Einstein Telescope and activities in Poland

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Let start from the Current Network of GW detectors

aLIGO Hanford, 4 km

GEO, Hannover, 600 m

AdV, Cascina, 3 km

aLIGO Livingston, 4 km

LIGO INDIA

It will operate as part of the LIGO Network and Collaboration

KAGRA

LIGO Scientific Collaboration:

Virgo Collaboration:

KAGRA Collaboration:

What is Einstein Telescope (ET)?

- ET pioneered the concept of a 3rd generation GW observatory, evolved in the following key requirements
  - **ET must be a 3rd generation GW observatory**, and thus its sensitivity aims to be at least one order of magnitude better with respect to the nominal sensitivity of advanced detectors in all the detection frequency band
  - **ET must be both a precision measurement and a new discovery project**, and thus it aims to be a wide frequency band observatory,
  - **ET science has a special focus on massive (or intermediate mass) black holes**, and thus it aims to have an extraordinary sensitivity at low frequency (few Hz)
  - **ET must have a high reliability**, and thus it aims to obtain a high observation duty cycle
  - **ET must be able to make science in a standalone configuration**; ET aims to have localisation and GW polarisation disentanglement capabilities and to show a more uniform sky coverage. Nevertheless, it is worth to note that the ET full science potential will be achieved in a 3G network, and it is important that other projects, like the Cosmic Explorer (CE) project in US, are developed in parallel to ET. In case of a full 3G global network, this requirement can be revised.
  - **ET must have a lifetime of several decades,** (50 years in the ET proposal), being capable to host the evolution of the detectors, without limiting their sensitivity.
- ET path in the last decade:
  - A conceptual design
  - Few enabling technologies
  - A scientific collaboration (currently under definition)
  - An official ET project (recently entered in the ESFRI roadmap and whose structure is under definition by the funding agencies engaged on ET)

European Strategy Forum on Research Infrastructures

ESFRI Roadmap

ET EINSTEIN TELESCOPE

Proposal submitted by:

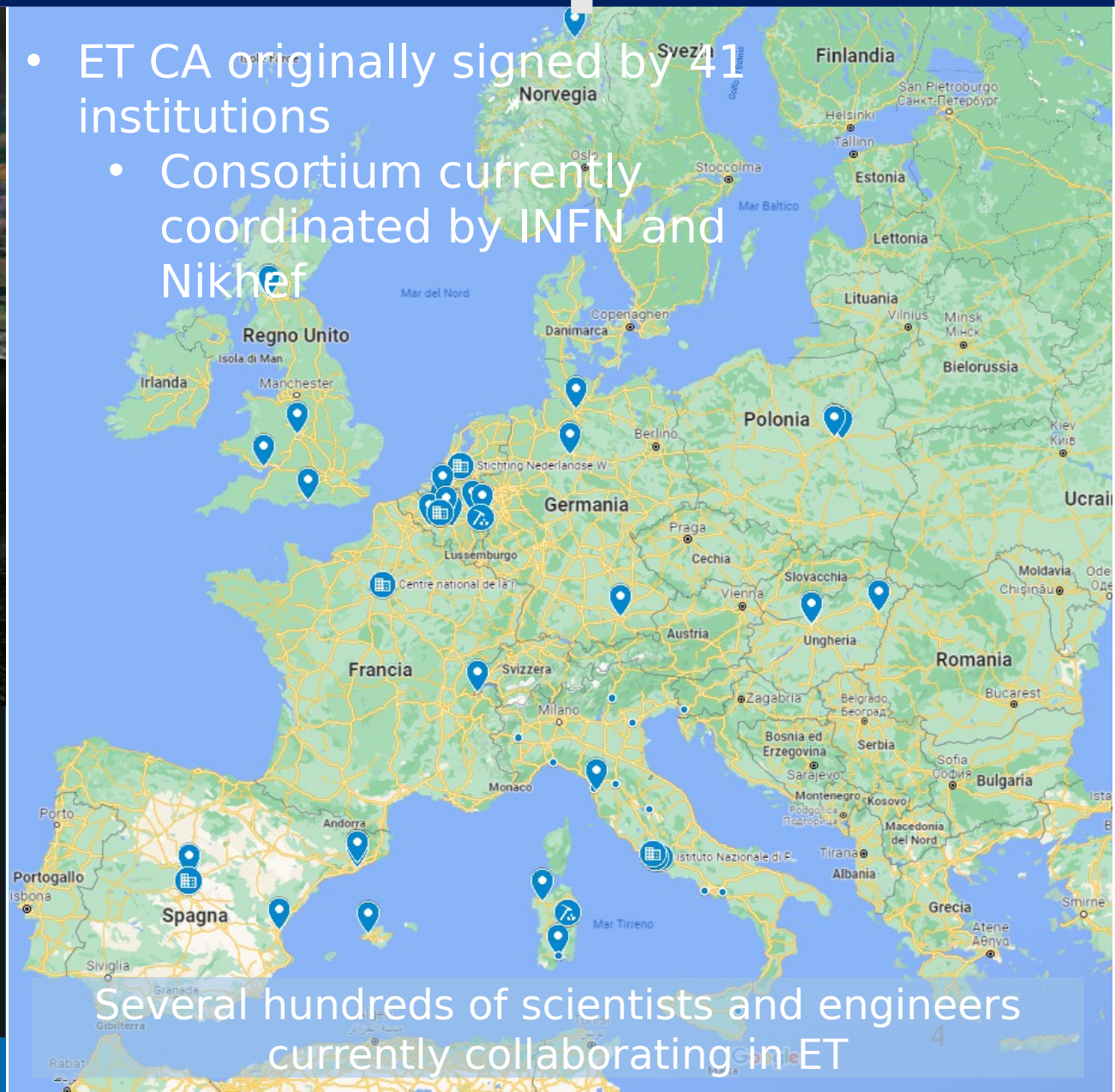
- Belgium
- **Italy** (Lead Country)
- Netherlands
- Poland
- Spain

Now in the project and in the collaboration activities also agencies or institutions belonging to:

- **France**
- **Germany**
- **Hungary**
- **Switzerland**

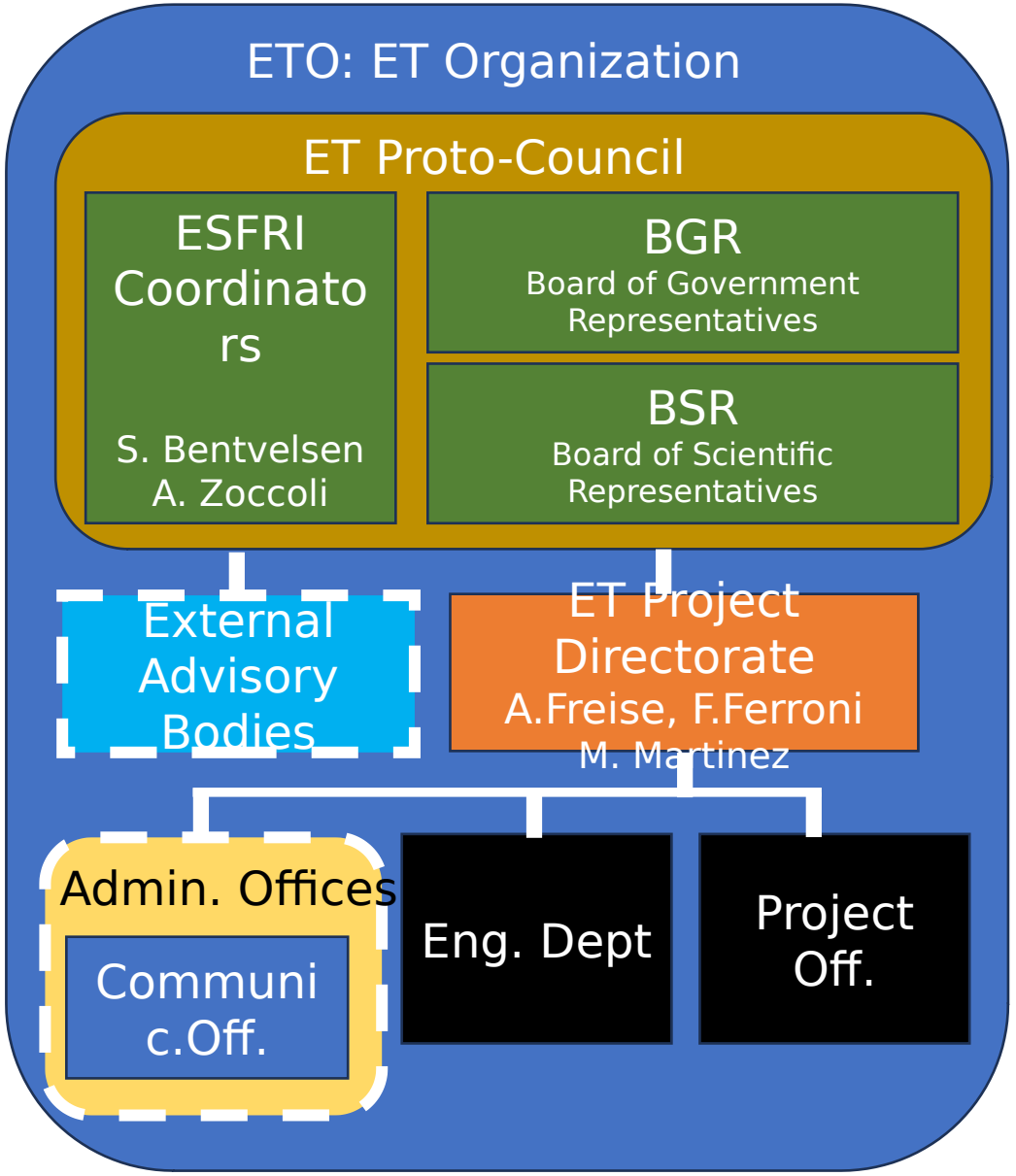
Preparatory funds available in some country (IT, NL, …) and an H2020 INFRA-DEV call just submitted

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



Several hundreds of scientists and engineers currently collaborating in ET

The ET framework

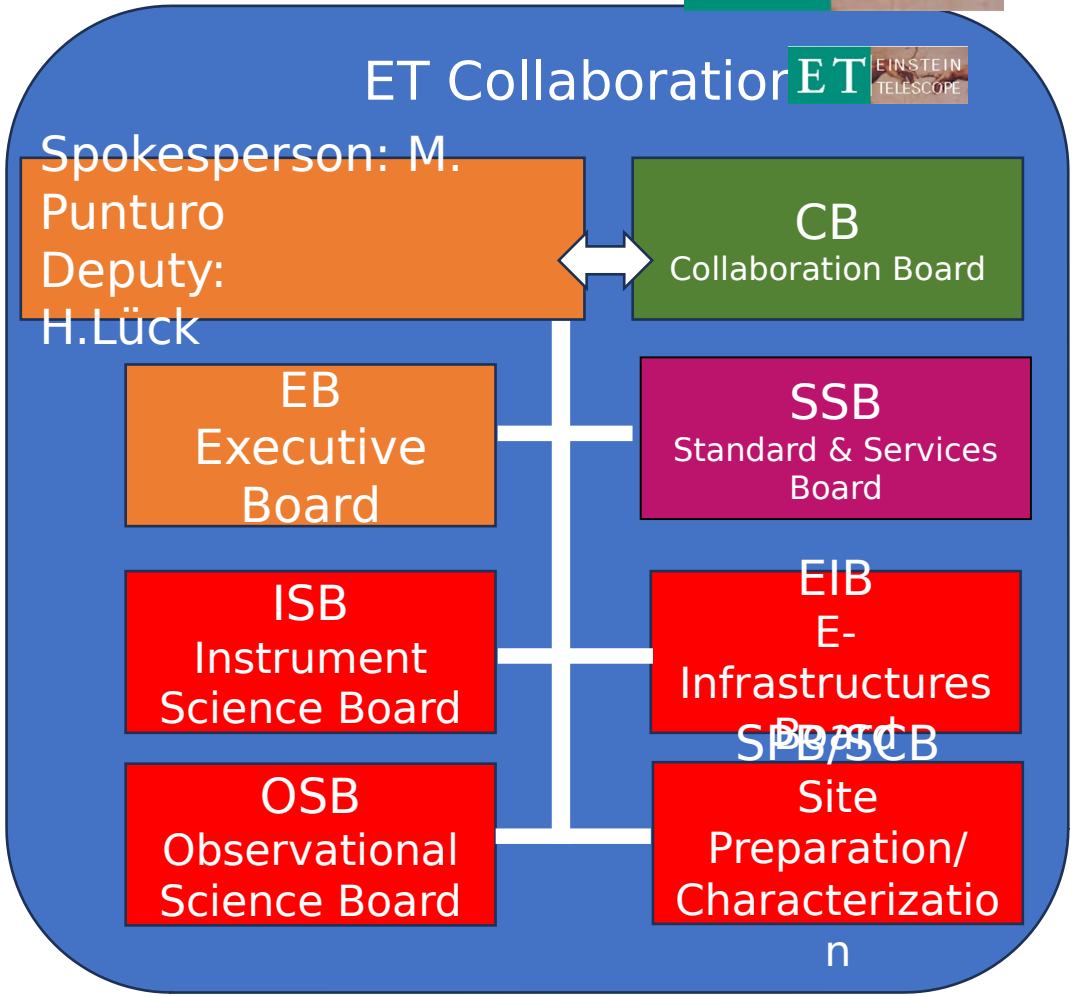


Projects

Infradev ET-PP
Implementation plan of ET Observatory
M. Martinez
(Managed by Project Directorate)

Design of ET Vacuum Pipe
P. Chiggiato
(CERN coordination)

Civil Engineering
(CERN advisory)



National Host Teams

EMR Host Team

Sardinia Host Team

Lusatia Host Team

Site

Three sites under considration:

- Sardinia

- EMR region

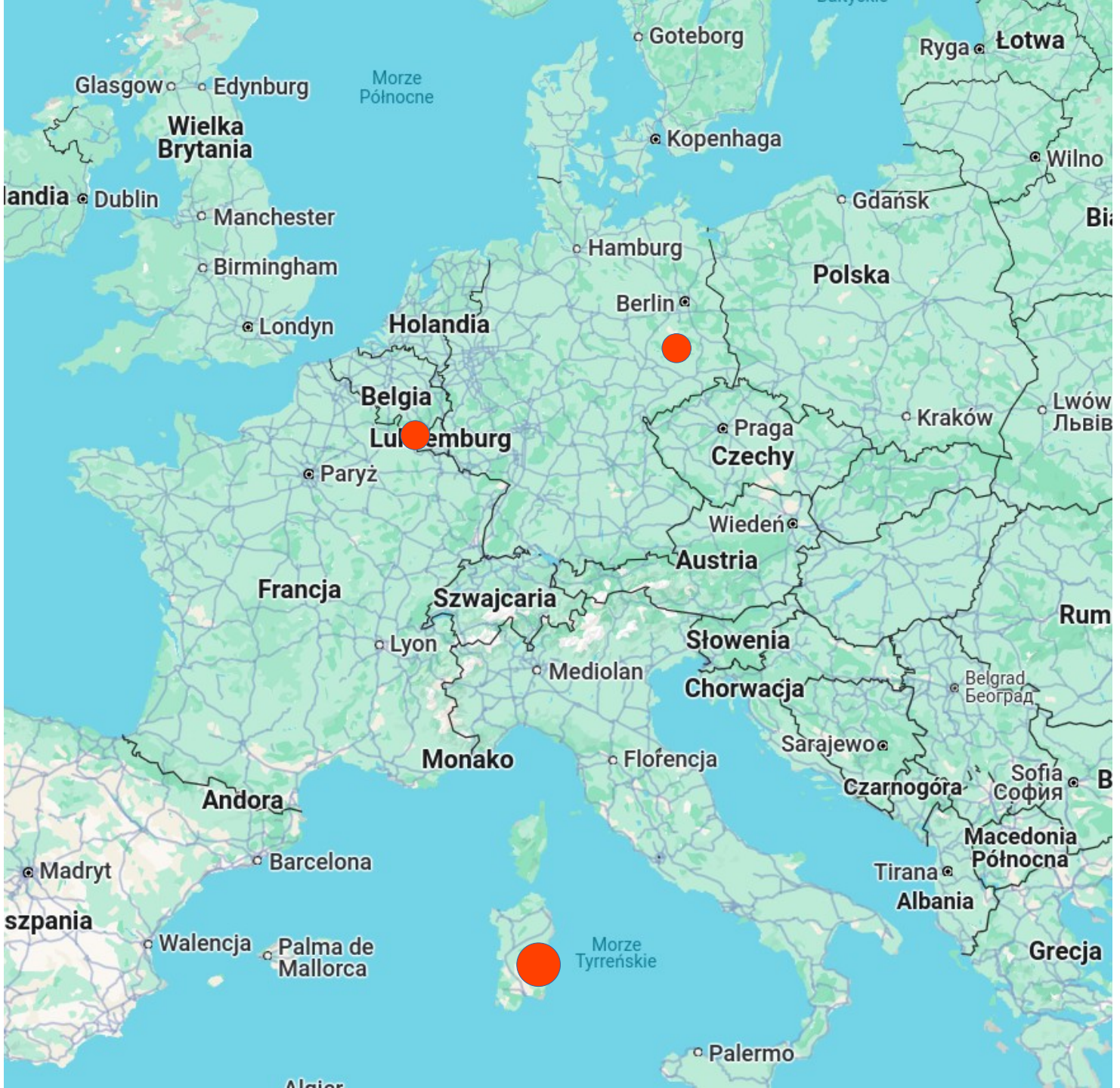
- Lusatia (Łużyce)

Still a question

- one site - triangle confoguration

- two sites – two L

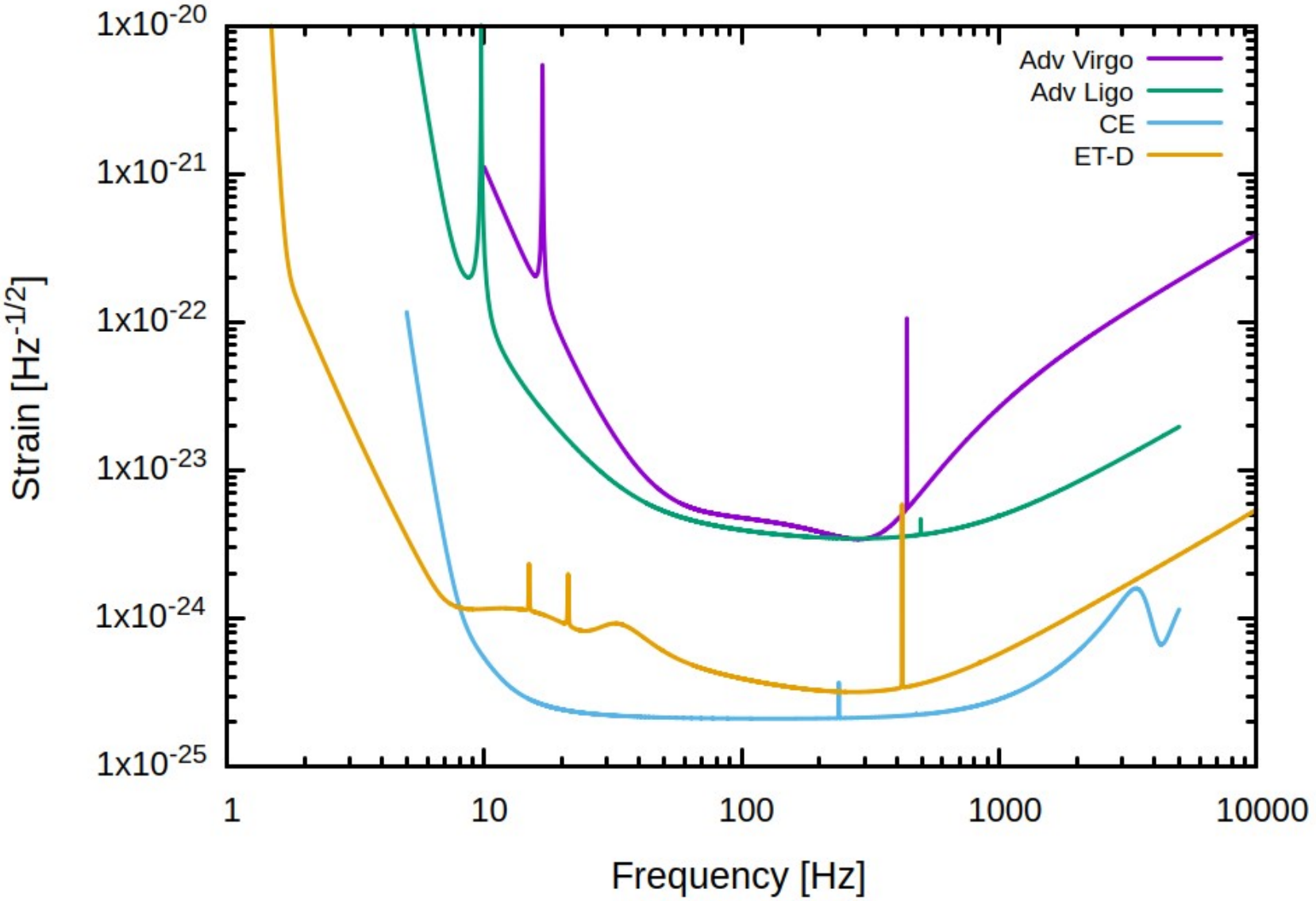
Site characterization – see talk by Mariusz Suchenek



Science - OSB

- Blue book – the ET science case
- ET science case must be refined and updated wrt to the 2020 ESFRI document
- The CoBA paper initiated the evaluation of the science return with different geometries
- Now two geometries, Δ of 10km and 2L of 15km, need to be deeply studied
- Again, the ET science case document is both a scientific target of the ET collaboration and a formal deliverable of the ET-PP project – currently in internal circulation to be published soon

ET planned sensitivity



ET Science in a nutshell

ASTROPHYSICS

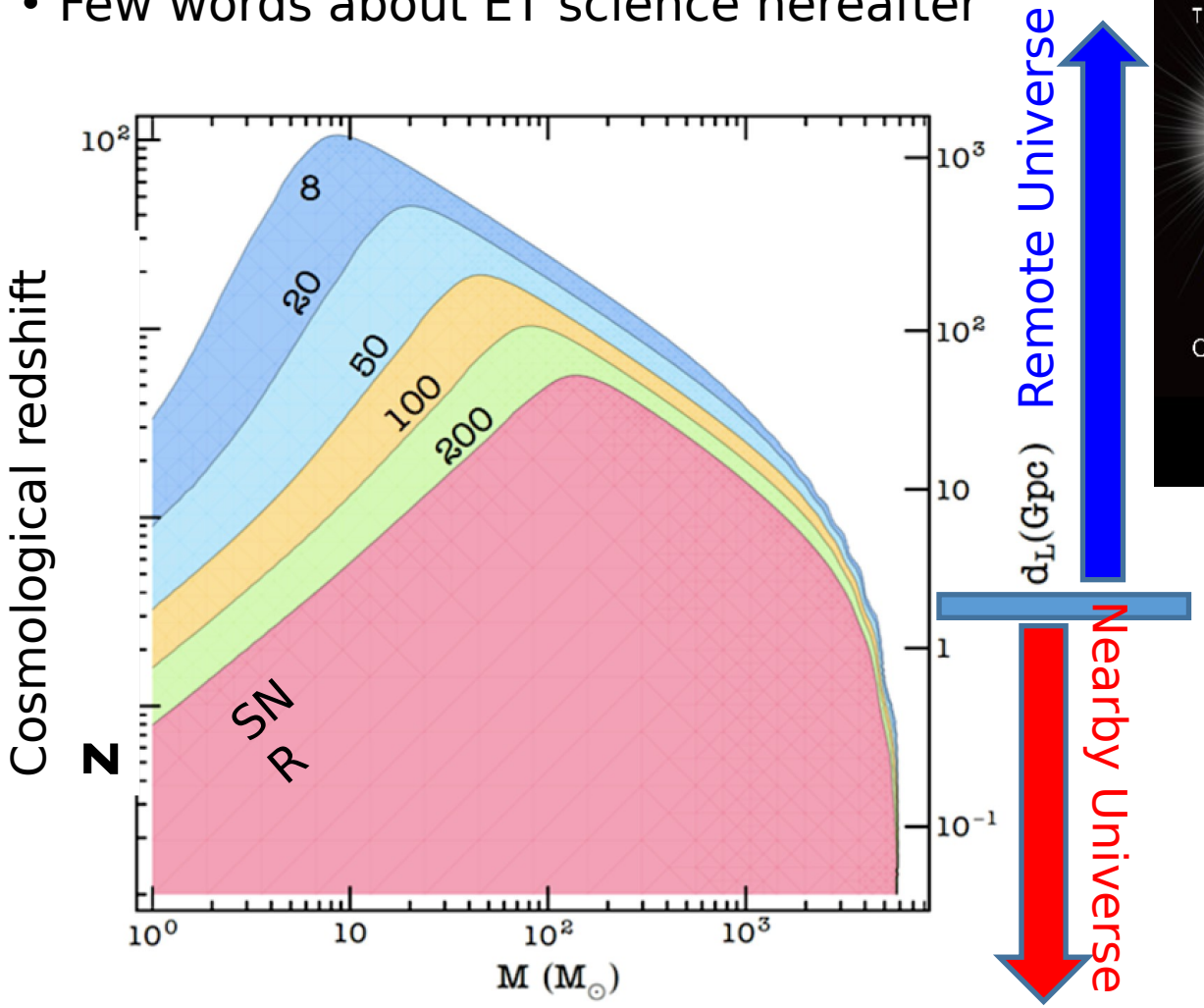
- **Black hole properties**
  - origin (stellar vs. primordial)
  - evolution, demography
- **Neutron star properties**
  - interior structure (QCD at ultra-high densities, exotic states of matter)
  - demography
- **Multi-band and -messenger astronomy**
  - joint GW/EM observations (GRB, kilonova,...)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

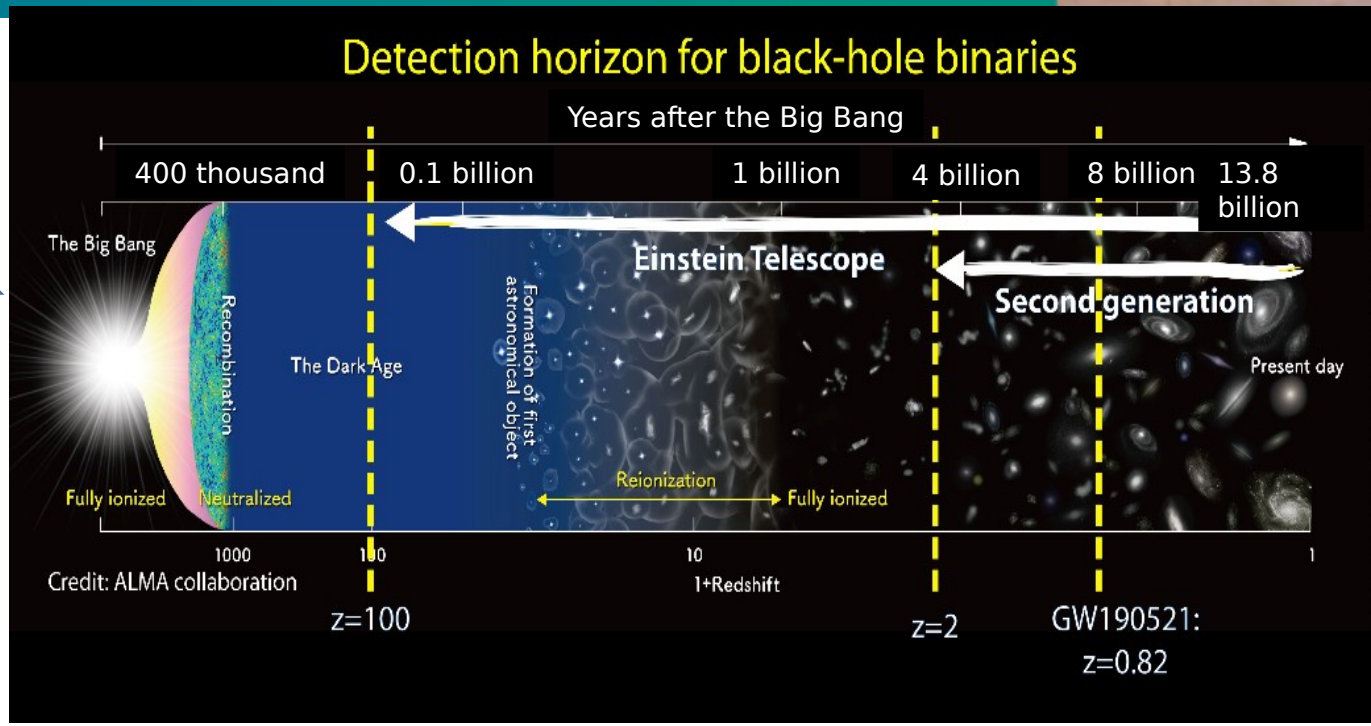
FUNDAMENTAL PHYSICS AND COSMOLOGY

- **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 be both a discovery machine and a precision measurement instrument
- Few words about ET science hereafter



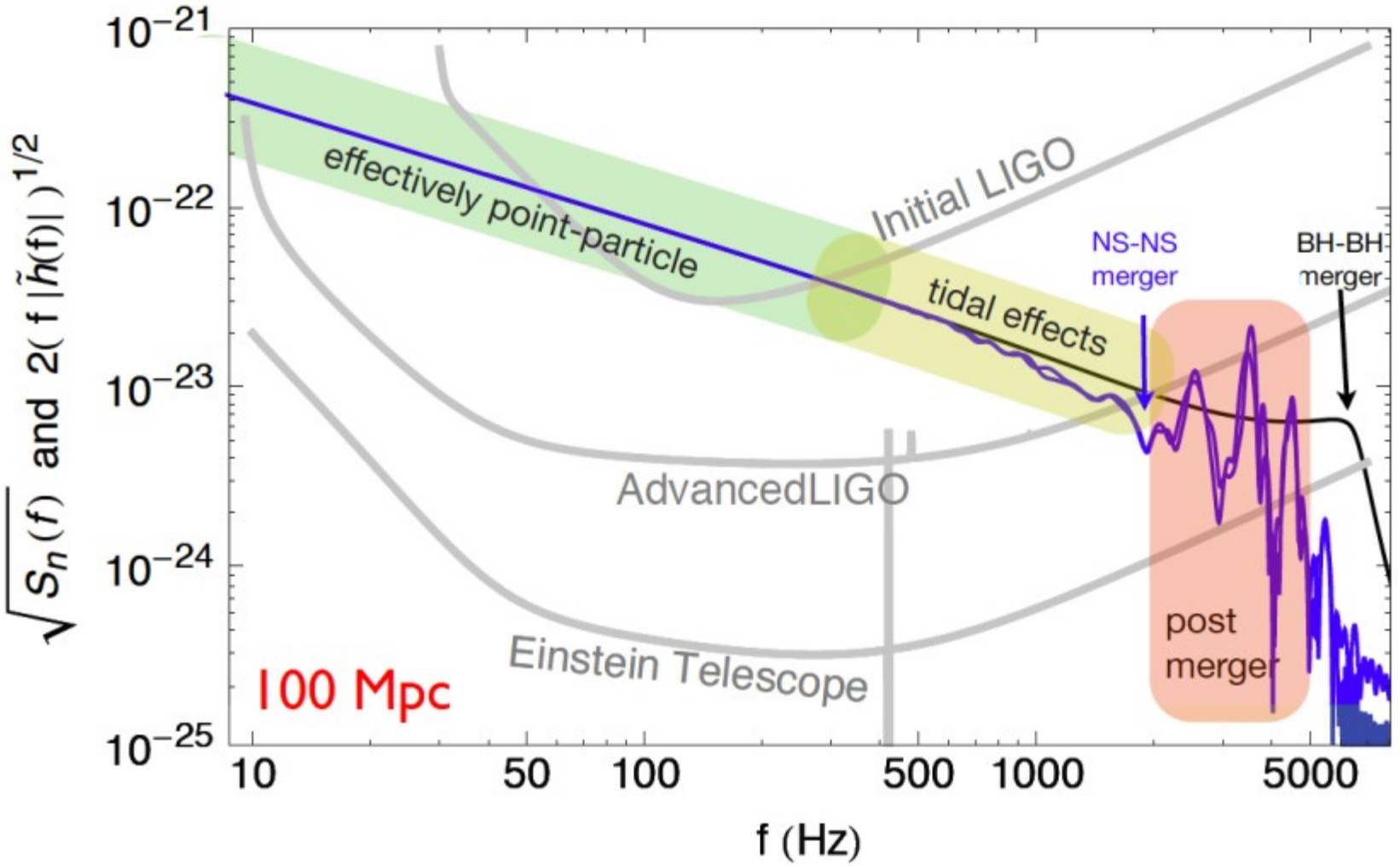


The combination of

- distances and masses explored
- number of detections
- detections with very high SNR

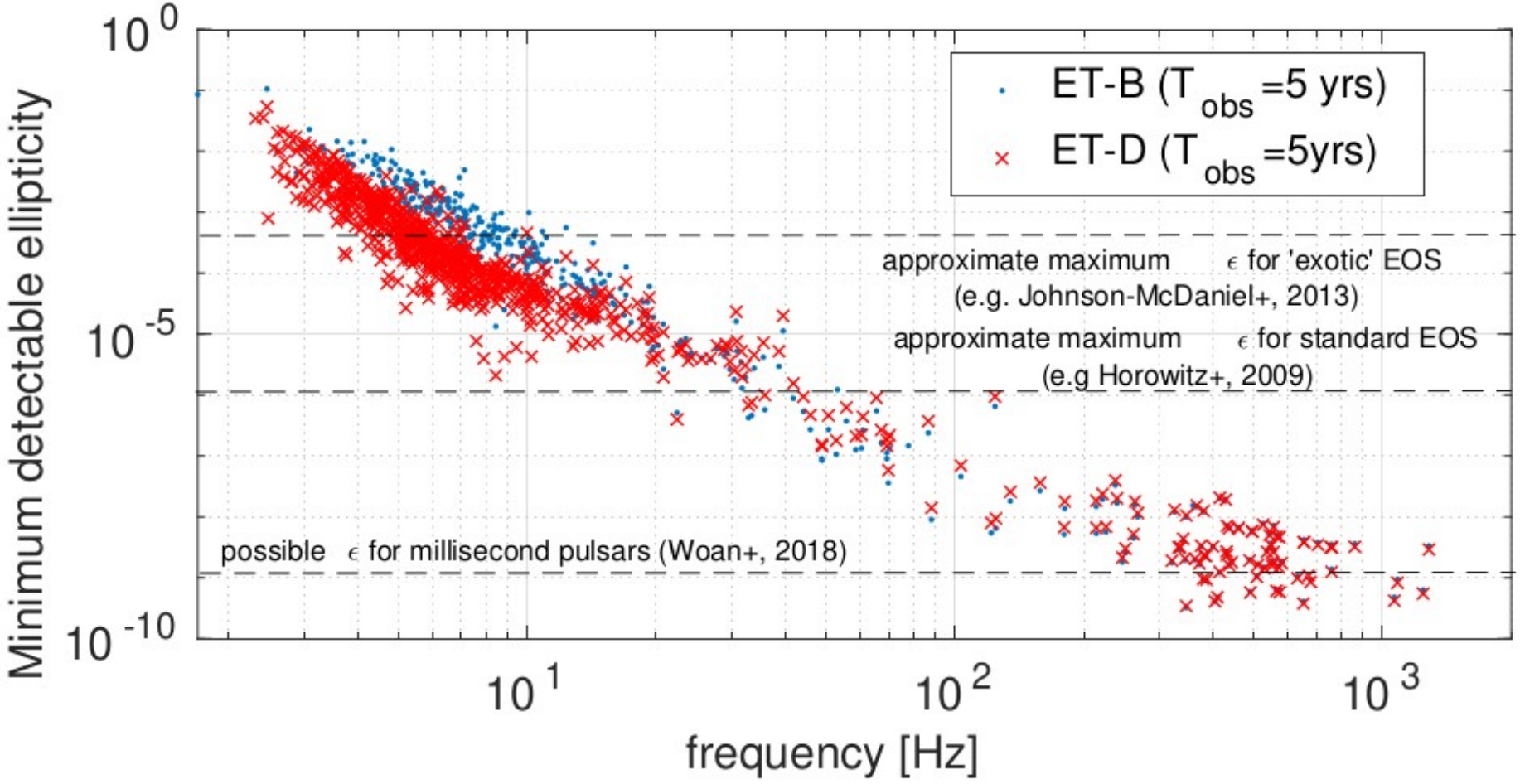
will provide a wealth of data expected to generate **revolutions in astrophysics, cosmology and fundamental physics**

Neutron star properties



Maggiore et al. 2020

GW from pulsars



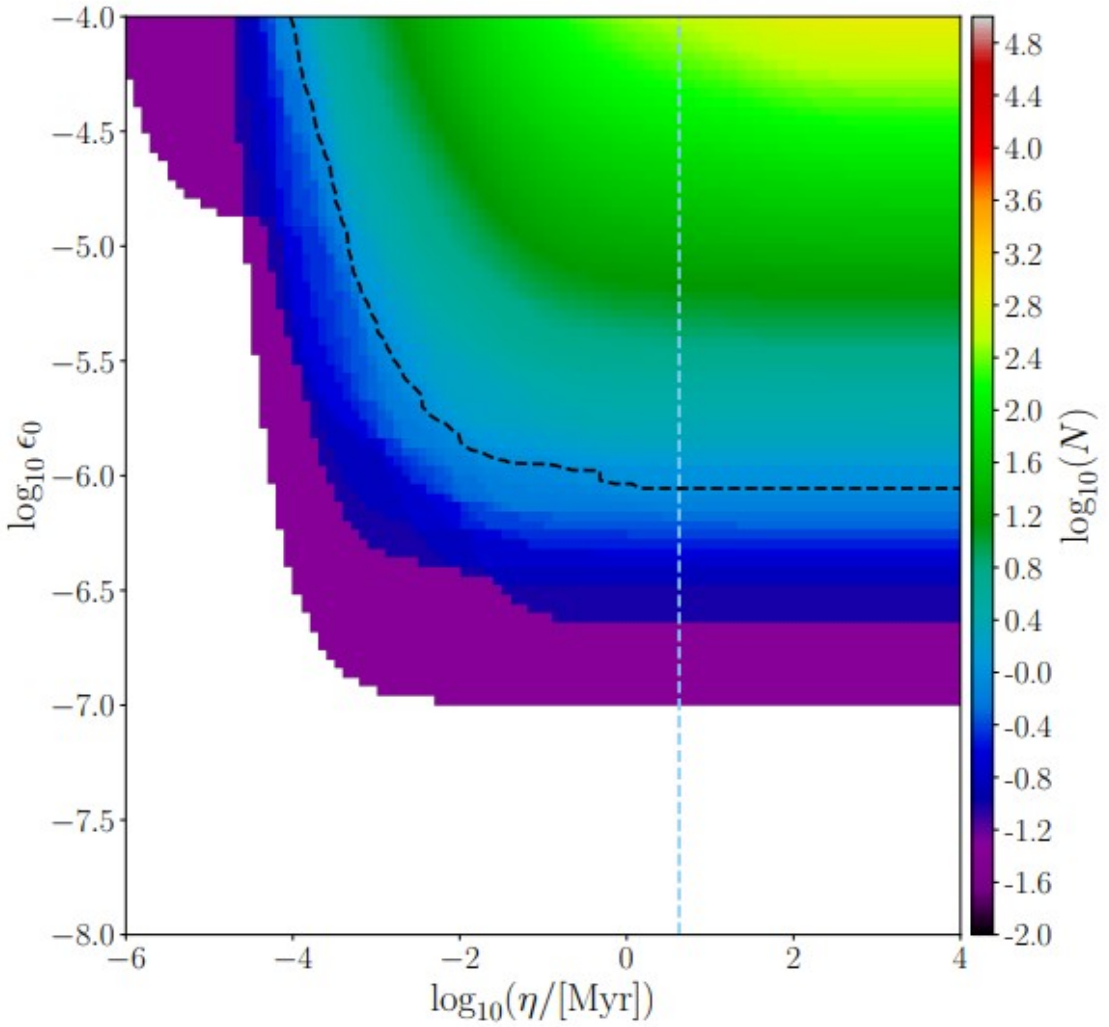
Maggiore et al 2020

Pulsar detectability

Pulsar population based on radio observations

Model includes velocities magnetic field evolution, spin down, positions in the Milky Way, motion in the Milky Way potential

Parameterized evolution of eccentricity: Exponential devay with timescale eta

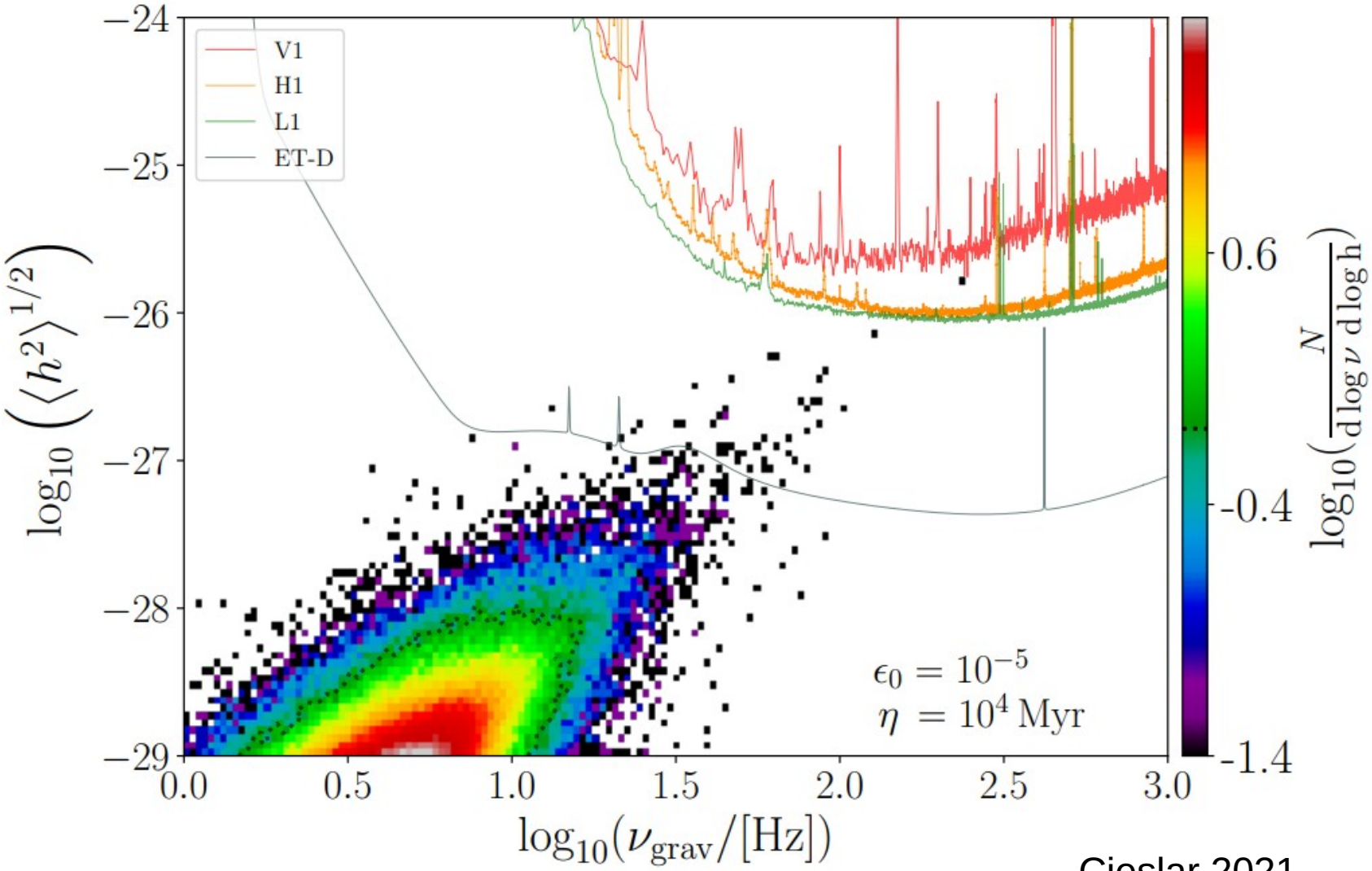


(d) 2ν. ET-D Einstein Telescope detector, configuration D.

Cieslar 2021

Pulsar population

Sensitivity in one year observation.

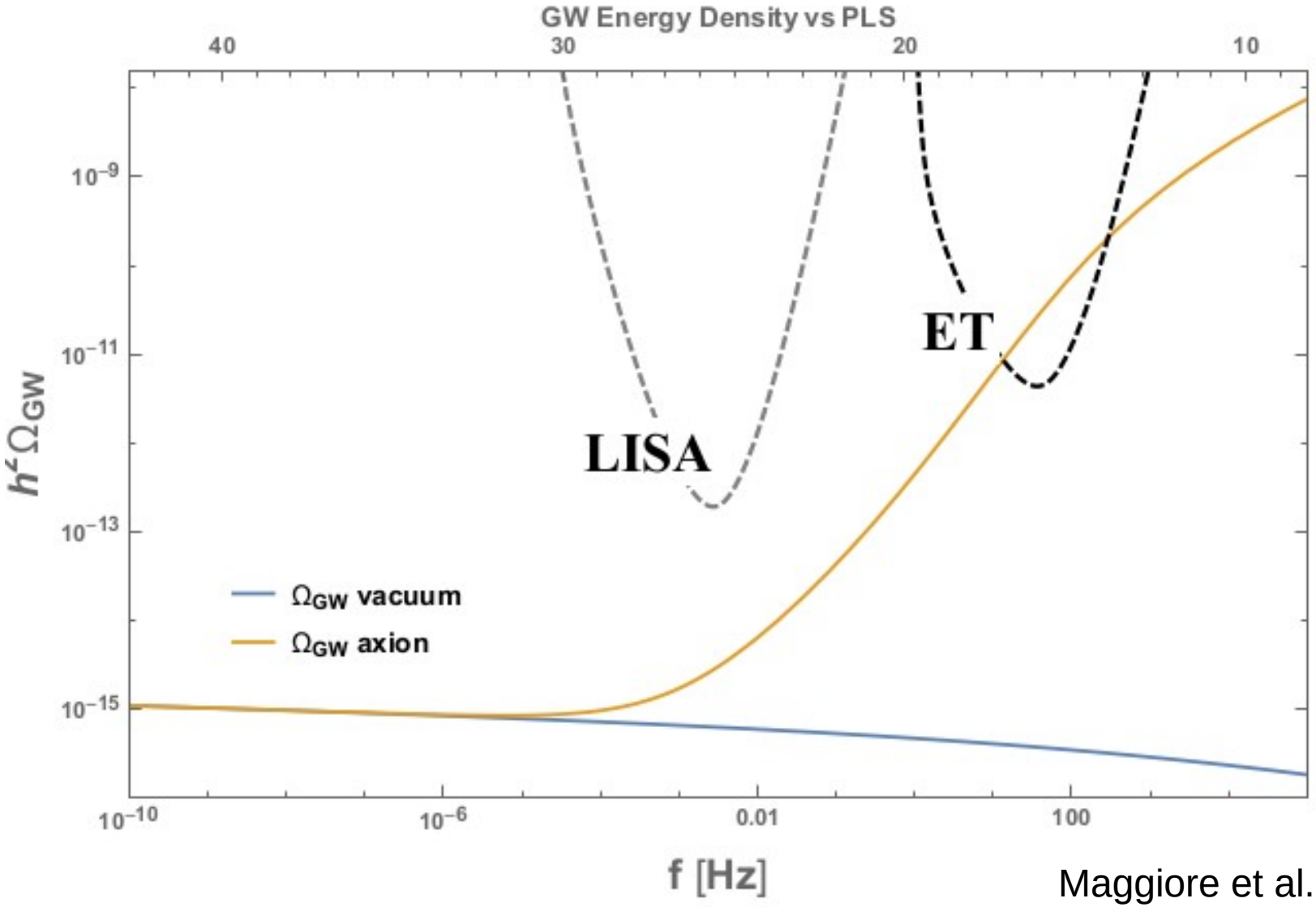


Cieslar 2021

Backgrounds

Ability to subtract binary foreground

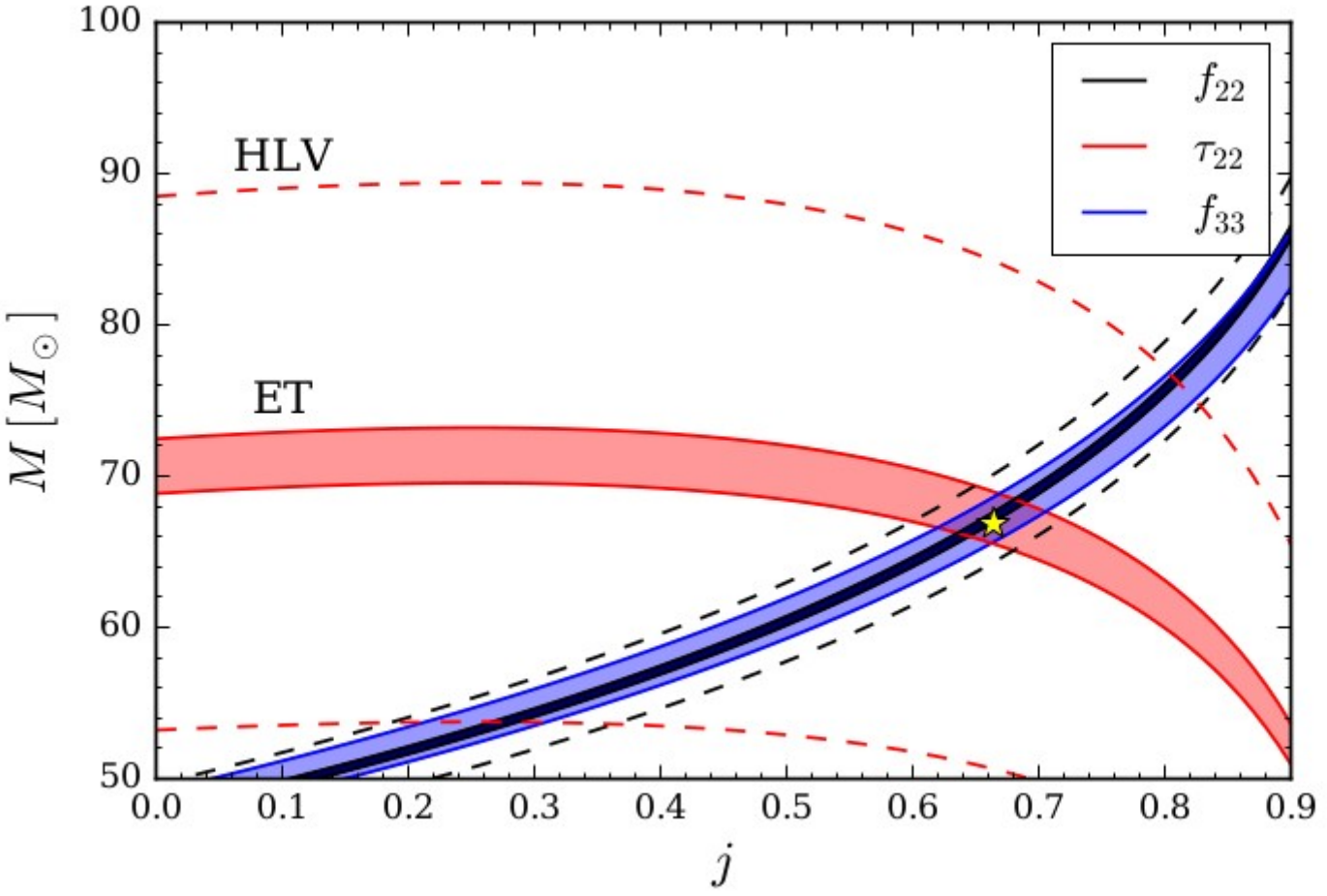
Three (x2) interfermeters, independent noise.



Maggiore et al. 2020

GR tests

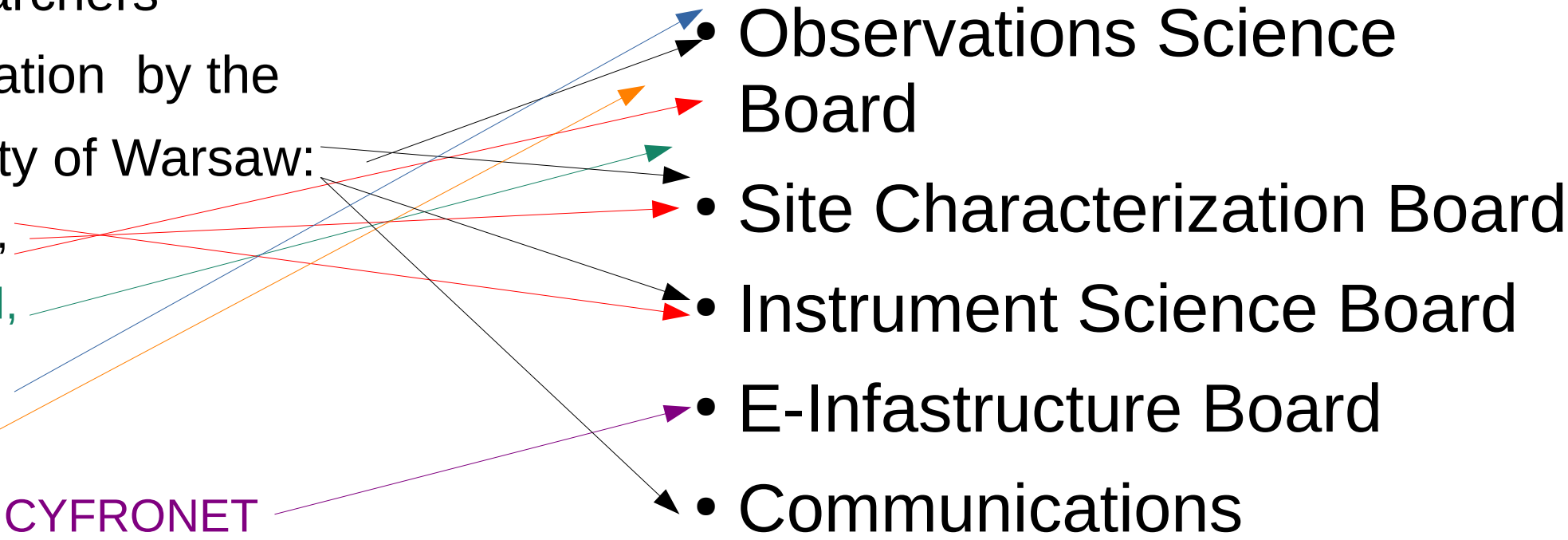
QNM analysis with very high accuracy



Polish ET Consortium

- Institutions involved in ET
- 31 researchers
- Coordination by the

  University of Warsaw:
  - CAMK,
  - IMPAN,
  - NCBJ,
  - UJ,
  - AGH - CYFRONET



We are open and do welcome new members!

Polish ET Consortium - activities

- ET-PP Infradev Horizon Europa 2022-2026
- MNiE grant
- Playing role in Site Preparation, Organization, Technology Transfer, Communication and Education ET Science
- Organized 3rd ET Symposium Nov 24’

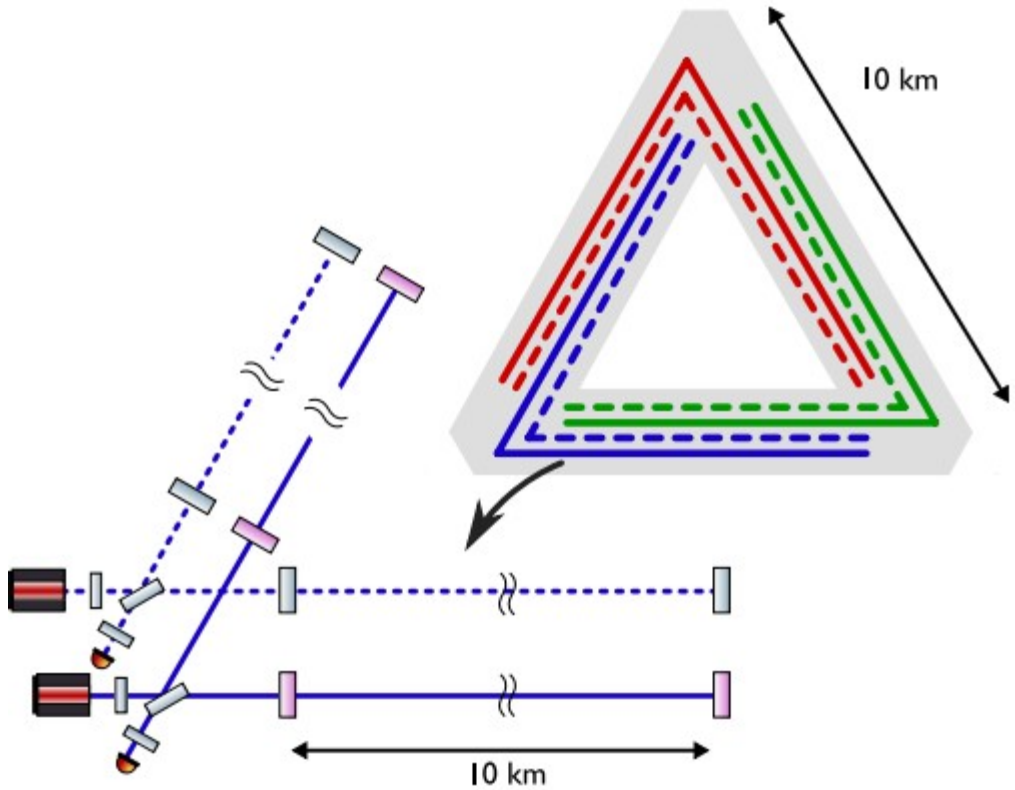
Technological challenges
or where can one contribute

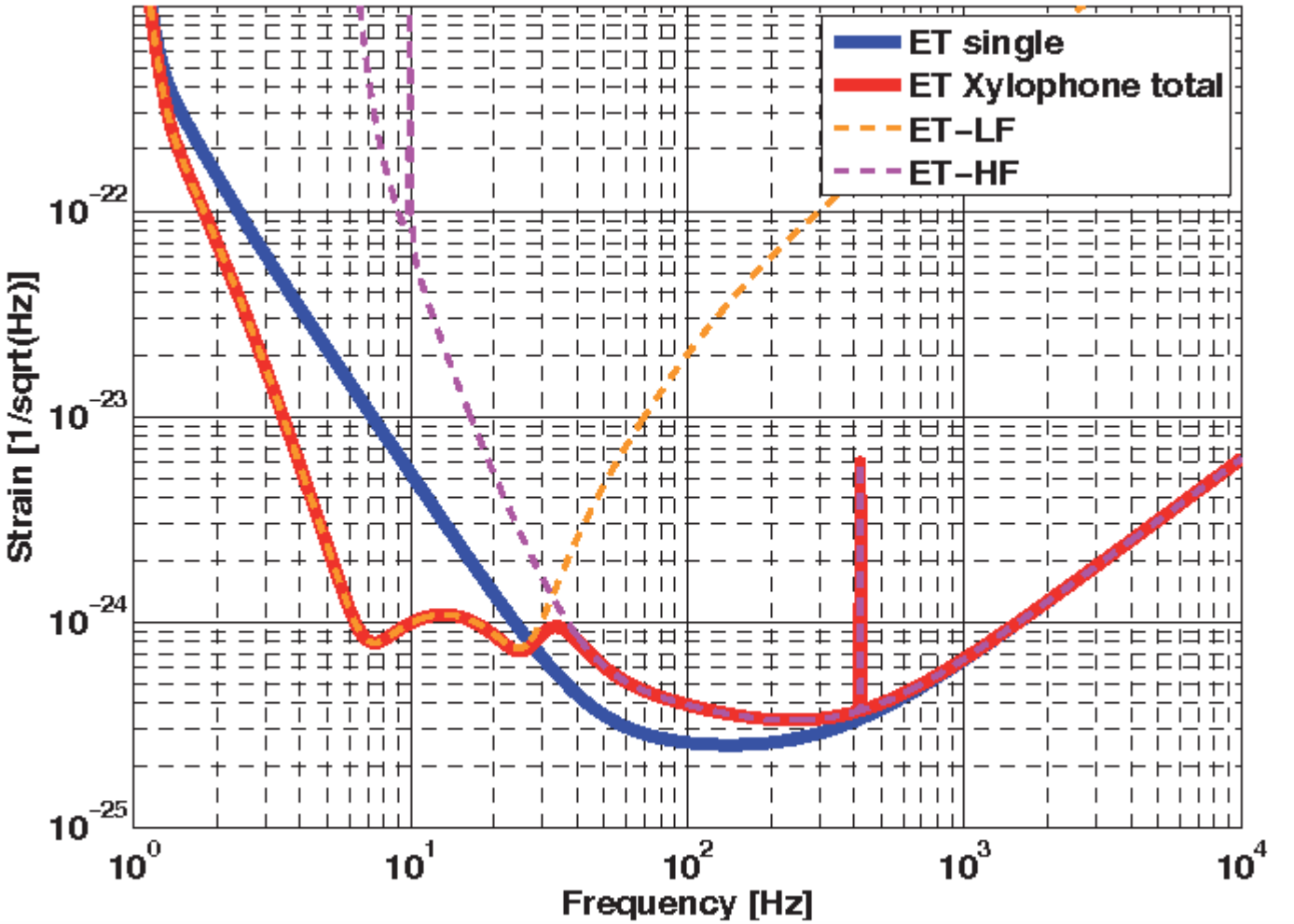
- Cryogenics with low vibrations
- Mirror coating
- Ultra durable Vacuum system
- Calibration of ET
- Detector modeling with high laser power
- Newtonian Noise cancellation
- Data analysis in signal rich data stream
- And much more….

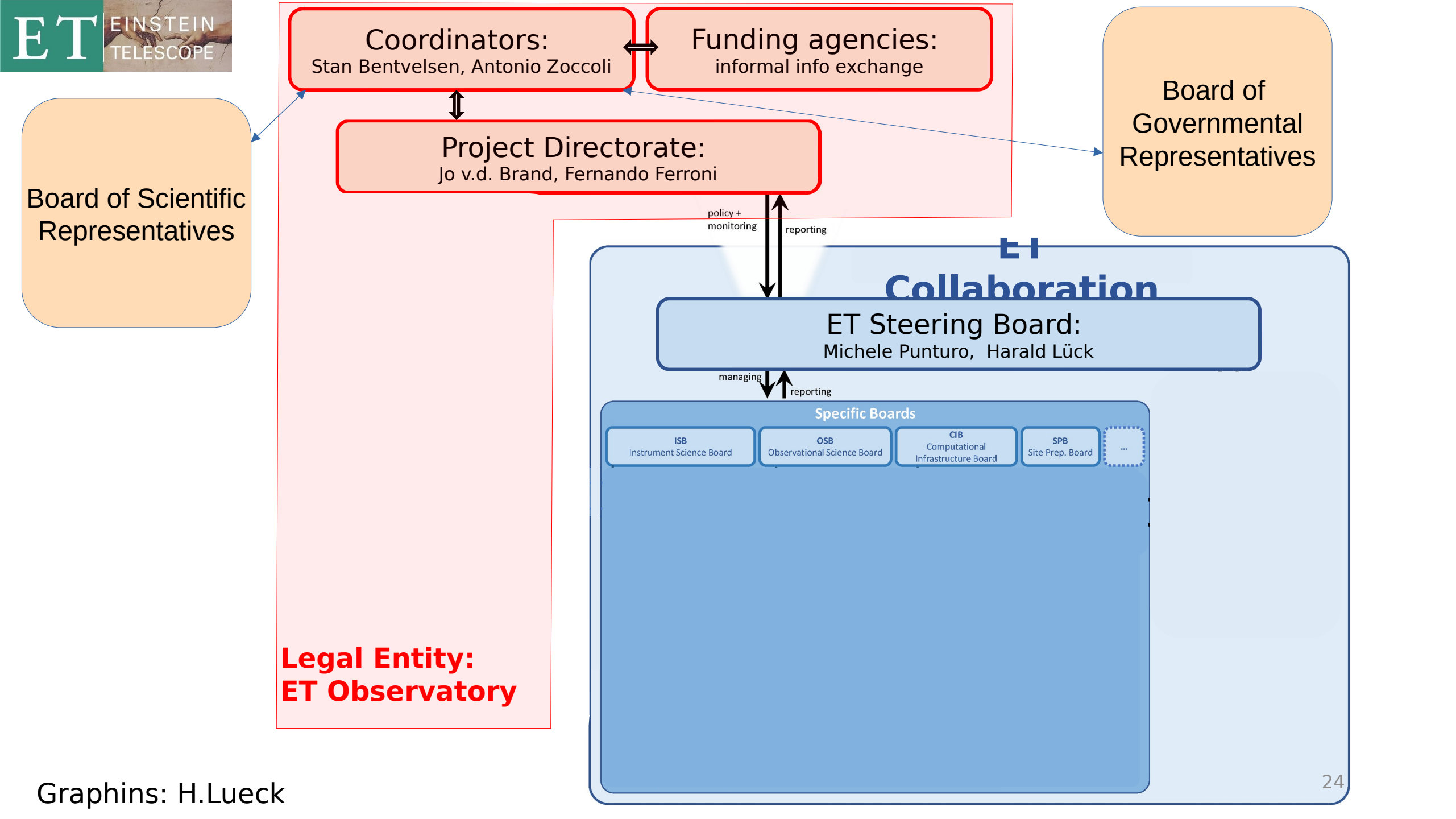
Summary

- Gravitational wave astronomy is blooming
- ET is a quickly developing project
- We have a small but important group in PL
- There is still plenty of work to be done
- We welcome new groups to join the effort!

ET xylophone confguration



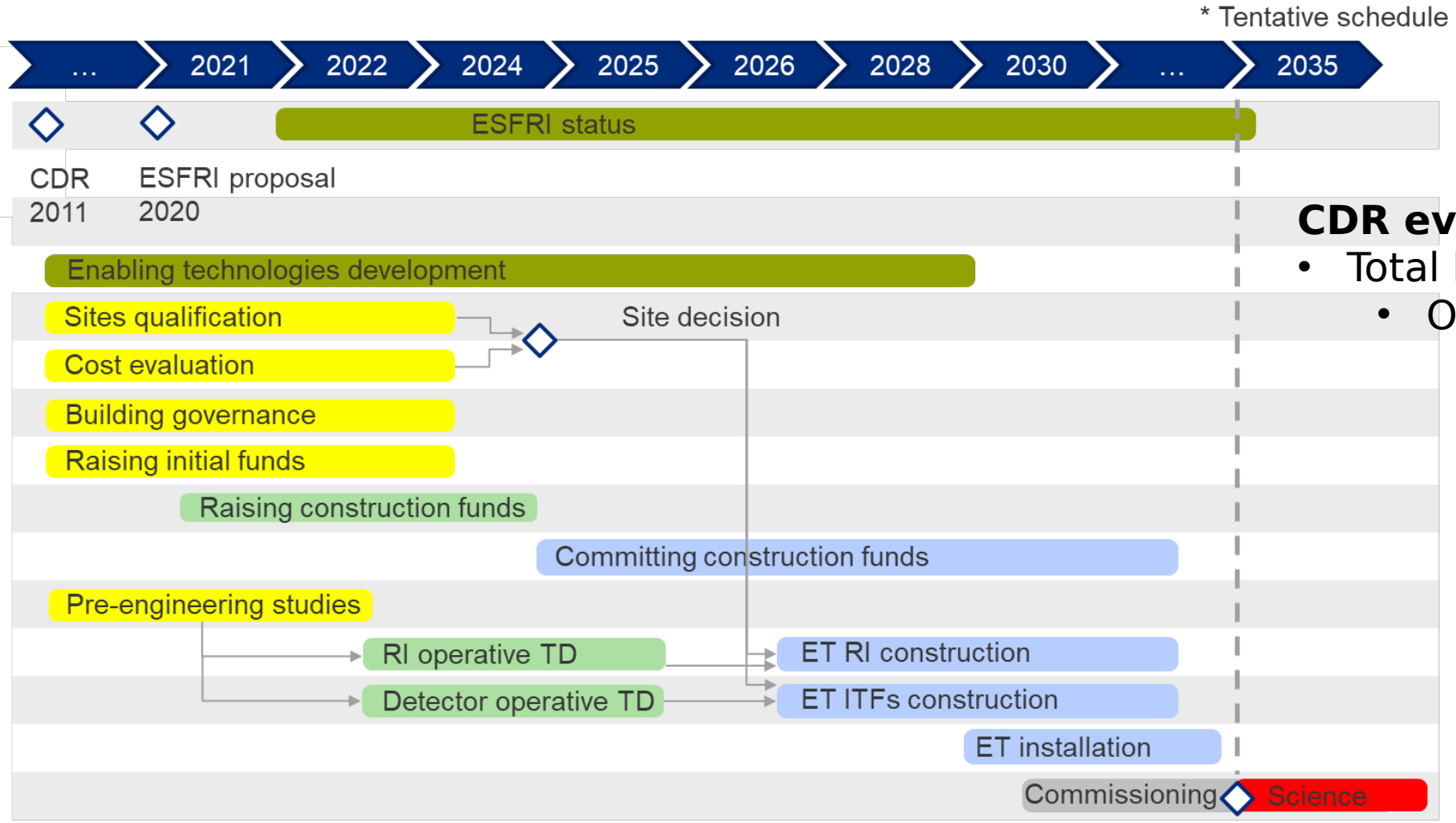




Graphins: H.Lueck

ET timeline

- 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€

Detectability of binaries