+CESouth)

ET, the European 3G idea

- The 3G detector conceived in Europe is a new GW observatory
  - 3G: Factor 10 better than advanced (2G) detectors
  - New:
    - We need a new infrastructures because
      - Current infrastructures will limit the sensitivity of future upgrades
      - In 2030 current infrastructures will be obsolete
  - Observatory:
    - Wide frequency range, with special attention to low frequency (few Hz)
      - LF and HF technologies separated
    - Capable to work alone and produce science results (though aiming to be in a 3G net)
      - (poor) Localization capability
      - Polarizations (triangle)
      - Redundancy
    - 40-50-years lifetime of the infrastructure
      - Compliant with the upgrades (a big-science facility)

Cryo-LF/QNR techniques

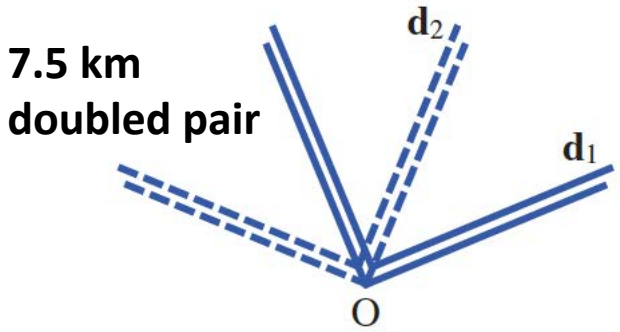
Standalone operation for localization is now unconceivable

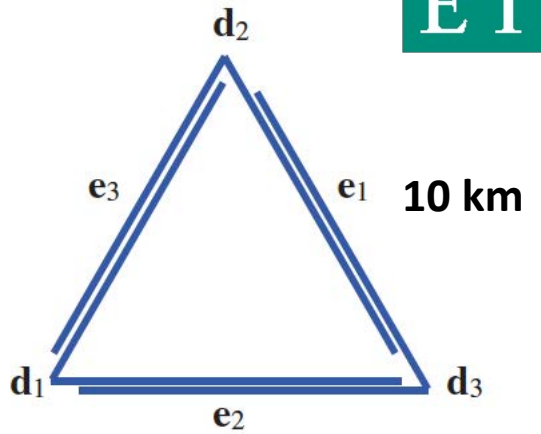
ET was born as a triangle

The triangle/L debate

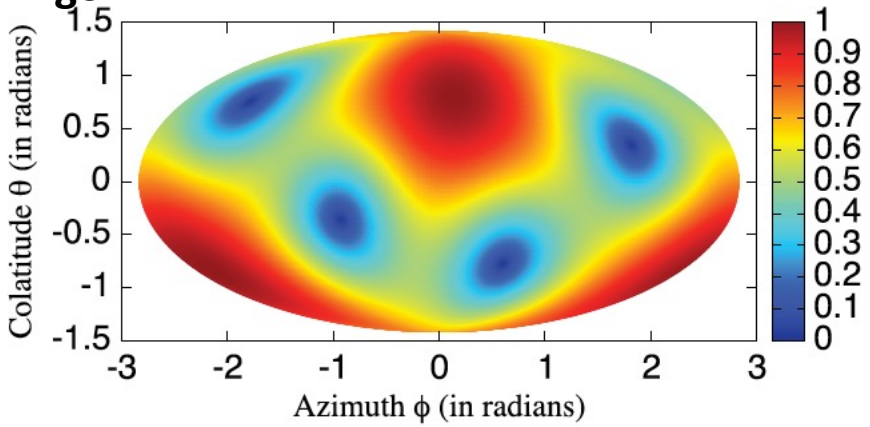
Basics here: Class. Quantum Grav. 29 (2012) 124013
The debate is still alive !!

Triangular or L ?

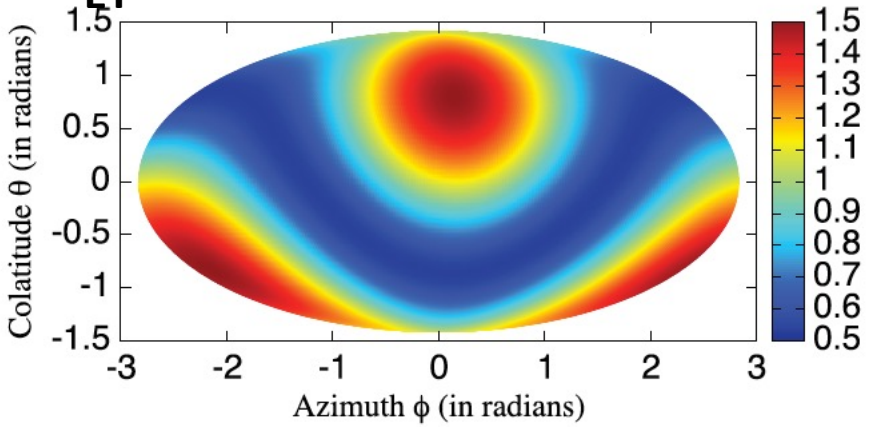




Virgo



ET



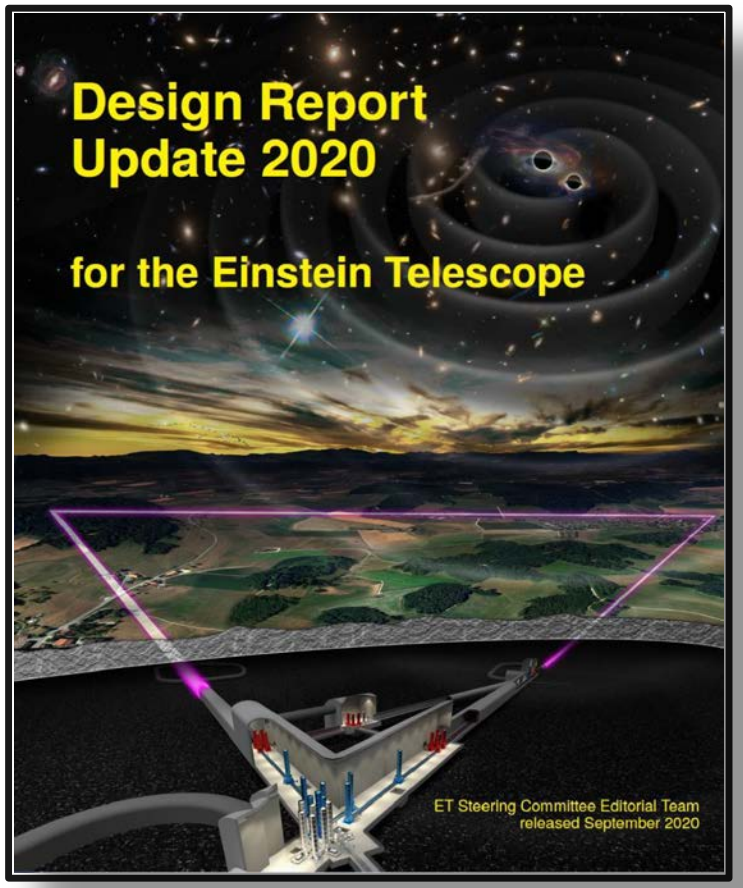
- Characteristics of a triangular array : sum of outputs depends only on background noise
- Reconstruction of signal **polarizations** and **null stream veto**
- Two L shaped arrays (misaligned) **do not provide null stream veto**
- For two L shaped interferometers a wide separation would be essential ➔ localization
- **Animated debate** on **actual** infrastructure cost/feasibility going on, though at present focused on triangle

Conceptual Design Studies

https://tds.virgo-gw.eu/?call_file=ET-0106C-10.pdf

ESFRI

https://apps.et-gw.eu/tds/?content=3&r=17245

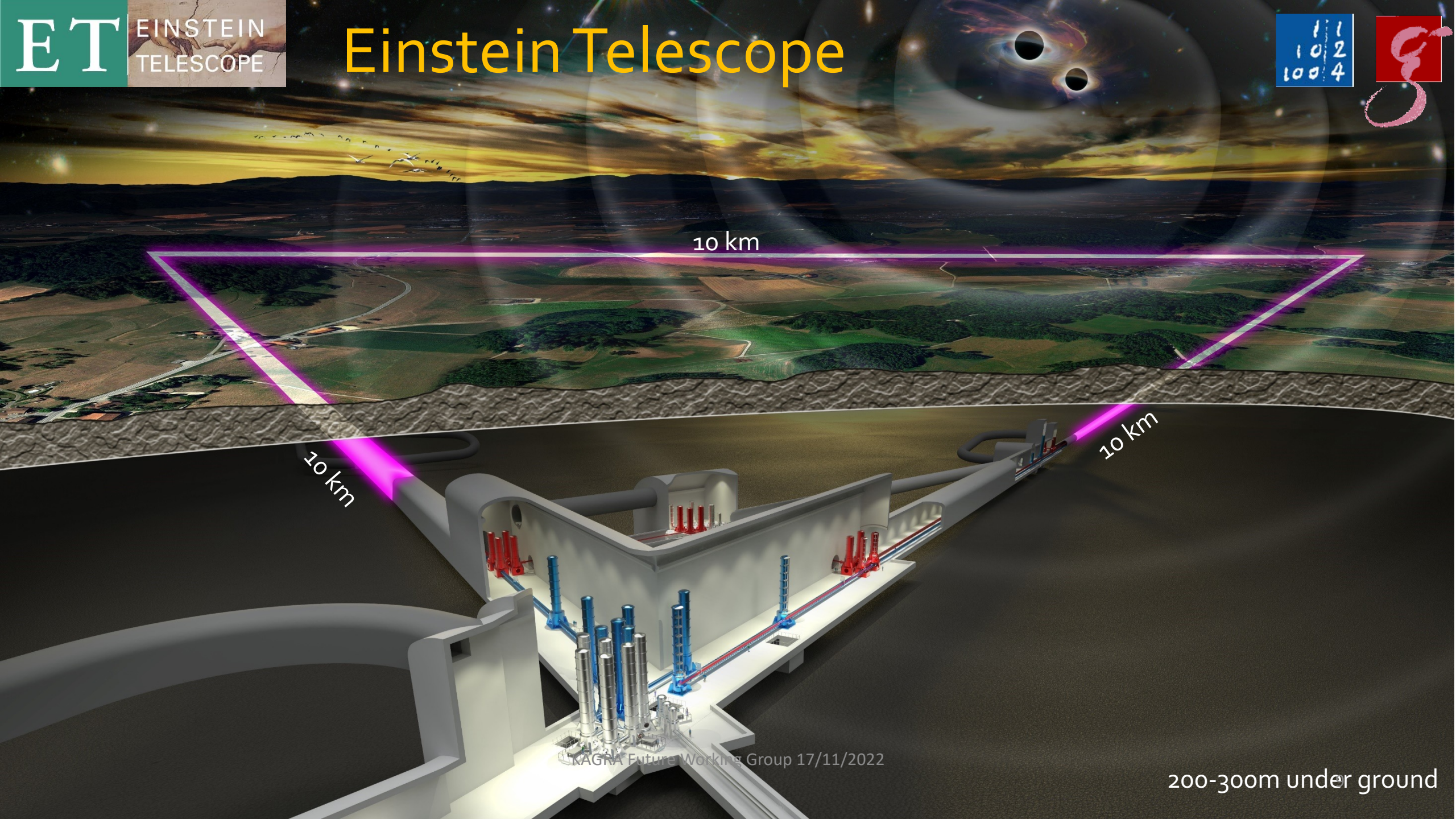


- In 2020 governments of 5 EU countries (Italy, the Netherlands, Belgium, Spain and Poland) submitted the ET application to ESFRI (European Strategy Forum on Research Infrastructure).
- July 2021 ET obtained ESFRI status, as the highest value project ever to feature on an ESFRI roadmap.

❖ **Constitution of the ET collaboration Budapest 6 June 2022 !!**

❖ **Site definition (2024)**

Einstein Telescope

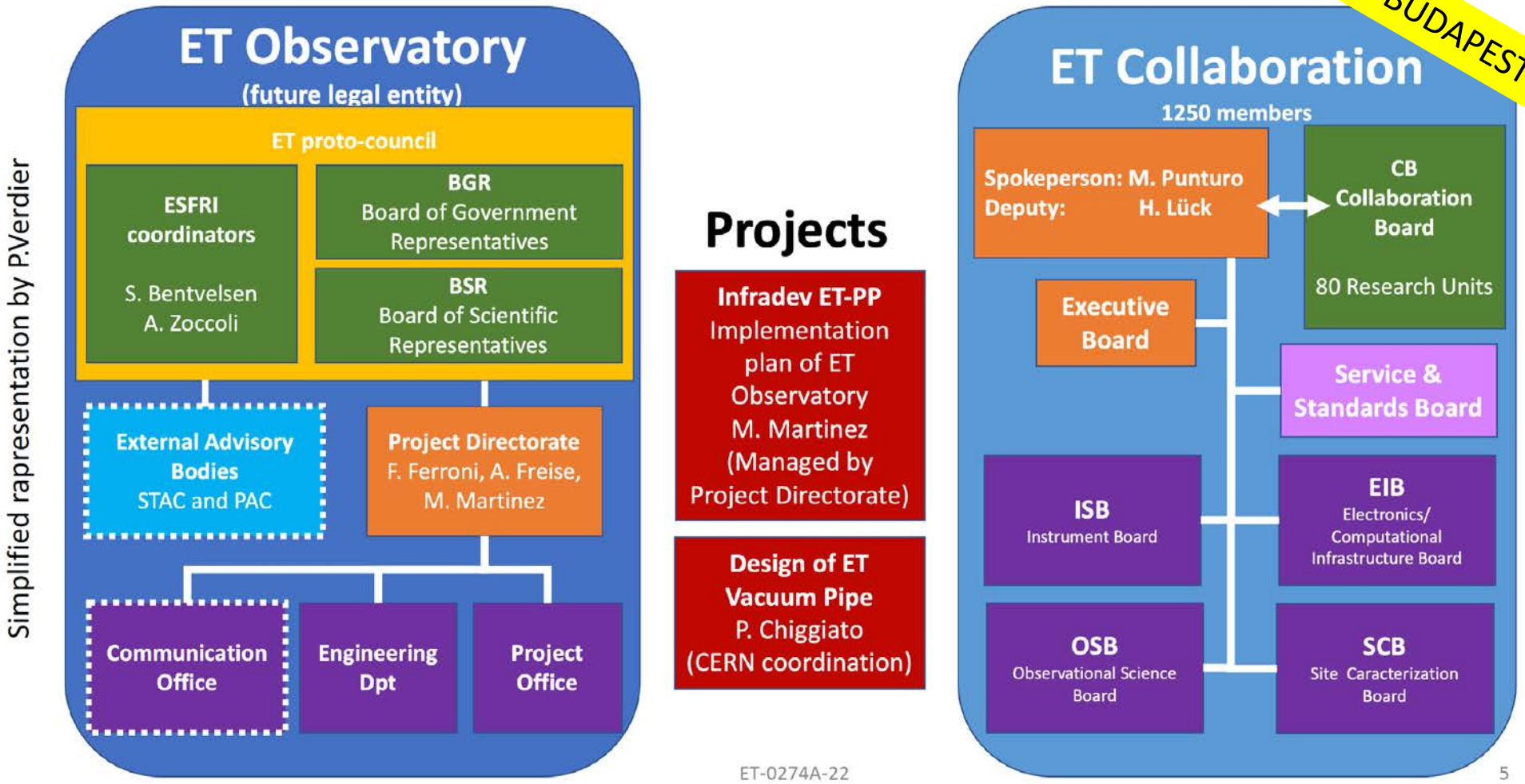


KAGRA Future Working Group 17/11/2022

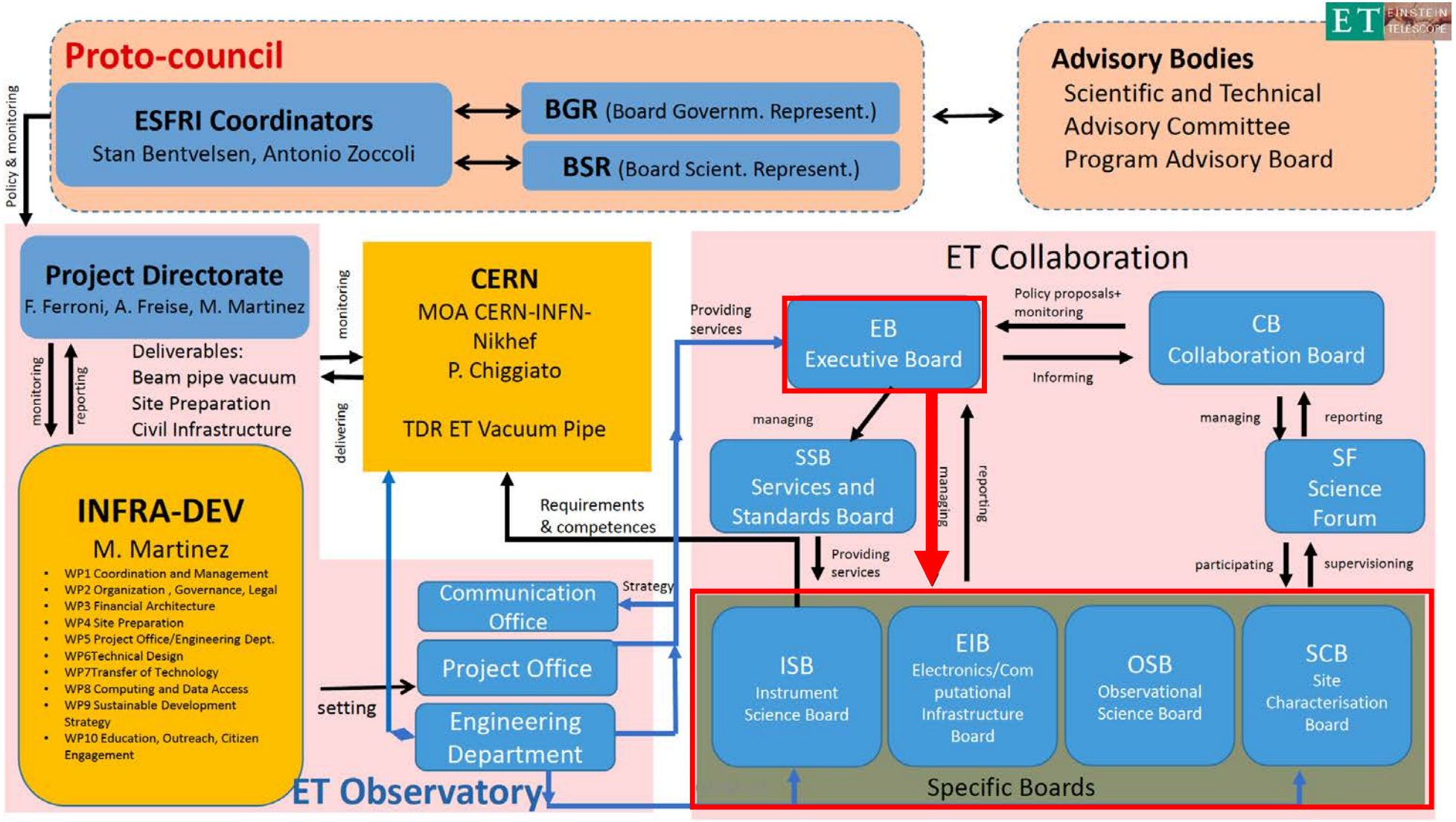
200-300m under ground

ET, the structure, the first two projects

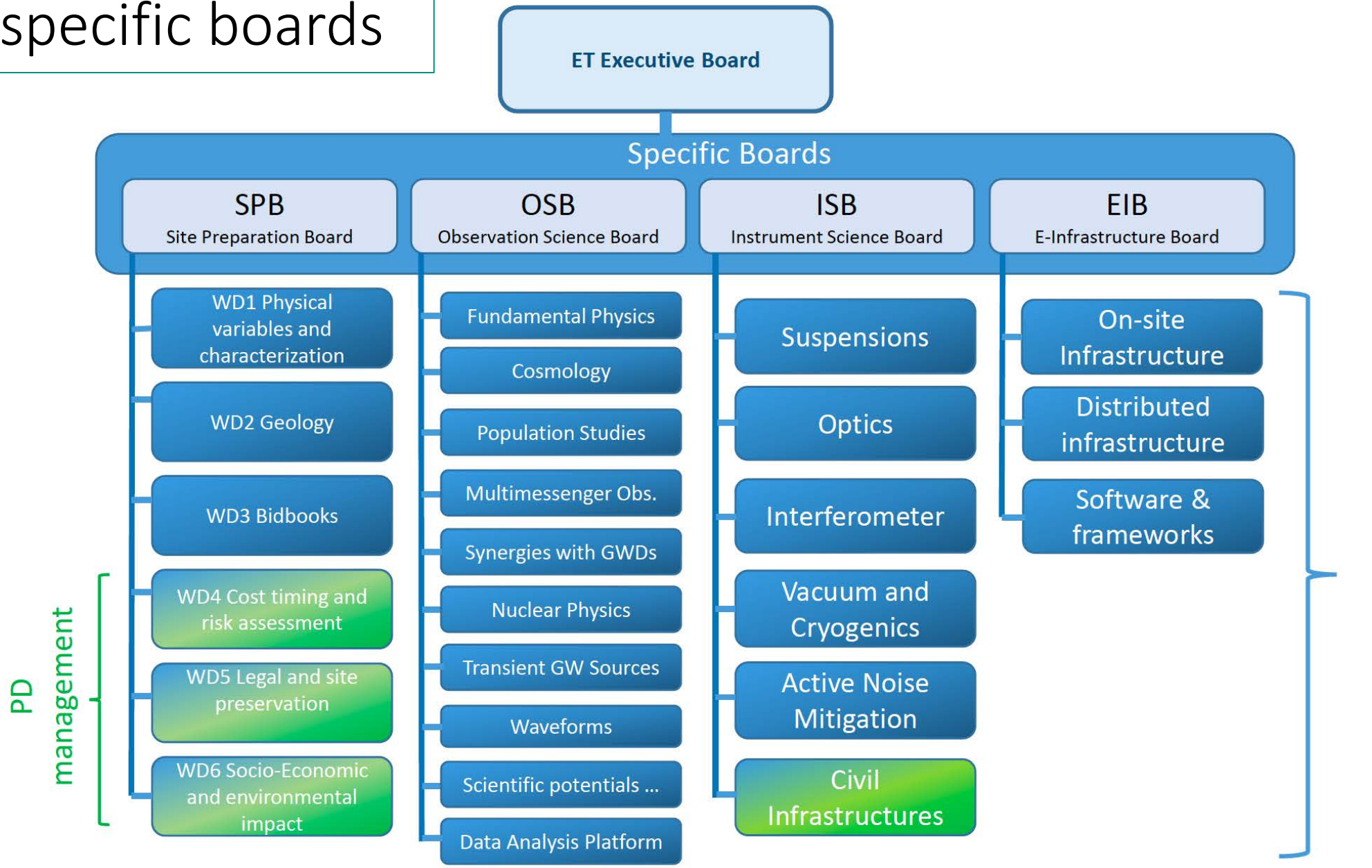
COSTITUTED IN BUDAPEST /JUNE 2022



ET, the structure, operative interconnections



ET, specific boards



ET-0274A-22

The EB Activities

From the ET bylaws

- The Executive Board (EB) manages the core activities of the ET collaboration.
- The EB has the duty to coordinate the technical and daily activities.
- It is composed by ex-officio members and additional members proposed by the SP and endorsed by the Collaboration Board. Ex-officio members will be the Collaboration Spokesperson (SP), the Deputy Spokesperson (DSP) and one delegate of each Specific Board. […]
- It is led by the ET Collaboration Spokesperson.
- EB members are nominated by the Spokesperson and endorsed by the Collaboration Board.
- It submits important decisions to the Collaboration Board for endorsement.
- **manages Specific Boards** that can change according to the different phases of the project. […]
- **takes on the duty to realise the various stages of the TDR for ET**. The progress will be reported to the CB at every CB meeting.
- proposes, through the SP or DSP, the agenda of the General Assembly meeting to the Chair of the CB

The work of the Executive Board shall be transparent to the Collaboration. […] Minutes of the meeting will be taken and will be made available to the Collaboration

EB composition

Current Members

Chairs: Michele Punturo (Interim ET Spokesperson)
Harald Lueck (Interim ET deputy-spokesperson)

Members: Stefano Bagnasco (EIB co-chair)
Gianluca Gemme (ISB co-chair)
Ed Porter (OSB co-chair)
Domenico D'Urso (SPB delegate)
Patrice Verdier(EIB co-chair)
Achim Stahl (EIB co-chair)
Stefan Hild (ISB co-chair)
Michele Maggiore (OSB co-chair)
Marica Branchesi (OSB co-chair)
Frank Linde (SPB co-chair)

Observers: Alessandro Variola (Head of the Project Office -PO)
Alessio Rocchi (Technical Coordinator in the PO)
Patrick Werneke (Head of the Engineering Dept.)

The most urgent work is done by **ISB**

https://indico.ego-gw.it/event/465/

N: **single** site vs **multiple** site: CoBA process (looking at the science aims)

Hybrid (erroneously called “Xylophone” in the last 20 years): are we able to have an ET-LF ? if yes, when? R&D on Enabling Technologies: Cryogenics

Δ or L The debate opened 10 y ago is still debated in CoBA process

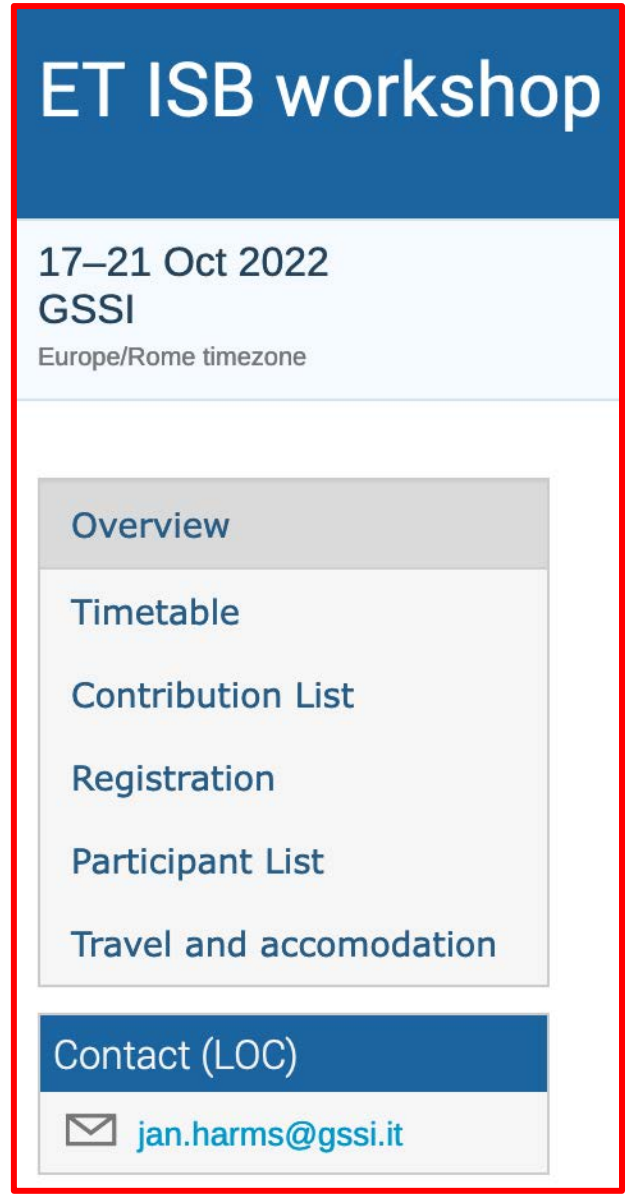
Materials for cryogenic ET-LF: Silicon or Sapphire test masses and/or suspension

Coatings: relevant for both HF (3 MW!) and LF (suitable for crystalline TM)

Electronics (analog and digital, usually forgotten): impacts on **ET-LF cryo**. We play with hierarchical control through wise mechanical design. Is a substantial reduction envisaged through new driving electronics (over 10-20 years timeline !!!) ?

Magnetic Noise: we pump E.M. energy in the cavern, ITF actuators sense it, recently estimated as a potentially serious issue, but based upon Virgo/LIGO sites

Newtonian Noise suppression (and maybe subtraction) in caverns !
… many others



CORRELATED NOISE @ Δ

K. Janssens, Correlated noise and how it can prevent us from reaching our science goals with the ET

example

mpact from infrastructural magnetic noise

Assumptions:
- Pessimistic scenario: Virgo magnetic noise of CEB, 100% coherent
- For ASD, assume 'technical noise', i.e. 1/10 of target sensitivity curve

Results:
- Many orders of magnitude improvement needed at frequencies <30 Hz, both for ASD as well as GWB
- ASD: affected >30Hz if coupling is similar as Virgo
- GWB: one to two orders of magnitude improvement needed >30Hz

Conclusions:
- See slide 12

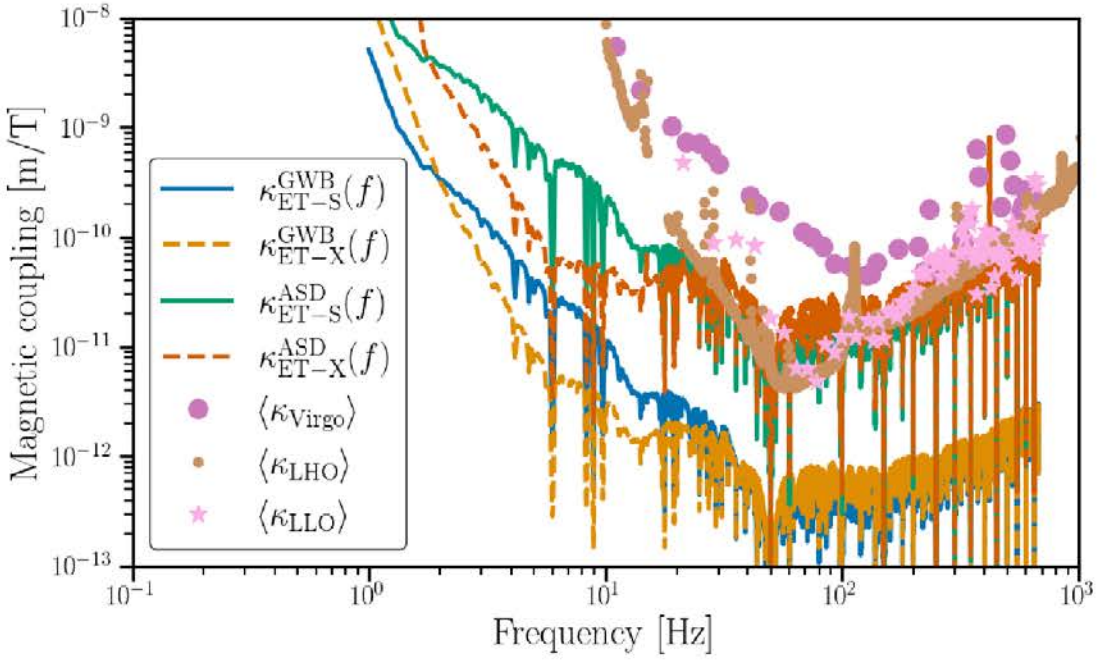


Fig. 4 : The needed magnetic coupling for the ET for unaffected ASD and GWB sensitivity. As comparison the average coupling for Virgo and LIGO during O3 are given.

K. Janssens, et al, Phys. Rev. D 104, 122006 – https://doi.org/10.1103/PhysRevD.104.122006

CORRELATED NOISE @ Δ

Conclusions magnetic noise

Conclusions:

- (Correlated) magnetic noise forms a serious threat for all science goals for the ET.
- Even if infrastructural noise sources are minimized, fundamental, environmental noise sources will lead to strong limitations.
- Investments (person power and budget) are needed to achieve reduction of magnetic coupling by 4-5 orders of magnitude at 7 Hz.

Work items:

- Measure and understand magnetic coupling down to 1Hz. Currently: 7Hz (LLO), 9Hz (LHO), 11Hz (Virgo)
- Seriously consider LIGO actuator design, which outperforms Virgo magnetic coupling by an order of magnitude between 10Hz-100Hz. However Virgo seems to perform better <10Hz. This should be investigated, given the limited measurements.
- Investigate additional mitigation techniques
  - Shielding
  - Optical fibres
  - Noise subtraction with a magnetometer array
  - Suspensions design
- Understand and minimize currents flowing near coupling sensitive locations (seems to be particular problematic)
- Careful consideration of electromagnetic noise introduced by instruments

CORRELATED NOISE @ Δ

Noise sources \ Affected search	Triangle			2L	
	ASD	GWB		ASD	GWB
Seismic noise	-	< 4Hz		No	No
Rayleigh NN	-	< 5Hz $\mathcal{O}(10^3)$ @ 3 Hz		No	No
Body wave NN	-	*Optimistic* < 10Hz $\mathcal{O}(10^2)$ @ 3 Hz	*Pessimistic* < 50Hz $\mathcal{O}(10^6)$ @ 3 Hz	No	No
Infrastructural magnetic noise	*Pessimistic* 1Hz-700Hz $\mathcal{O}(10^5)$ @ 7 Hz	*Pessimistic* 1Hz-700Hz $\mathcal{O}(10^6)$ @ 7 Hz		No	No
Lightning glitches	< 50Hz $\mathcal{O}(10^4 - 10^5)$ @ 7 Hz	-		< 50Hz $\mathcal{O}(10^4 - 10^5)$ @ 7 Hz	-
Schumann resonances	< 20Hz $\mathcal{O}(10^3)$ @ 7 Hz	< 30Hz $\mathcal{O}(10^4)$ @ 7 Hz		< 20 Hz $\mathcal{O}(10^3)$ @ 7 Hz	< 30Hz $\mathcal{O}(10^4)$ @ 7 Hz

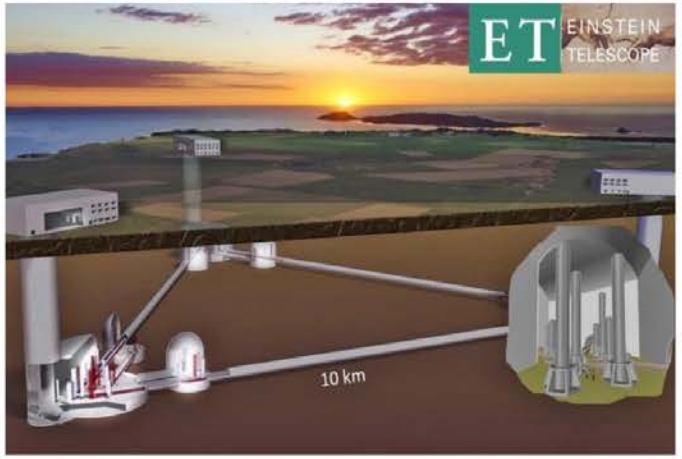
The second most urgent work is done by **SCB**

- Where we realize ET? ET design could crucially depend on the site(s) selection CoBA process
- Site decision is a complex procedure, deliverable of the ET-Preparatory Phase, involving several actors and bodies (Collaboration, Observatory, Agencies, Governments)
- SPB/SCB (site preparation and characterization boards) has a pivotal role in this process Characterizing the sites proposed to host ET
- Defining the technical comparison procedure
- Site decision was foreseen within 2024 but probably will be further bebated (… newcomers !!)

R&D preparatory investments display national intentions of Countries

Fabulous political support for ET

Sardegna: Italy

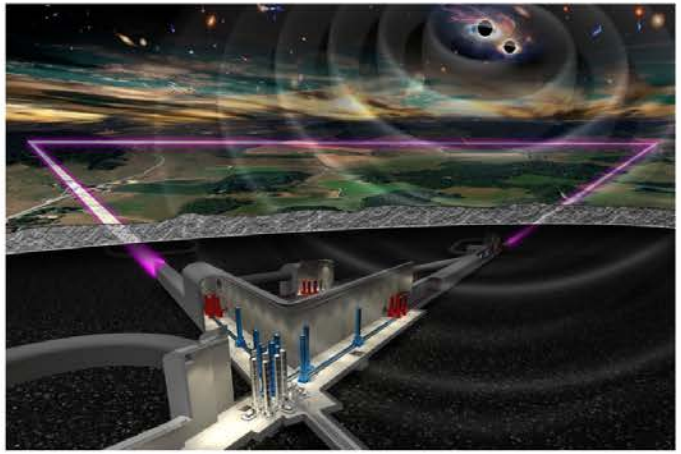


50 M€ for R&D/preparatory work

R&D/preparatory work funding
Multi 100 M€ funding to host ET if in Sardinia

Nov. 15th, 2022

Euregio Meuse-Rhine: Netherlands



42 M€ for R&D/preparatory work

R&D/preparatory work funding
Multi 100 M€ funding to host ET if in the Euregio Meuse-Rhine

1st ET Annual Meeting

Saxony: Germany

New research center, ~ 170 M€/yr

DZA

Pressemitteilung

Forschung von Weltrang in der Lausitz

Deutsches Zentrum für Astrophysik – Forschung. Technologie. Digitalisierung. (DZA) gewinnt Wettbewerb zur Strukturförderung

3

S

Focus on Italian preparation R&D

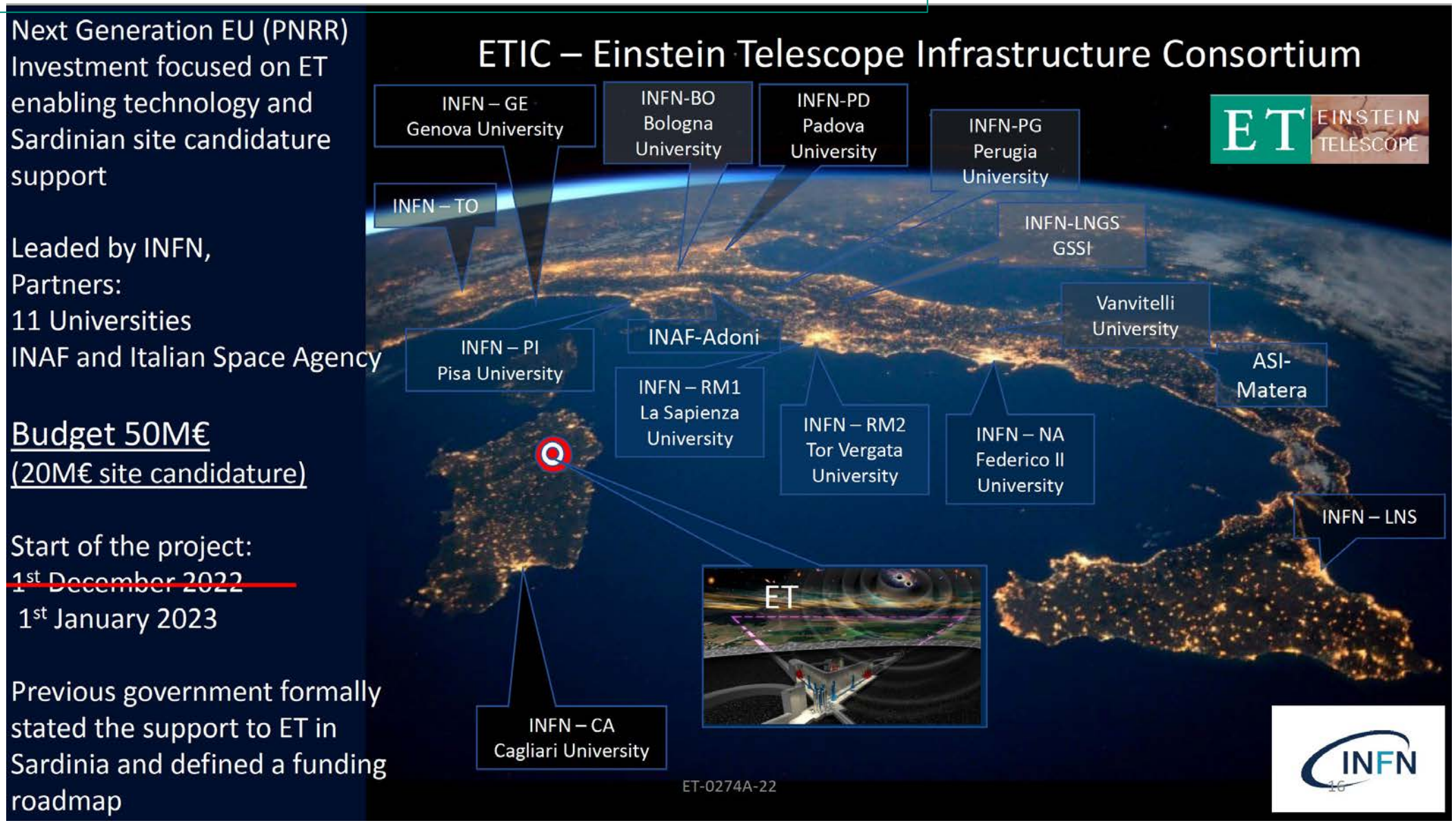
Next Generation EU (PNRR)
Investment focused on ET enabling technology and Sardinian site candidature support

Leaded by INFN,
Partners:
11 Universities
INAF and Italian Space Agency

Budget 50M€
(20M€ site candidature)

Start of the project:
~~1st December 2022~~
1st January 2023

Previous government formally stated the support to ET in Sardinia and defined a funding roadmap



KAGRA and the Japanese GW community

- On June 2022 ET collaboration was constituted (1250 res.), several Research Units, the large majority in EU, there is no national restriction.
- At present few Japanese scientists are affiliated to EU RUs joining ET.
- It is quite important to gather Japanese collaborators in this framework, as soon as KAGRA engagement allows to do it (after O4?)
- In order to foresee direct responsibilities on key positions concerning scientific developments in ISB, it would be relevant to have in key positions the Japanese RUs BEFORE the site decision (personal opinion)
- An extraordinary contribution can be provided by Japanese scientific and technical expertise (spin-offs are almost sure)