

# Einstein Telescope status

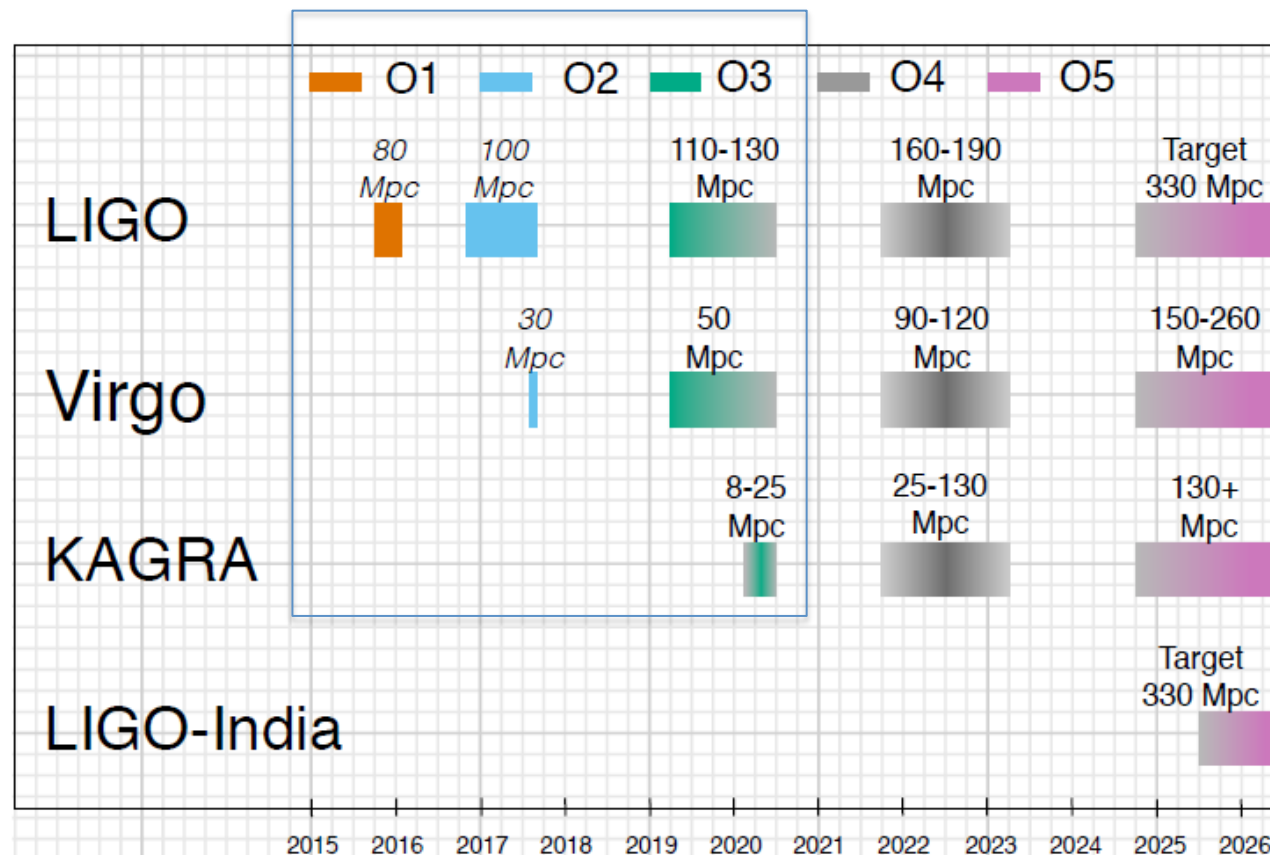
Matteo Barsuglia

APC/CNRS

# Einstein Telescope in short

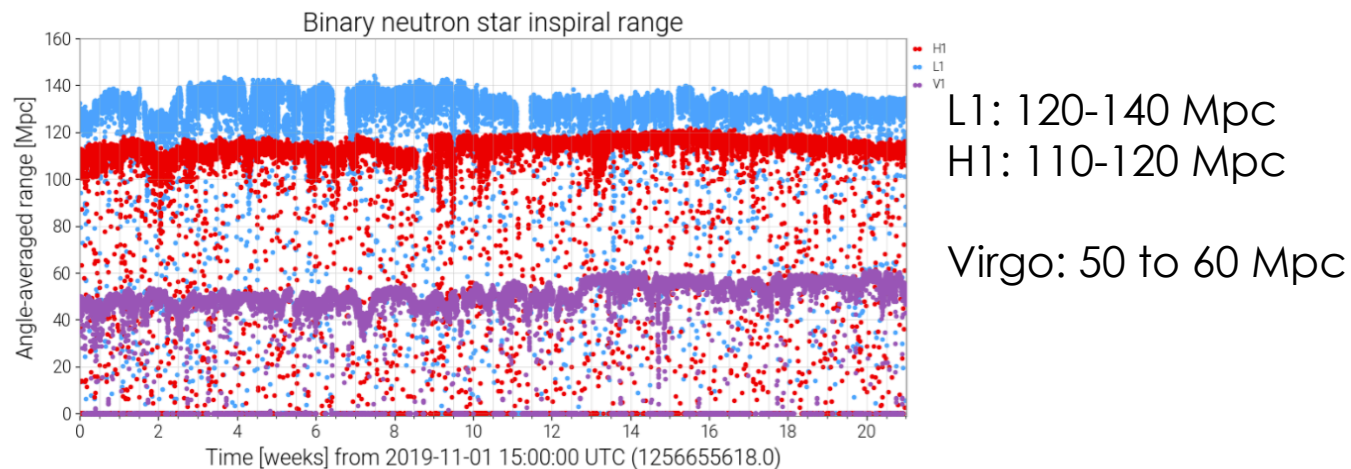
- A future ground-based gravitational-wave observatory
- Unique science potential
- Gain  $\sim 1$  order of magnitude in sensitivity with respect to 2<sup>nd</sup> generation instruments
- Enlarge the bandwidth to lower frequencies ( $\sim$  a few Hz)
- A new infrastructure (longer arms, underground) + new technologies
- Many opportunities to contribute

# LIGO-Virgo observing runs



# GW observations so far

- **50 sources detected (O+O2+O3a)**
- First GW catalog 2018 (11 sources), Second GW catalog (2020) (39 sources)
- Analysis O3b on going
- During O3 ~ 1 candidate/week - max  $z \sim 0.8$
- Duty cycle 3 detectors ~ 50%, 2 detectors 80%

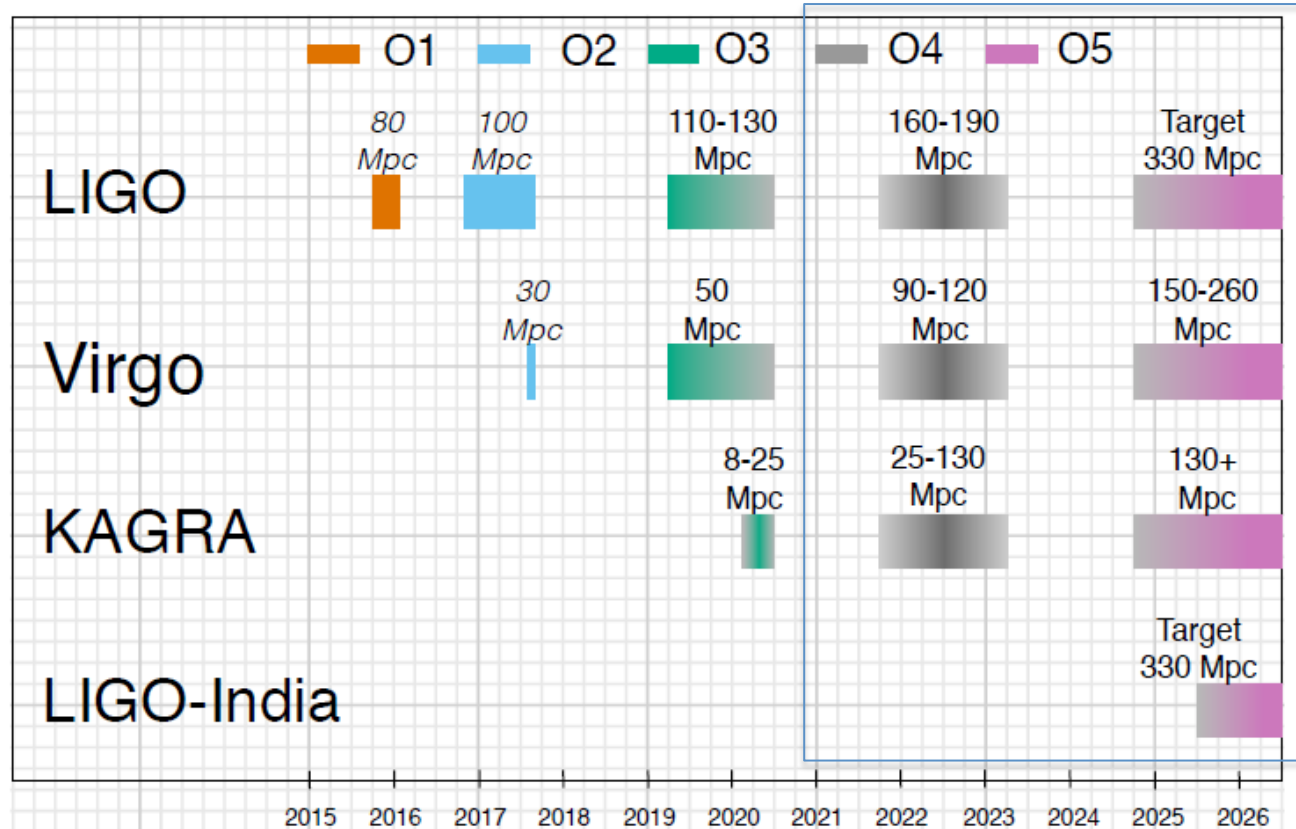


GWTC-2: Compact Binary Coalescences Observed by LIGO and Virgo  
During the First Half of the Third Observing Run, [arxiv.org/abs/2010.14527](https://arxiv.org/abs/2010.14527)

# Results

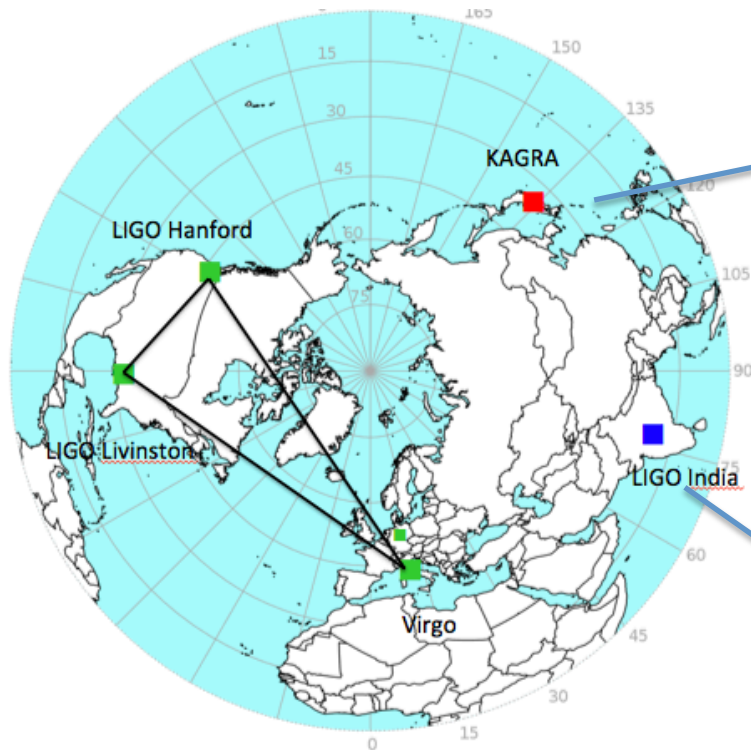
- Speed of gravitational-waves
  - Tests of gravitational-wave polarisation
  - Tests on the emission at GW higher harmonics
  - Various GR tests (PPN, GW propagation, consistency tests)
- 
- First observations of a BNS merger
  - First observations of BBH systems (and BBH mergers)
  - Observation of a new population of black-holes with high masses (up to 140  $M_{\text{sun}}$ )
  - Statistics on BBH (mass distribution, spins, merger rate vs  $z$ )
  - Link between GRB and neutron star mergers
  - Link between kilonova and neutron star mergers
  - Alternative measurement of Hubble constant
  - Measurements on NS tidal deformability and constraints on EoS
- 
- Alerts to electromagnetic observatories

# LIGO-Virgo observing runs



Prospects for observing and localizing gravitational-wave transients with Advanced LIGO, Advanced Virgo and KAGRA, <https://arxiv.org/abs/1304.0670>

# The GW detector network in the next years

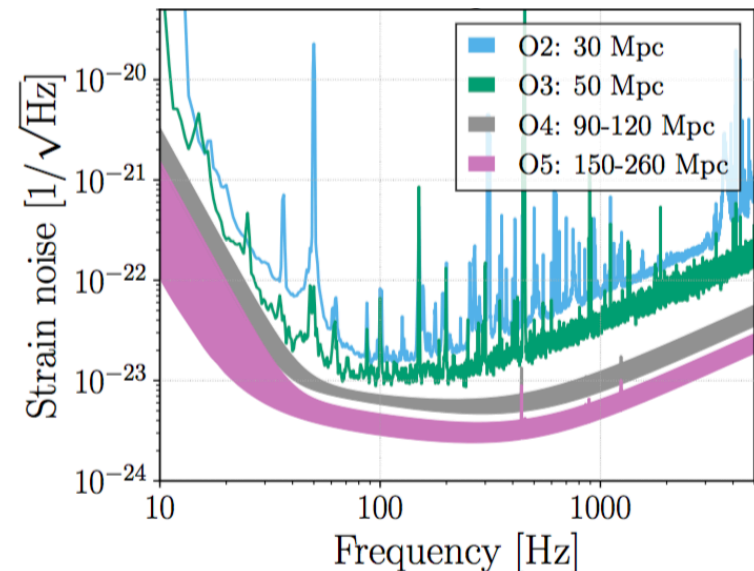
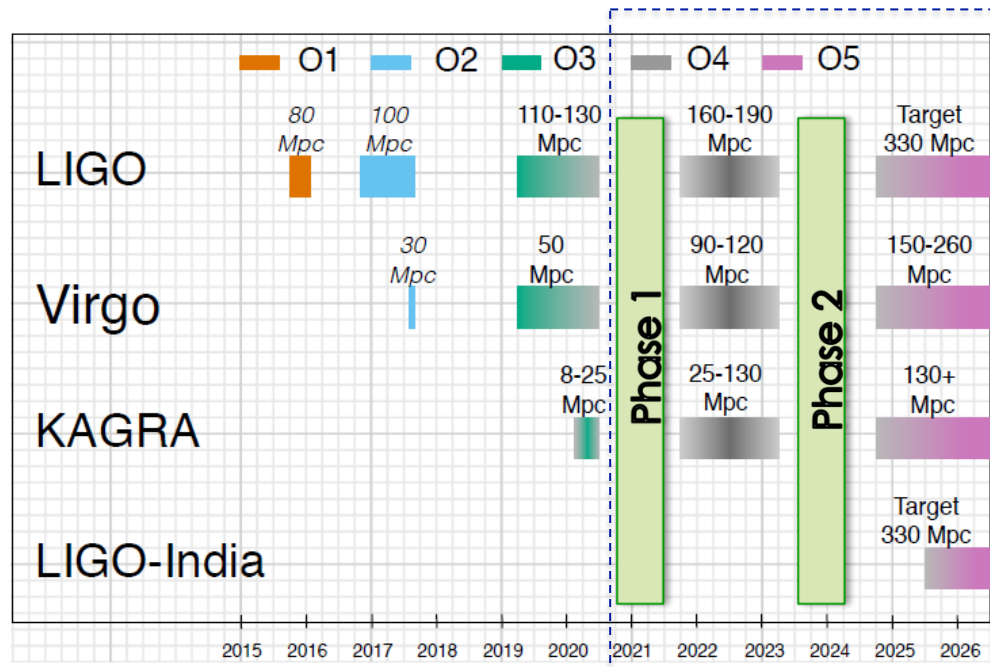


- KAGRA: cryogenic and underground
- Under commissioning

- Site in Maharashtra state
- Land acquisition completed



# Next observing runs: Advanced Virgo+



Advanced Virgo+ in short:

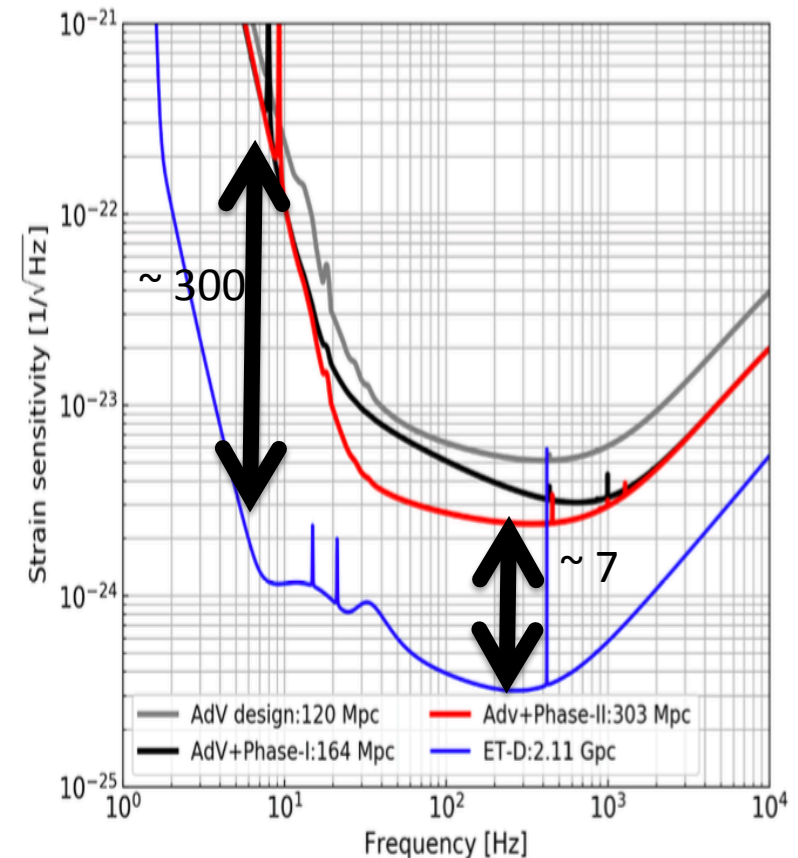
- 2 phases - phase 1 before O4 (O4:2022), phase 2 before O5 (O5:2025)
- Goal: to increase the BNS range by a factor  $\sim 3-5$  with respect to O3



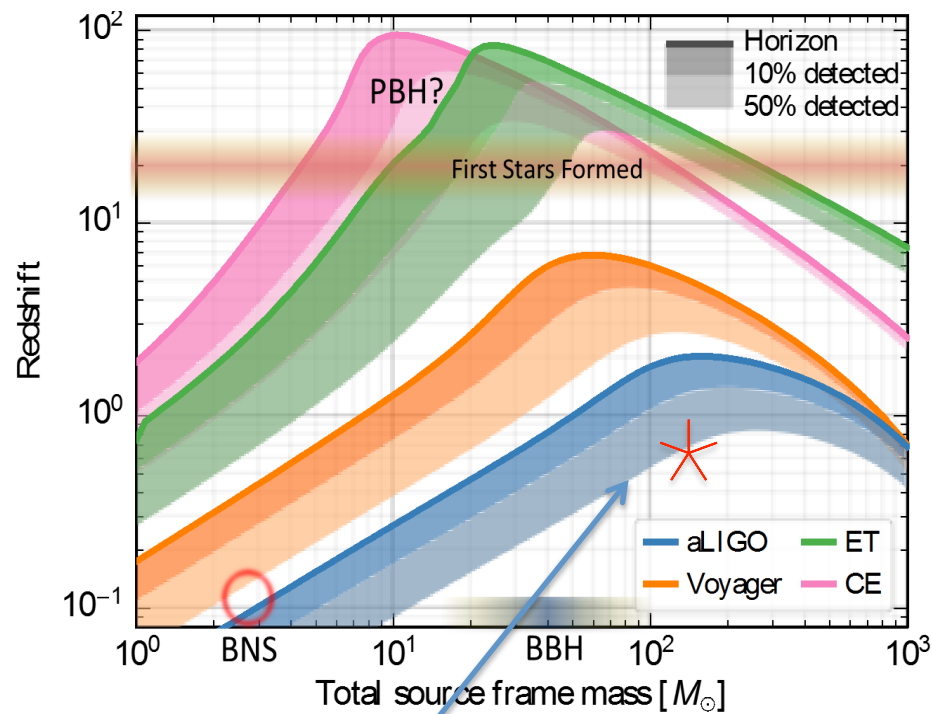
# Why a new infrastructure?

## Why now ?

- The first detections (2015-2020) shown all the scientific potential of the field
- Despite their upgrade plan, Virgo and LIGO will be eventually limited by the infrastructure
- We need to start to prepare now a new detector (~ 15 years preparation)
- Similar effort in US (Cosmic Explorer)  
<https://cosmicexplorer.org/>

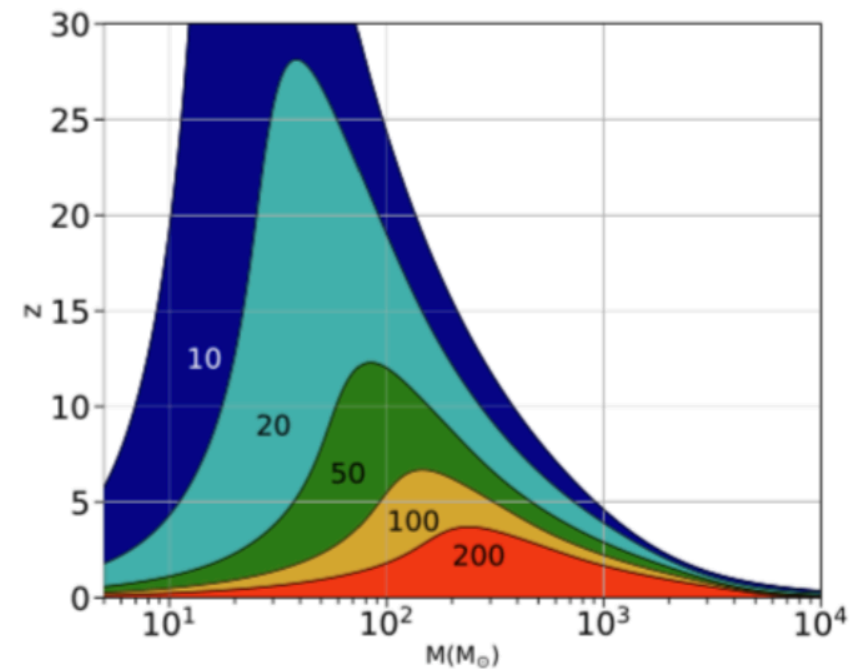


# Compact objects with ET



GW190521  
 $z = 0.8$ ,  $M = 150$

ET science case  
<https://arxiv.org/pdf/1912.02622>



# Some of the scientific questions addressed by ET

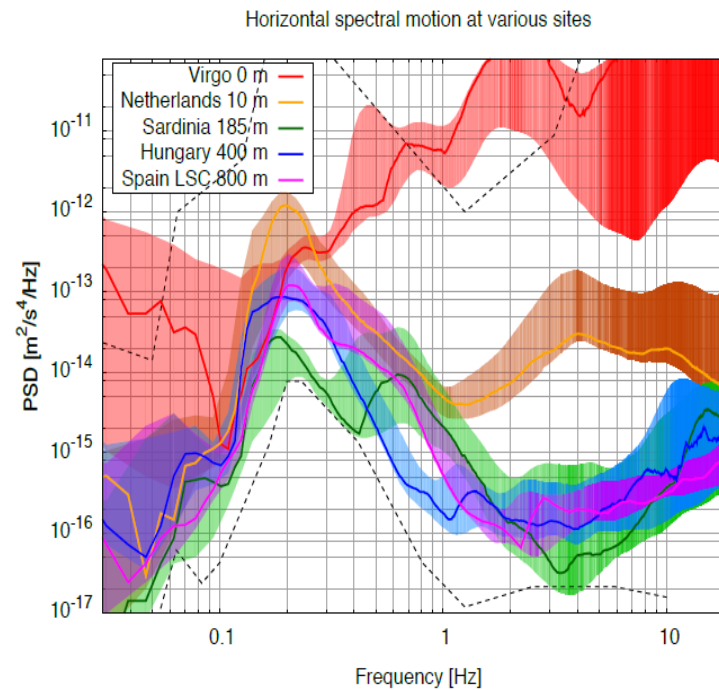
- **Black-holes evolution**
  - Black-hole mergers in the entire Universe
  - Intermediate-mass black-holes
  - Possibility to check the existence of PBH
- **Nature of gravitation**
  - Nature of black-holes
  - Process in the primordial Universe
  - Signs of quantum gravity (i.e. échos)
- **Nature of dark energy**
  - An alternative cosmology
  - Test of modified gravity theories
- **Nature of matter at the smaller scales**
  - Study of nuclear matter in a laboratory not possible on Earth
- **Physics of Supernovae**

## **Complementarity and synergies with LISA**

See talks by: D.Steer, A.Lamberts, T.Regimbau, J.Novak, L.Blanchet, F.Daigne

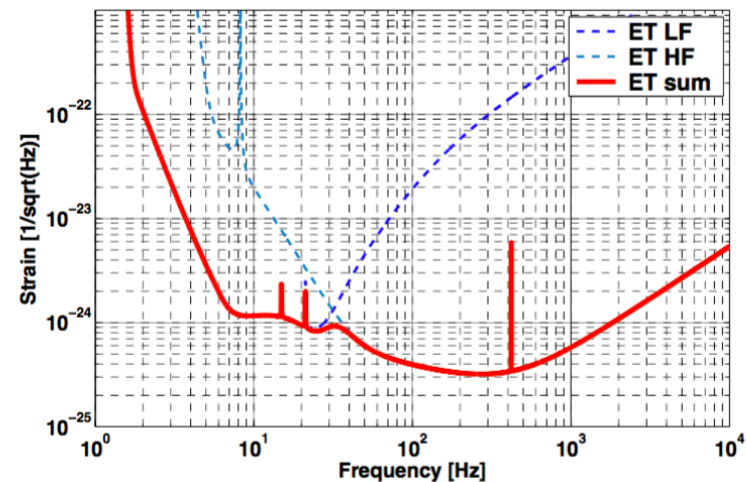
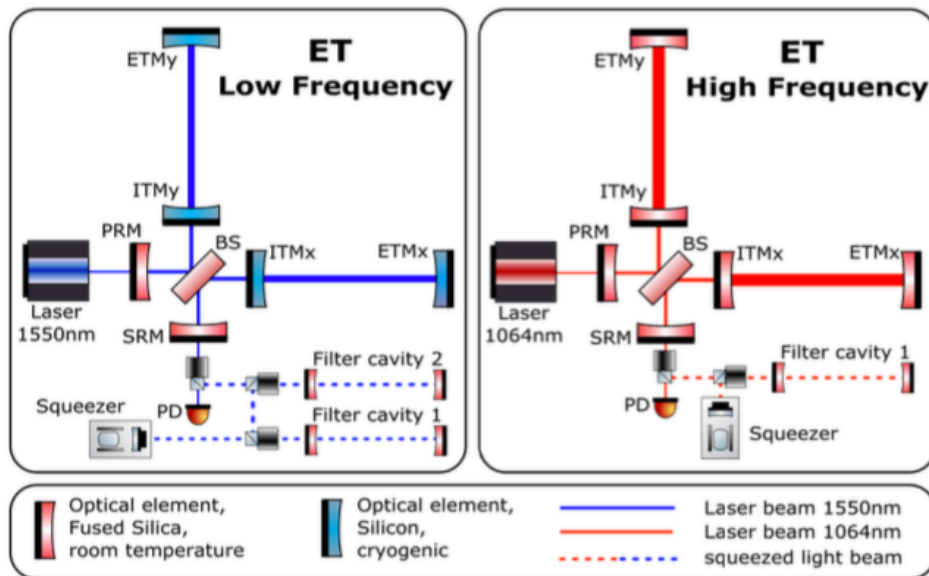
# ET design – main features

- 10- km long arms (signal increase)
- Underground (seismic noise reduction)
- « Xylophone » (two combined detectors)
- Cryogenics (thermal noise reduction)
- Triangle configuration → polarisation



# xylophone

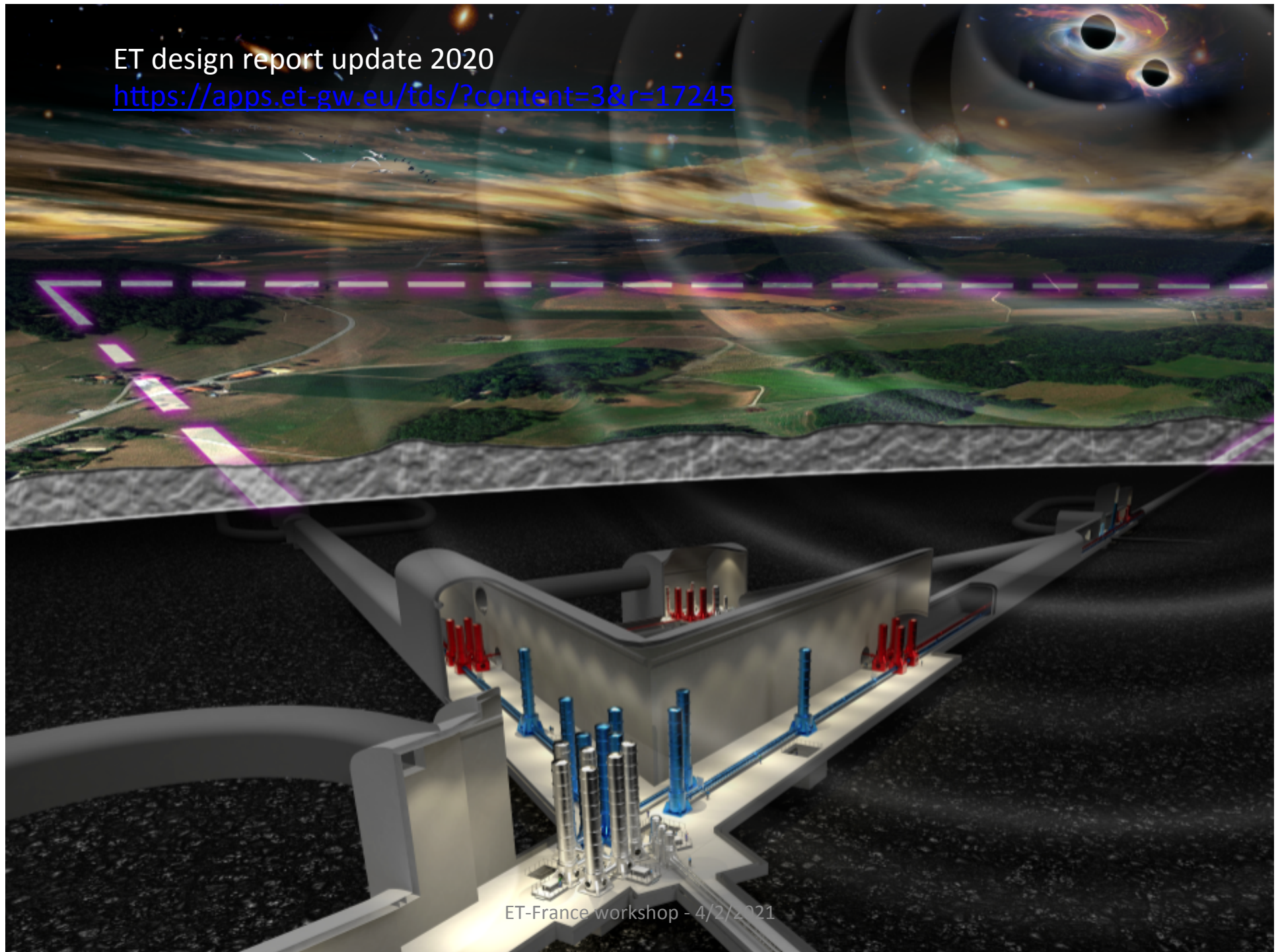
- Improving at low and high frequency with a single detector is very challenging
  - HF requires more laser power
  - LF requires cold mirrors
- Split the detection band over 2 “specialized” instruments





ET design report update 2020

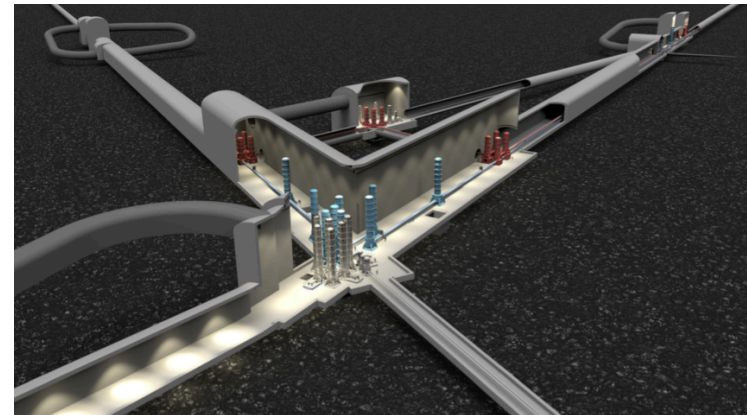
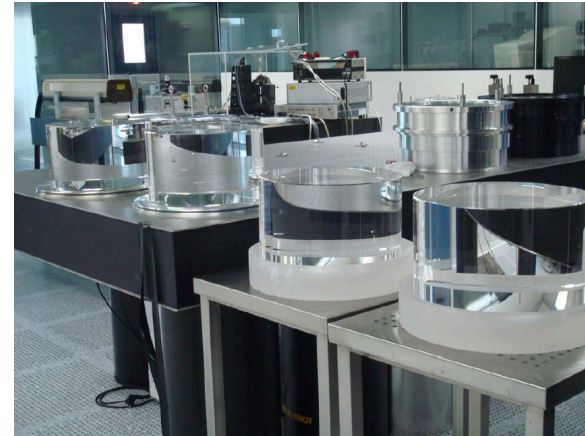
<https://apps.et-gw.eu/tds/?content=3&r=17245>



ET-France workshop - 4/2/2021

# The ET technologies and challenges

- Extrapolation of current or planned technologies for Virgo and LIGO
  - Squeezing (non classical states of light)
  - High-power lasers
  - Large mirrors
  - New mirror's coatings
  - Thermal compensation techniques
  - Seismic suspension systems
- Technologies not tested in Virgo and LIGO (prototypes and/or R&D on-going)
  - Cryogenics (also in KAGRA)
  - New cryogenic materials
  - New laser wavelengths
- R&D program needed
- Underground facilities



# Possible planning

- September 2020 ET submitted at ESFRI
- 2021-2022 formalisation of the ET collaboration
- 2023: Technical design report (infrastructure related aspects)
- 2024: Selection of the hosting site
- 2026: Full technical design report
- 2027 Beginning of the excavation works
- 2032 Start of installations
- 2036 Data taking



# Possible planning - Sites

- 2021-2022 formalisation of the ET collaboration
- 2023: Technical design report (infrastructure related aspects)
- **2024 Selection of the hosting site**
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# ET organization – status

- Today: **a proto-collaboration**
  - Temporary governing body *ET steering committee*
  - Steering committee ~ 20 persons in Europe
    - 3 from France - M.Barsuglia (APC), N.Christensen, (OCA), R.Flaminiio (LAPP)
  - Various national ET communities: ET-Italy (~100 persons), NL-BE-DE consortium (a few tens of persons), Spain, Poland
- **Goal in 2020**
  - prepare and submit ESFRI proposal, review science, design, impact, cost, planning, etc...
- **Goal in 2021**
  - Define ET Collaboration organization
  - Form various committees (science, instrument, site,...)
  - ~ **september 2021: start the ET collaboration (ET groups)**

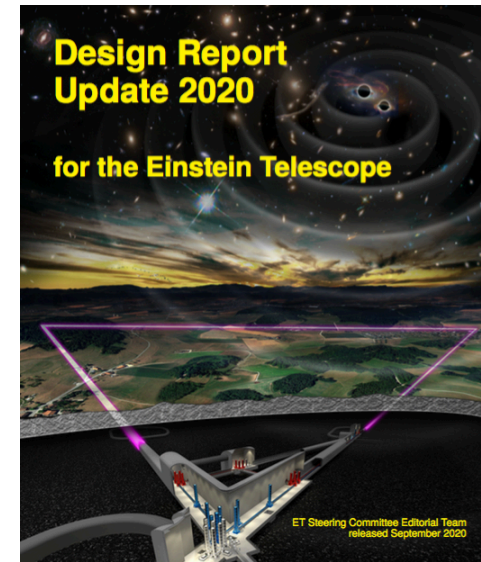
# ESFRI proposal

- ESFRI: European Scientific Forum for Research Infrastructures  
**<https://www.esfri.eu/>**
- Application sent September 2020 (answer in September 2021) for the 2021 update of the ESFRI
- During the application preparation, opportunity to review:
  - the science,
  - the design,
  - the timeline,
  - Evaluation of the social and economic impact
- 5 political support: Italy (leading country), The Netherlands, Belgium, Poland, Spain
- Consortium with ~ 40 institutions

# ET committees: Instrument science board (ISB)

- Goals:
  - 1/ Write the ET technical design report
    - 2 phases: phase 1: 2023, phase 2: 2026
  - 2/ Identify critical R&Ds for ET
- 2 co-chairs
- 5 divisions (2 co-chairs for each division)
  - Suspensions
  - Interferometer
  - Vacuum and cryogenics
  - Active noise mitigation
  - Infrastructure
  - Optics (see talk by **Edwige Tournefier**)

See talk by **Jérôme Degallaix**



+ Talks by: **M.Turconi, M.Was, L.Rolland, B.Sassolas, A.Amato**

# ET Observational science board (OSB)

## Main Goals:

- 1/ write ET science case (blue book)
- 2/ prepare ET data-analysis
- 3/ coordinations with other observatories

- 3 co-chairs (M.Maggiore, M.Branchesi, E.Porter)
- 9 divisions (2 co-chairs per division)
  1. Fundamental physics
  2. Cosmology
  3. Population studies
  4. Multi-messenger observations
  5. Synergies with other GW observatories
  6. Nuclear physics
  7. Burst sources
  8. Scientific potential of different detector configurations
  9. Data analysis platforms

# Other ET committees under construction

- E-infrastructure board (EIB)
- Site preparation board (SPB)
- Internal financial board (IFB)

# Summary

- ET: Unique science potential
  - ESFRI proposal submitted - ET Collaboration being organised
  - ISB started to work on technical design and R&D definition
  - OSB under formation: soon OSB will start writing ET blue book
  - After the summer: formalisation of the ET Collaboration
- 
- **Opportunities (and perfect timing) to contribute:**
    - Instrument design and technology
    - Definition and preparation of the observational science
    - Preparation of the data analysis methods and algorithms
    - Organisational aspects

ET web site: <http://www.et-gw.eu/>

ET relevant documents: <http://www.et-gw.eu/index.php/relevant-et-documents>

ET-France mailing list: <https://listserv.in2p3.fr/cgi-bin/wa?SUBED1=ET-FRANCE-L&A=1>