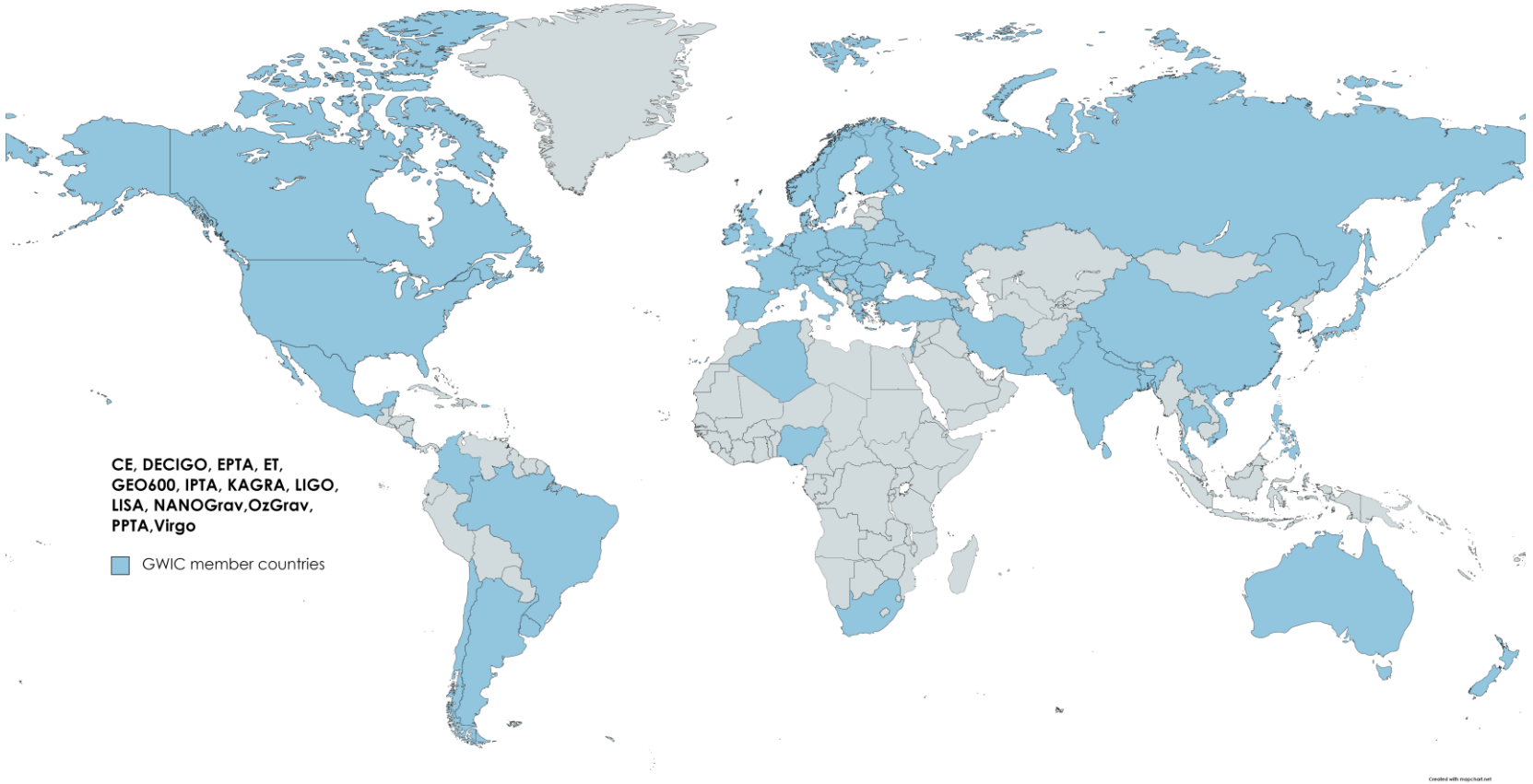
Gravitational wave science report to APPEC GA

Jo van den Brand for Einstein Telescope

Presentation to APPEC GA meeting
July 18, 2022; jo@nikhef.nl



Overview

Topics for today

1. Introduction: GWIC member projects and collaborations
2. Scientific highlights
3. Overview of GW activities
4. Next Generation Gravitational-Wave Observatories: Einstein Telescope and Cosmic Explorer
5. Summary

Included for reference

- More information about GWIC
- Links to GWIC 3G subcommittee reports

Introduction

GWIC mission: facilitate international collaboration and cooperation in the construction, operation and use of the major gravitational wave detection facilities world-wide. See https://gwic.ligo.org

GWIC member projects and collaborations

Project	Focus	Project	Focus
DECIGO	Space-based	LIGO	Ground-based
Einstein Telescope	Ground-based (nextgen)	LISA community	Space-based
Cosmic Explorer	Ground-based (nextgen)	NANOGrav	Pulsar timing
European Pulsar Timing Array EPTA	Pulsar timing	OzGrav/PPTA	Ground-based/Pulsar timing
GEO 600	Ground-based	Virgo	Ground-based
KAGRA	Ground-based	GW Theory Community	All

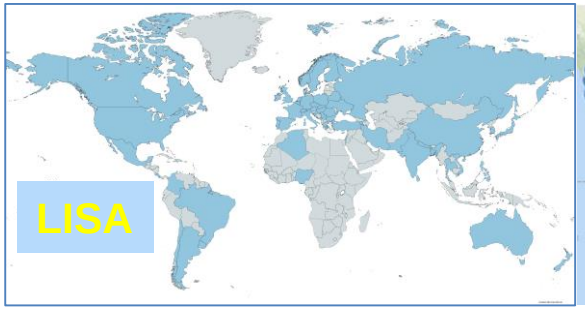
Statistics about GWIC member projects

- LISA about 1,550 members from 60 countries, IPTA about 200 members
- LIGO SC, Virgo and KAGRA about 2,000 members
- Cosmic Explorer and Einstein Telescope about 1,000 members

Slides represent the opinion of GWIC members

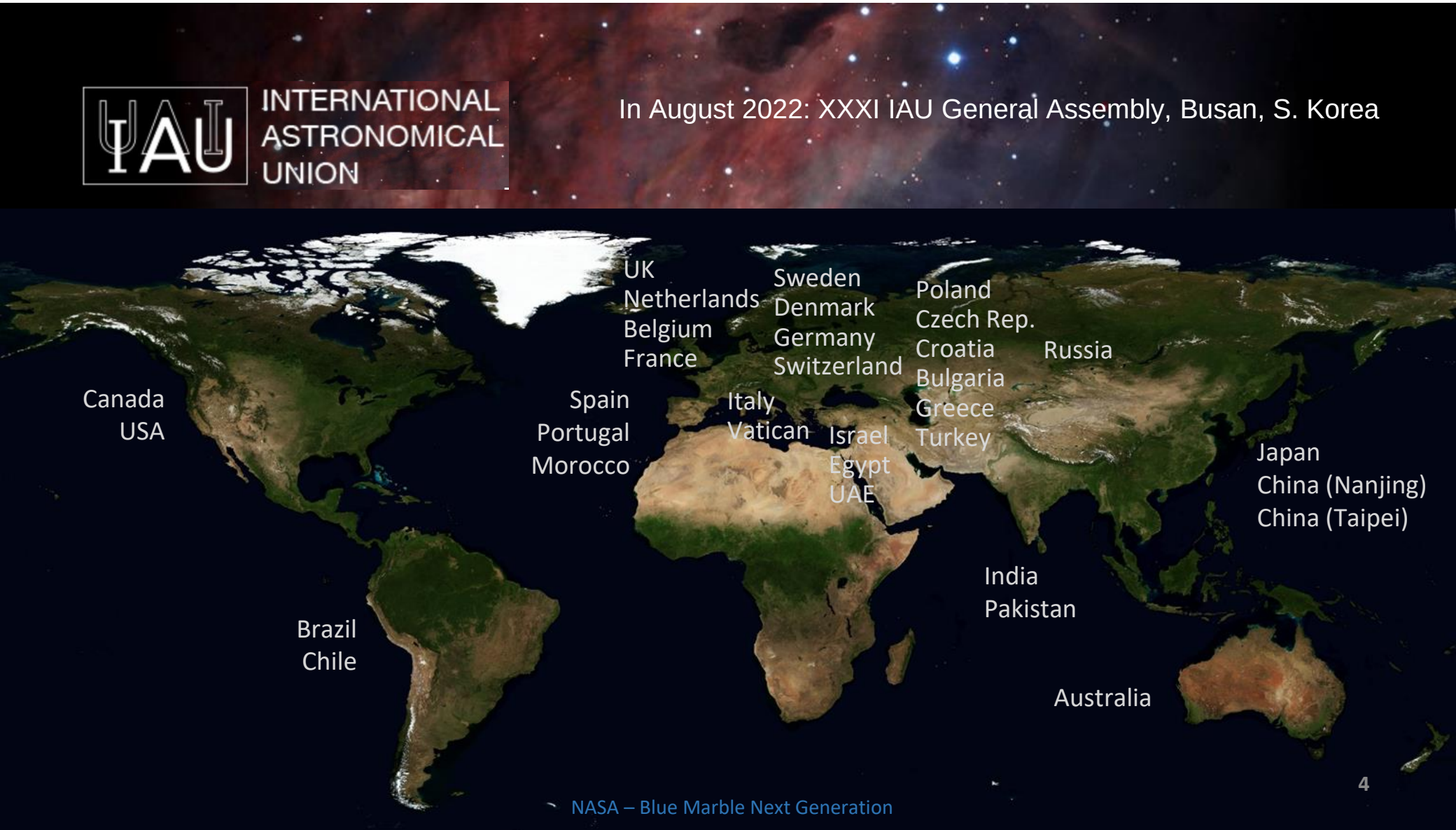
Affiliated members

- GWIC is Working Group 11 of IUPAP
- International Society of General Relativity and Gravitation – ISGRG is an Affiliated Commission (AC2) of IUPAP
- IAU Commission D1



IAU – International Astronomical Union

Commission D1:Gravitational Wave Astrophysics has members from over 30 countries



Overview

Topics for today

1. Introduction: GWIC member projects and collaborations
2. **Scientific highlights**
3. Overview of GW activities
4. Next Generation Gravitational-Wave Observatories: Einstein Telescope and Cosmic Explorer
5. Summary

Gravity

Gravity is the least understood fundamental interaction with many open questions. Should we not now investigate gravity experimentally, in ways it was never tested before?

Gravity

- Main large-scale organizing principle in the Universe
  - Structure formation
- Most important open problems in contemporary physics
  - Acceleration of the Universe is attributed to Dark Energy
  - Standard Model of Cosmology features Dark Matter
  - Or does this signal a breakdown of general relativity?

Large world-wide intellectual activity

- Theoretical: combining GR + QFT, cosmology, …
- Experimental: astronomy (CMB, Euclid, VRO), particle physics (LHC), Dark Matter searches (Xenon1T), …

Gravitational waves

- Dynamical part of gravitation, all space is filled with GW
- Ideal information carrier, almost no scattering or attenuation; weak so big detectors
- The entire Universe has been transparent for GWs, all the way back to the Big Bang

Gravitational wave science can impact

- Fundamental physics: black holes, spacetime, horizons, matter under extreme conditions
- Cosmology: Hubble parameter, Dark Matter, Dark Energy
- Astronomy & astrophysics: stellar evolution, nucleosynthesis, galaxy environments and mergers

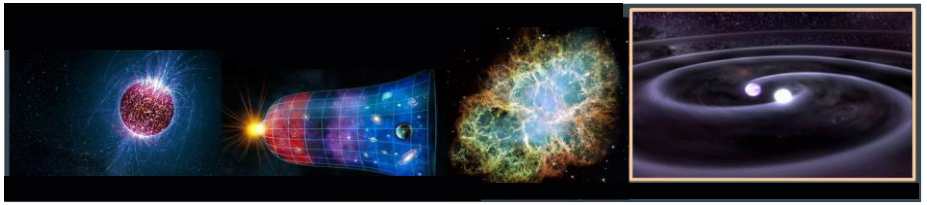
6

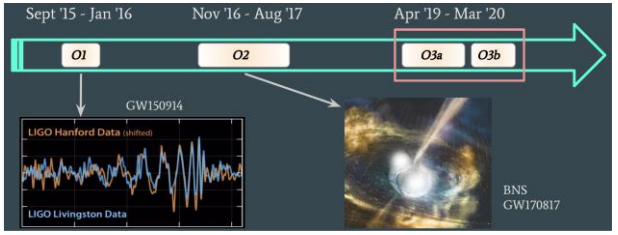
Recent results from LIGO, Virgo and KAGRA

Gravitational-wave science has made a transition from novelty (first detections, 2015) to populations. Around 90 detections have been made to date. See https://arxiv.org/pdf/2111.03634.pdf

Sources of GW

- So far only compact binary coalescence observed
- Discovered systems
  - Black hole – black hole
  - Neutron star – neutron star
  - Neutron star – black hole: during O3b first confirmed detection of NS-BH systems: GW200105 and GW200115
    - However, marginal tidal deformability measurements
    - Modest sky localization and large distances (280 and 300 Mpc)
  - Electromagnetic counter parts so far only for GW170817
  - Many open questions: formation channels, how often does this happen, matter?



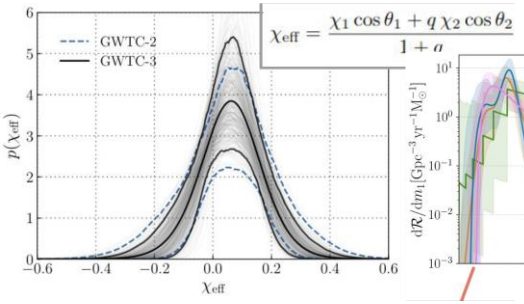


Population properties

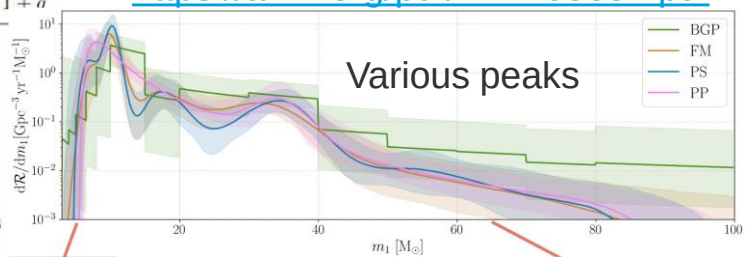
- Spin and info on formation channels
  - Generally low spin
  - Signs of precession
- Masses
- Lower mass gap
- Pair instability supernovae 50 – 120 Msolar

$$\text{GW200105:} \quad m_1 \simeq 8.9M_\odot, \quad m_2 \simeq 1.9M_\odot$$

$$\text{GW200115:} \quad m_1 \simeq 5.7M_\odot, \quad m_2 \simeq 1.5M_\odot$$



https://arxiv.org/pdf/2111.03634.pdf

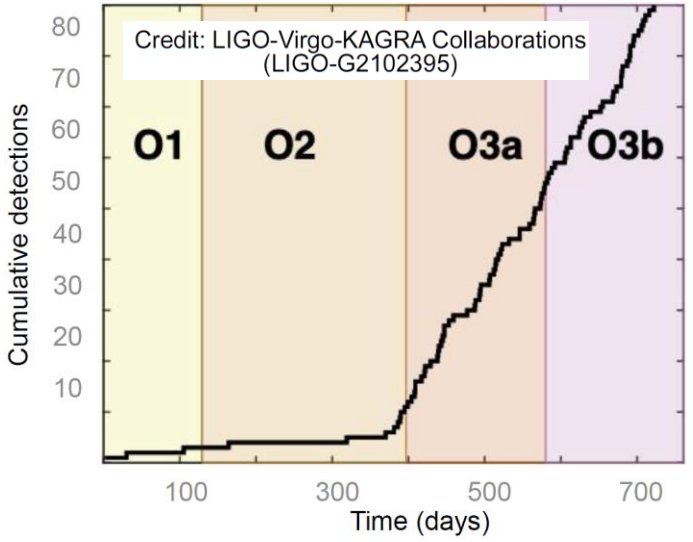


Recent results from LIGO, Virgo and KAGRA

LIGO and Virgo coordinate science data taking. In between the observation runs, the instruments are upgraded and commissioned to achieve better sensitivity. Several interesting events observed in O3

Performance

Better sensitivity rapidly translates in an increase in event rate



Discoveries

GW150914

- First astrophysical source
- Binary black holes exist

GW170817

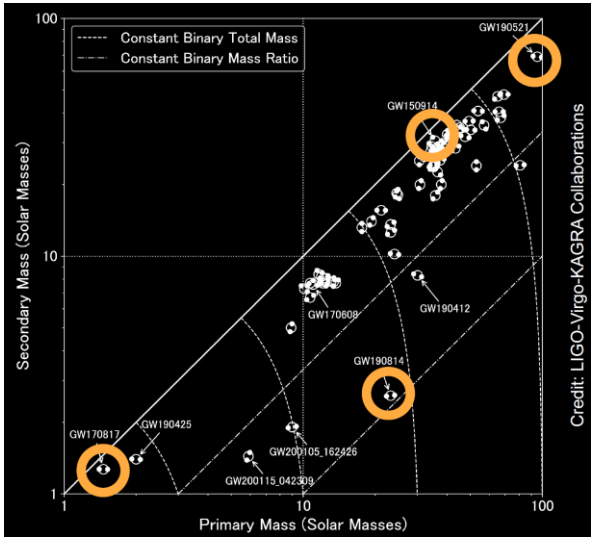
- Binary neutron star mergers are gamma-ray burst progenitors

GW190521

- The most massive binary system
- Black holes exist in pair-instability mass gap

GW190814

- Compact objects exist with masses between 2-5 Msun



Recent publications and “open” data

LIGO, Virgo and KAGRA release data segments with each publication. Bulk strain data releases (18 months after each 6 month observation period); see https://www.gw-openscience.org

Low-latency alerts broadcast publicly

- Striving for sub-minute delays (or even before the coalescence)
- Pointing information, and nature of event
- Enables telescopes etc. to search for sources
- Striving to be ready to repeat the spectacular success of GW170817 in a public mode

Full strain data released 18 months after acquisition

- Enables searches beyond those done in the LVK Collaborations
- Several groups have developed independent pipelines
- Proprietary period provides incentive for LVK Collaboration members to prepare, calibrate and thoroughly qualify the data, contribute and gain authorship on LVK papers

Vibrant community using these data; see for example “3-OGC: Catalog of gravitational waves from compact-binary mergers”, Nitz et al https://iopscience.iop.org/article/10.3847/1538-4357/ac1c03, and “New binary black hole mergers in the LIGO--Virgo O3a data”, Olsen et al https://arxiv.org/abs/2201.02252

Recent publications

Catalog paper GWTC-3: https://arxiv.org/pdf/2111.03606.pdf
Testing General Relativity: https://arxiv.org/pdf/2112.06861.pdf
Population and properties: https://arxiv.org/pdf/2111.03634.pdf
Lensing: https://arxiv.org/pdf/2105.06384.pdf

NSBH : https://arxiv.org/pdf/2106.15163.pdf
GW190425: https://arxiv.org/abs/2001.01761
GW190412: https://arxiv.org/abs/2004.08342
GW190814: https://arxiv.org/abs/2006.12611
GW190521: https://arxiv.org/abs/2009.01075

What others have to say about us …

ESFRI

The European Strategy Forum on Research Infrastructures (ESFRI) plays a key role in policy-making on Research Infrastructures in Europe. See https://www.esfri.eu/

Einstein Telescope appeared on the 2021 ESFRI Roadmap

- Composed of 36 national delegates nominated by research ministers of 36 EU countries and countries associated with Horizon 2020. It also includes a Commission representative
- On December 7th, 2021, ESFRI presented the 2021 ESFRI Roadmap on Large Scale Research Infrastructures; see https://roadmap2021.esfri.eu/
- “The Einstein Telescope (ET) responds to the desire from a broad scientific community to observe signals from across the cosmos to understand the very origins of our Universe. Despite their success, in terms of distances explored, the current reach of 2G observatories such as LIGO and Virgo is limited to a region that, on cosmological scales, is still our local neighbourhood, leaving much of the curiosity of scientists unquenched”

Astro 2020 Decadal

US National Academy study; used by NSF, NASA, DOE for guidance.
See https://www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020

Key conclusions

“Gravitational wave astrophysics is one of the most exciting frontiers in science”

“The discovery in 2015 of gravitational waves from a pair of merging 30 solar mass black holes is certainly one of the watershed moments in physics and astronomy of the last decades”

“Future upgrades of ground-based gravitational wave facilities, together with the launch of LISA make this a high priority for discovering new physics, and making astronomical measurements that will change paradigms”

“Exploring the cosmos in the multi-messenger and time domains is a key scientific priority for the coming decade, with new capabilities for discovery on the horizon with the Rubin Observatory, Roman, LIGO, Virgo, and KAGRA, and IceCube”

“The continued growth in sensitivity through planning the next-generation observatory, such as Cosmic Explorer, is essential. This will require investment in technology development now“

2020 Update of the European Strategy for Particle Physics
European Strategy Group

CERN has taken responsibility for technical coordination and design of one of the most expensive components in 3G observatories: the ultra-high vacuum system for the beam pipes

CERN collaboration with GW community

- MOU Nikhef-INFN-CERN for Einstein Telescope (kick-off meeting on May 18, 2022)
- CE with support from NSF

5

Synergies with neighbouring fields

A. A variety of research lines at the boundary between particle and nuclear physics require dedicated experiments and facilities. Europe has a vibrant nuclear physics programme at CERN, including the heavy-ion programme, and at other European facilities. In the global context, a new electron-ion collider, EIC, is foreseen in the United States to study the partonic structure of the proton and nuclei, in which there is interest among European researchers. ***Europe should maintain its capability to perform innovative experiments at the boundary between particle and nuclear physics, and CERN should continue to coordinate with NuPECC on topics of mutual interest.***

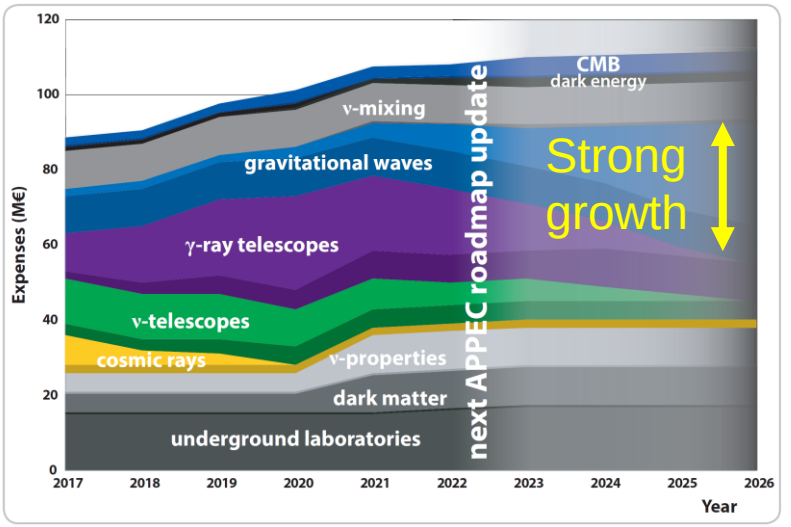
B. Astroparticle physics, coordinated by APPEC in Europe, also addresses questions about the fundamental physics of particles and their interactions. The ground-breaking discovery of gravitational waves has occurred since the last Strategy update, and this has contributed to burgeoning multi-messenger observations of the universe. ***Synergies between particle and astroparticle physics should be strengthened through scientific exchanges and technological cooperation in areas of common interest and mutual benefit.***

Astroparticle Physics European Consortium - APPEC

APPEC is a consortium of 19 funding agencies, national government institutions, and institutes from 17 European countries, responsible for coordinating and funding national research efforts in astroparticle physics. See https://www.appec.org/

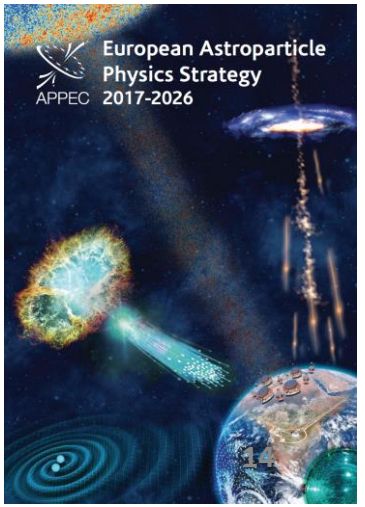
Roadmap 2017 - 2026

- Advice to funding agencies on spending profile assuming a resource-aware roadmap
- “With its global partners and in consultation with GWIC, APPEC will define timelines for upgrades of existing as well as next-generation ground-based interferometers”
- “APPEC strongly supports further actions strengthening the collaboration between gravitational-wave laboratories”
- “Strongly supports Europe’s next-generation ground-based interferometer, the Einstein Telescope (ET) project, in developing the required technology and acquiring ESFRI status”
- “In the field of space-based interferometry, APPEC strongly supports the European LISA proposal”



Roadmap update ongoing

- Town Meeting on 9 and 10 June 2022 in Berlin
- Looking forward to APPEC Roadmap update

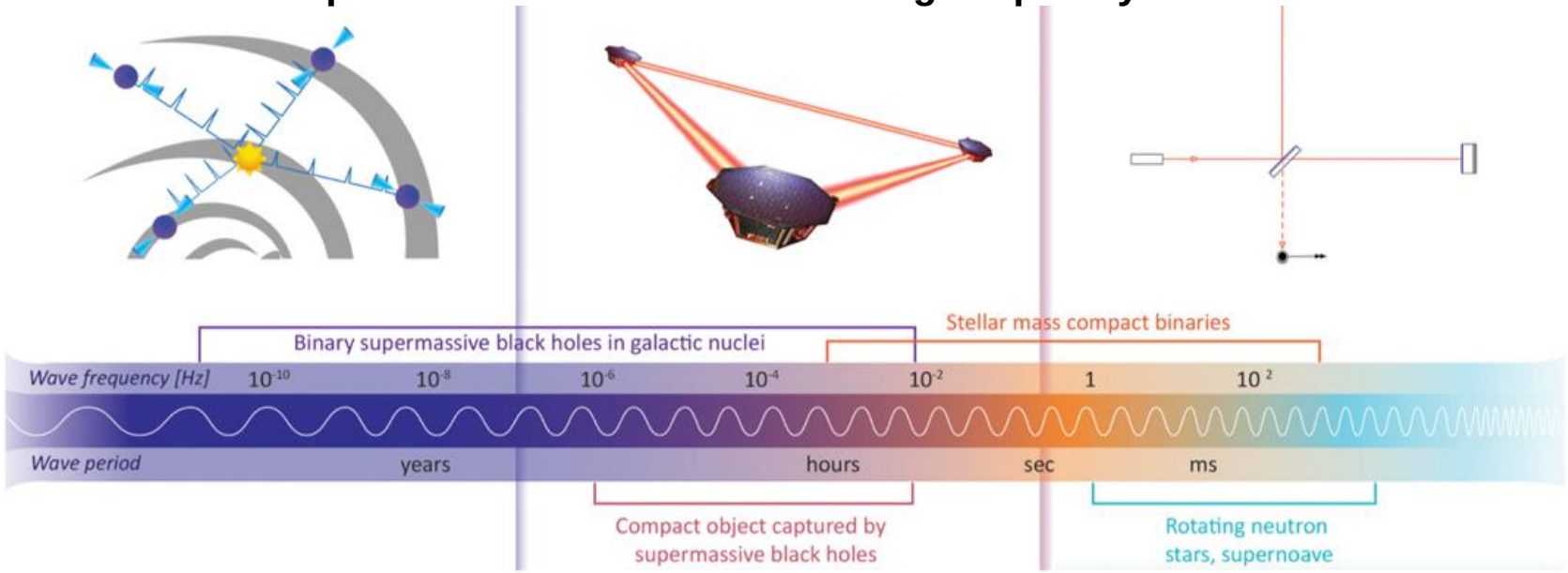


Overview

Topics for today

1. Introduction: GWIC member projects and collaborations
2. Scientific highlights
3. **Overview of GW activities**
4. Next Generation Gravitational-Wave Observatories: Einstein Telescope and Cosmic Explorer
5. Summary

Activities will be presented in order of increasing frequency band

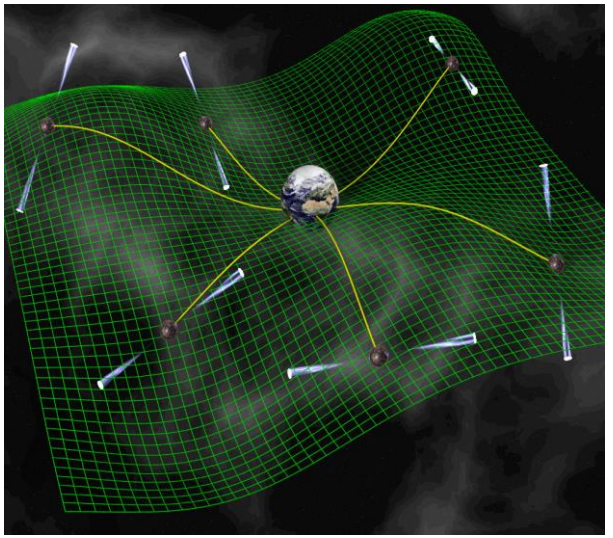


The International Pulsar Timing Array (IPTA)

IPTA uses pulsars to create a galaxy-scale detector to observe gravitational waves from supermassive black holes in the distant Universe. See http://ipta4gw.org/

Current Pulsar Timing Arrays (PTAs)

- Seek to detect nanohertz-frequency GWs by timing ~100 millisecond pulsars with large radio telescopes. Data shared through global International Pulsar Timing Array (IPTA) collaboration
- Unlike LIGO/Virgo/KAGRA, PTAs do not detect short, high- significance events. Instead, they first detect noise in individual pulsars, then a common noise-like signal, then spatially correlated noise yielding GW detection leading to new physics & astrophysics
- IPTA Countries and constituent PTAs:
  - USA, Canada - NANOGrav (70 Pulsars)
  - Germany, France, UK, Italy, Netherlands - EPTA (45 Pulsars)
  - Australia - PPTA (25 Pulsars)
  - India - InPTA (30 Pulsars)



Emerging PTAs

- South Africa (89 Pulsars) MeerKAT/MeerTime
- China (40 Pulsars) FAST/ China PTA
- SKA & DSA 2000 (later this decade)

Global PTAs and Telescopes

PTAs are rapidly growing in sensitivity. Firm detection likely by 2025

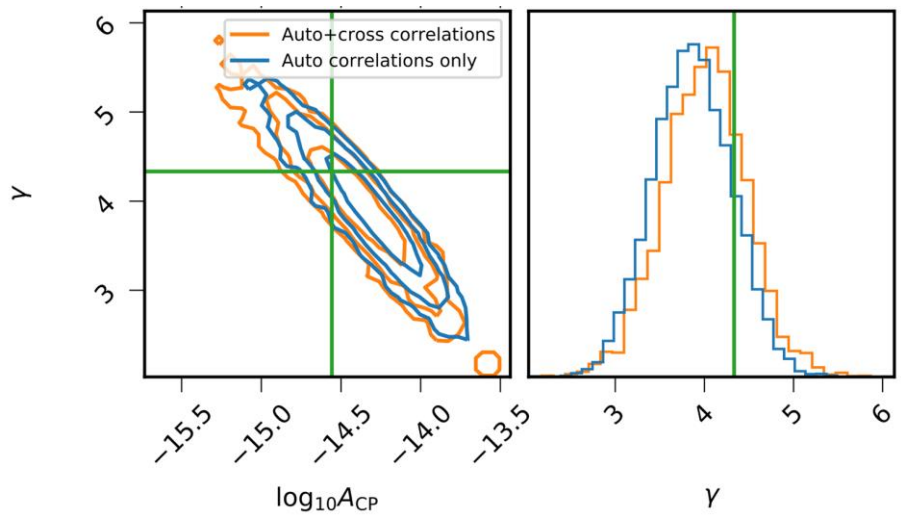
Progress

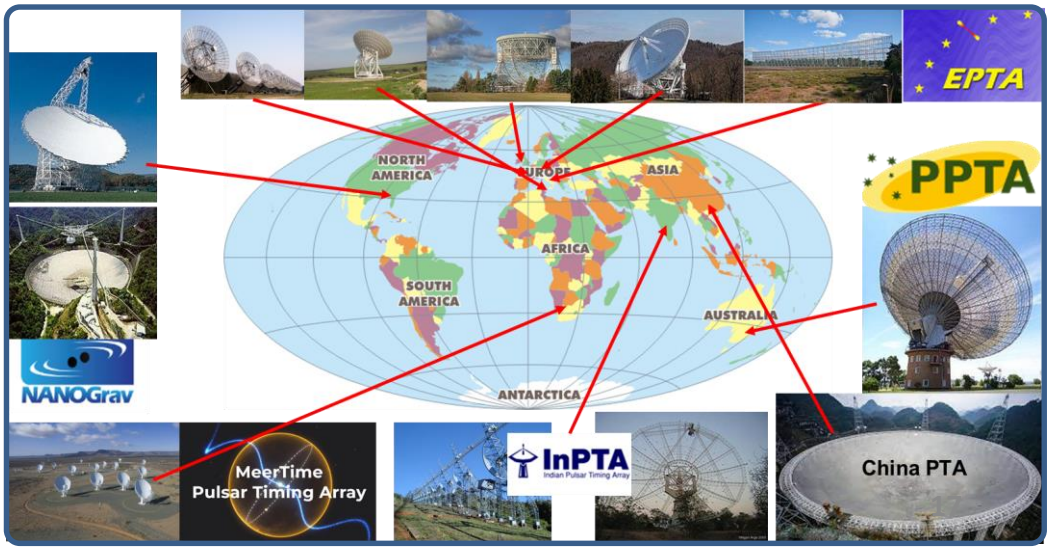
- IPTA “DR2” result published Jan 2022. Common process detected, consistent with expectations of supermassive black hole binary background. Spatial correlations not yet detected

Upcoming

- Coordinating publication of 3 new independent GW papers using recently completed data releases
- All 3 PTAs (EPTA,PPTA,NanoGrav) see interesting (and similar amplitude) potential GW backgrounds (shown on right)
- Combined dataset analysis and release (DR3) is also in progress

Significant IPTA funding





OzGrav

OzGrav contributes to a range of activities from PPTA to LIGO to 3G. See https://www.ozgrav.org/

OzGrav R&D

- On 2G++ and 3G detectors, PTAs, and data analysis
- Submitted proposal to the ARC to fund a NEW 35M 7 year Centre of Excellence commencing 2023/4
  - 17 proposals (including OzGrav) made the final round, about 9 will be funded
- Following recommendation from the mid term review of Australian astronomy - Carrying out a conceptual design and cost estimate for a 3G Pathfinder facility in Australia - NEMO
- Lobbying for gravitational wave detectors to be included under the Australian National Research Infrastructure framework

NEMO – Neutron Star Extreme Mater Observatory

- 4 km long, kHz band GW detector
- Science case: revolves around merger and ring-down phase of NS/NS mergers
- Neutron star Equation of State EOS studies => New information on nuclear matter plus other properties of neutron stars at two temperature extremes
- Cosmology once EOS known, independently measure redshift and luminosity distance
- International partnerships will be sought

Establish an Australian site for a future 3G detector

The LISA mission

LISA will explore the GW frequency range from 0.1 mHz to 100 mHz. See https://sci.esa.int/web/lisa

Science

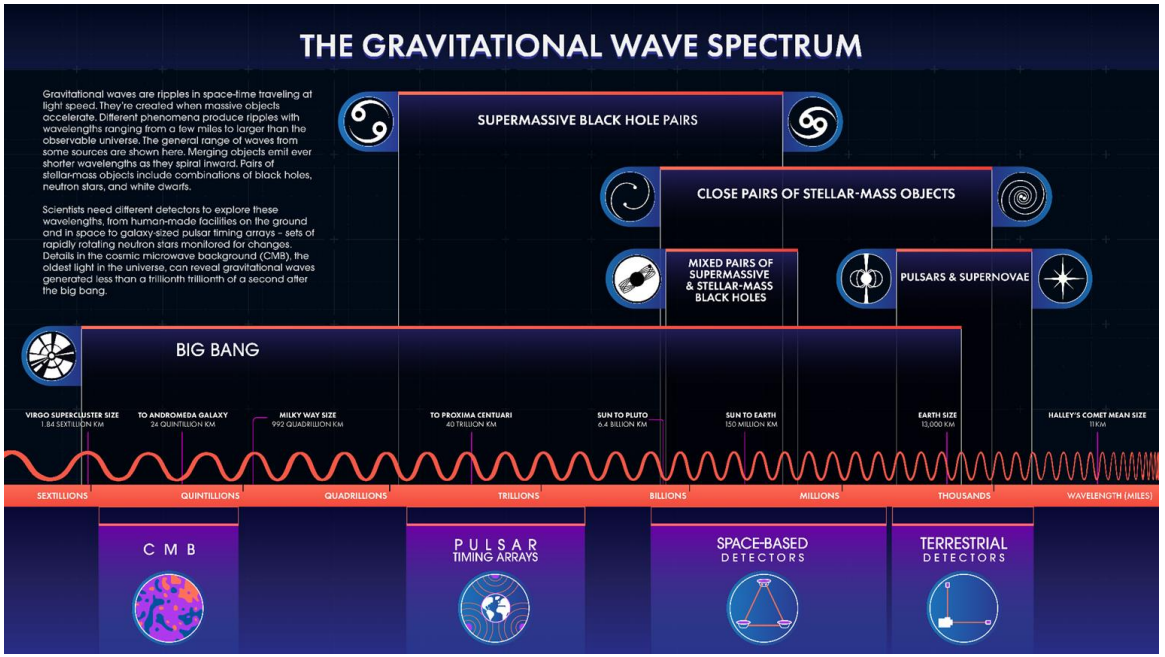
Targeting the origin and evolution of massive BHs, precision tests of GR, a census of galactic compact binaries, and potential new discoveries in the millihertz GW universe

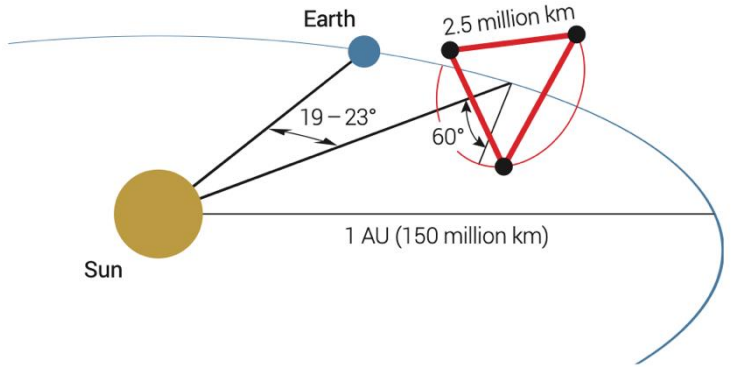
Detector

3 drag-free Spacecraft with 2.5 Gm laser transponder links

Mission

ESA large class mission with contributions from NASA and European Member States



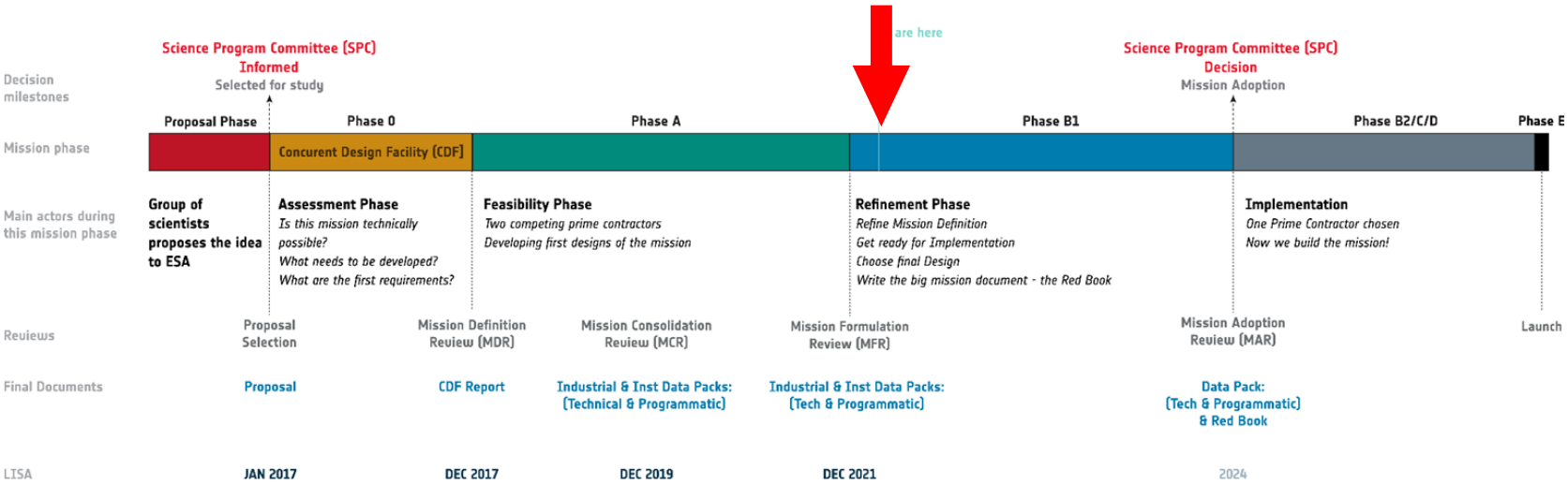


The LISA mission

Advanced to Phase B1 “preliminary definition” of the ESA program. 2021 Mission Formulation Review confirmed baseline and identified no show-stoppers

Key milestones

- 2023: Mission Adoption Review to consolidate detailed design
- 2024: Mission Adoption to confirm schedule and partner commitments
- Mid-2030’s: Launch
- Launch+2: 4 years nominal science + 6 years extended mission

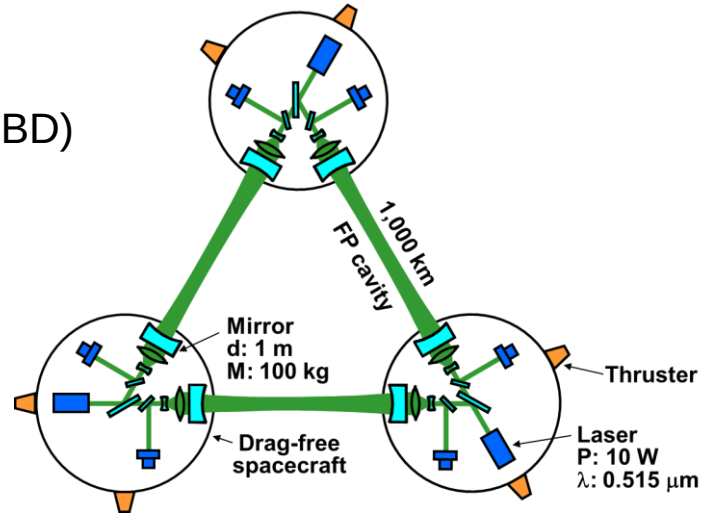


DECIGO: a Japanese 2nd-generation space detector

Deci-hertz Interferometer Gravitational Wave Observatory. See https://decigo.jp/index_E.html

DECIGO

- Frequency band: 0.1 Hz - 10 Hz
- Bridges the gap between LISA and ground-based detectors (GBD)
- Follow-up for LISA and predictor for GBD

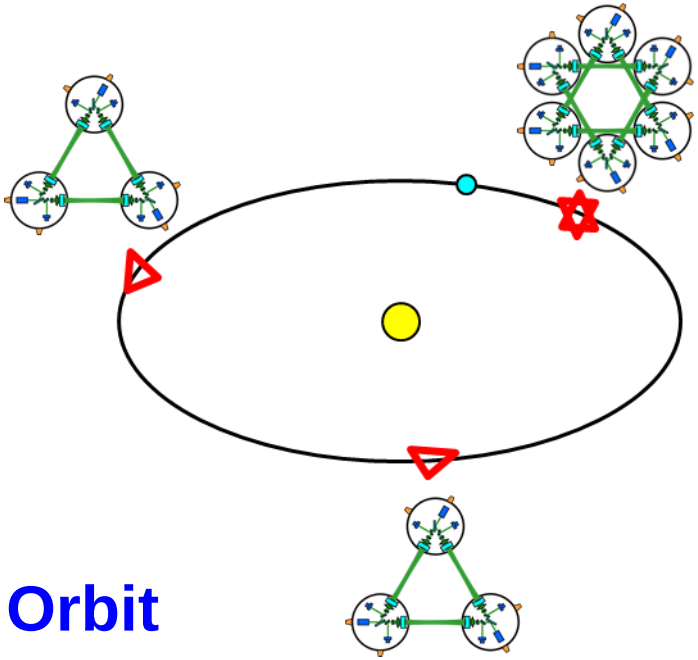


Pre-conceptual design

B-DECIGO

Pathfinder science mission for DECIGO

©NEC



Orbit

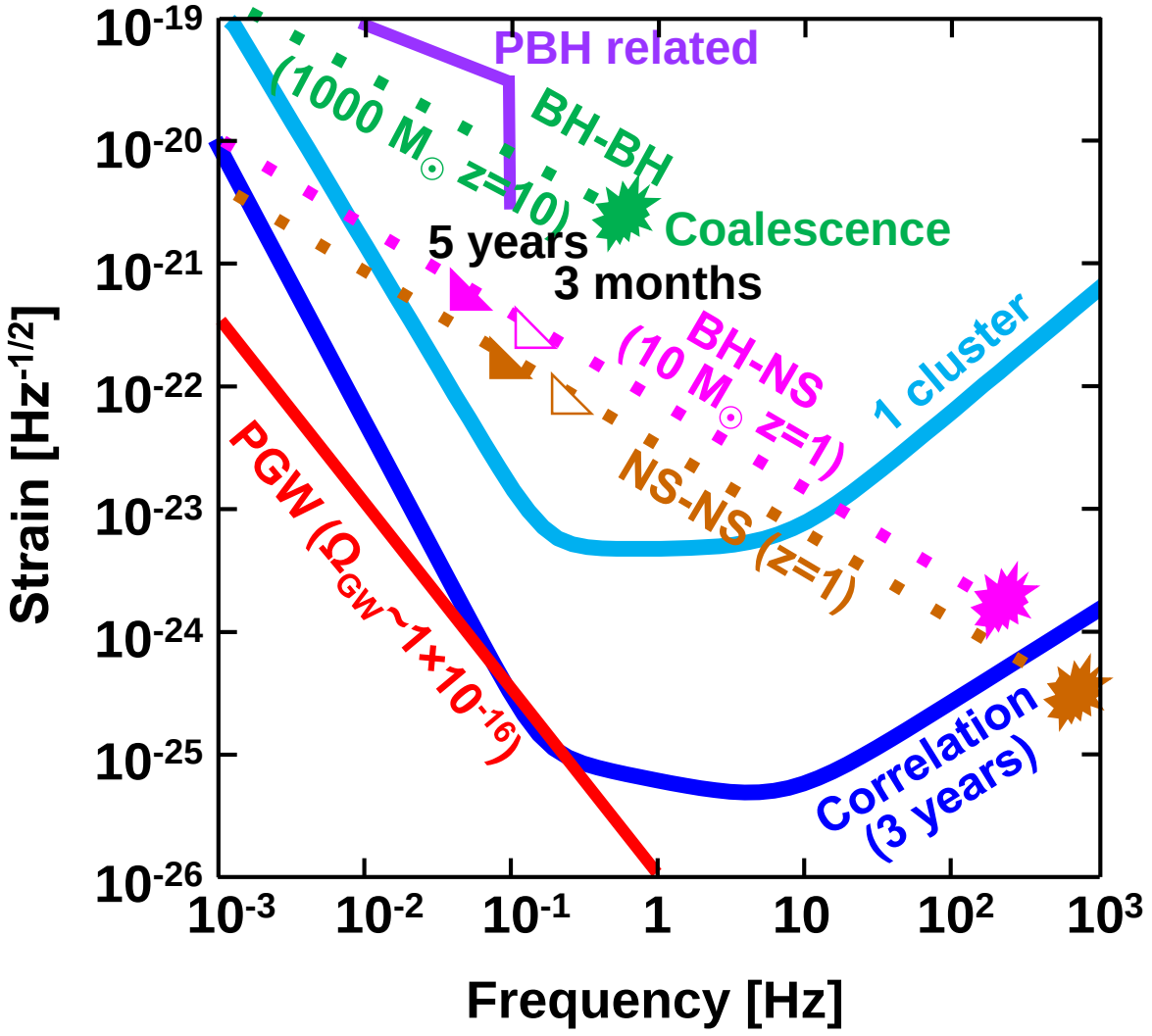
DECIGO: target sensitivity and aimed science

Deci-hertz Interferometer Gravitational Wave Observatory. See https://decigo.jp/index_E.html

Science goals

- Detect primordial gravitational waves (PGW)
- Prediction of NS-NS coalescences
- Measure acceleration of expansion of Universe
- Reveal formation of intermediate-mass BH
- Detect Primordial-BH related GWs
- Improve accuracy of general relativity

Design parameters: under optimization for PGW

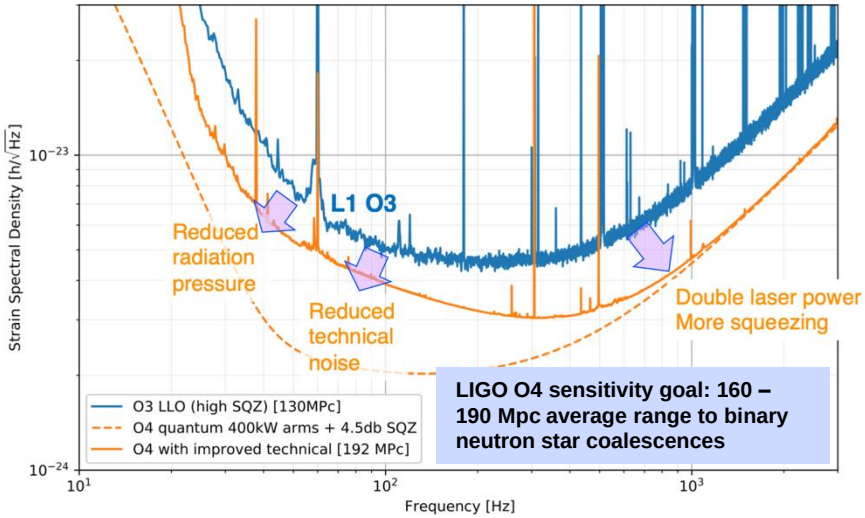


LIGO: the US NSF-supported GW Observatory

LIGO is preparing for Observation run 4 (O4). See https://www.ligo.caltech.edu

Status

- LIGO is currently completing the O4 Observing Run upgrade program (including Phase 1 of the NSF/STFC/ARC-funded Advanced LIGO Plus (A+) upgrade project)
- Still to be done: i) 300 m long filter cavity for improved 'frequency-dependent' squeezing, ii) end test mass replacement on the LIGO Livingston detector
- Major facility construction complete at LIGO Hanford, will complete at LIGO Livingston in June 2022
- New vacuum beamtube enclosure and end station to house filter cavity vacuum tube and end mirror
- Delays (primarily but not exclusively in facility construction) have pushed O4 start date for LIGO out from June 2022 to December 15, 2022. Now postponed to March 2023
- LIGO-Virgo-KAGRA run as a unified network; examining options for staggered O4 start
- Expect a 2x to 3x increase in compact binary merger rates from O4 improved sensitivity

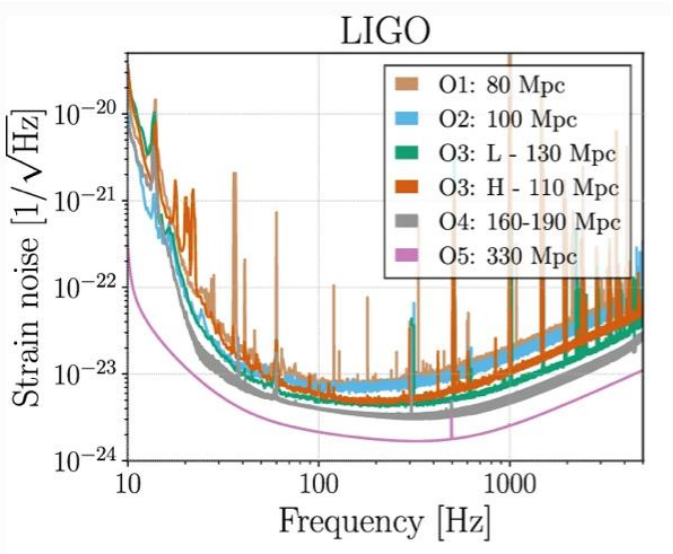


LIGO observatory status (II)

LIGO O5 sensitivity goal: 240 - 330 Mpc. See https://www.ligo.caltech.edu

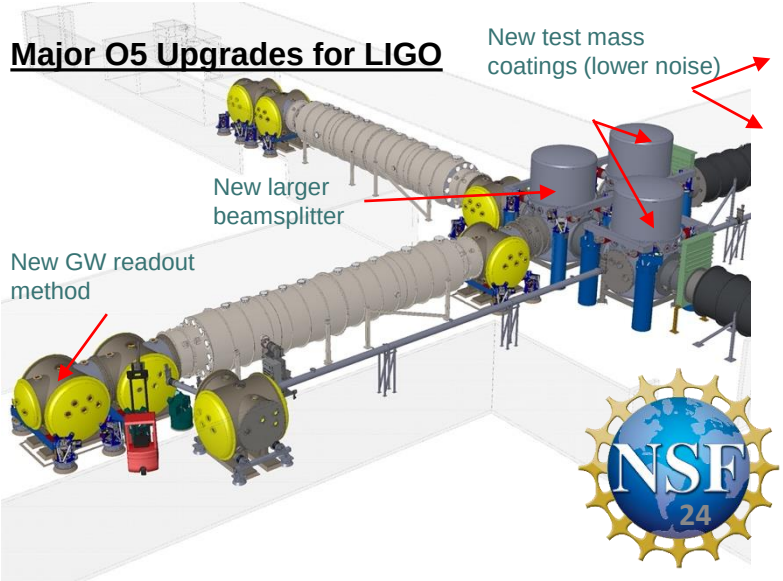
A+ Phase 2 upgrade

- Will be implemented for the O5 Observing Run upon completion of O4
- Major improvement: new test mass mirrors with lower thermal noise coatings
- Progressively increasing over the course of O5



LIGO Laboratory Education and Public Outreach

- New LIGO Exploration Center has been constructed at the LIGO Hanford Observatory
- Complements existing LIGO Livingston Science Education Center
- Will be open for field trips, public visits in June 2022.



LIGO-India status

Final project sanction is awaited. See https://www.ligo-india.in/

Host institutions

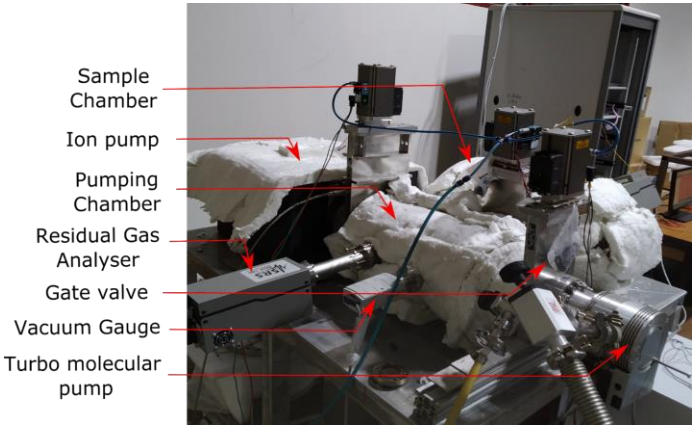
RRCAT (Raja Ramanna Centre for Advanced Technology), Indore;
IUCAA (Inter-University Centre for Astronomy and Astrophysics), Pune;
IPR (Institute for Plasma Research), Gandhinagar;
DCSEM (Directorate of Construction, Services and Estate Management), Mumbai

Above: Site-office construction completed.
Below: Outgassing measurements (IPR)

Currently 101 scientists from 15 Indian institutions are contributing to GW science via the **LIGO-India Scientific Collaboration**

Site location

Aundha, Hingoli District, Maharashtra (India)



Status

2019: Site land acquisition completed
2020: Geo-technical, topological, seismic, hydrological surveys completed
2022: Site-office construction completed; vacuum chambers and beam-tube prototype being assembled in RRCAT facility
Commissioning training modules assembled in IUCAA

LIGO-India off-site training and testing facility (RRCAT)

Vacuum chambers delivered to RRCAT facility

LIGO Scientific Collaboration

LSC is a global collaboration with about 1,500 members (714 FTE), about 1,000 authors from about 100 groups in about 20 countries. See https://www.ligo.org/

LSC

- New groups enquire about membership and join
- Seeing more postdocs moving to institutions that do not have LSC groups
  - Have mechanism for membership through an existing LSC group by request of the PI of the group they will affiliate with. Is it enough?

Increasing external visibility of LSC members

- Information about roles and responsibilities is being centralized
- Speakers Board
- Prizes

LSC LIGO Scientific Collaboration

Virgo Collaboration

Virgo is a European collaboration with 782 members, 537 authors from 133 institutions in 15 different countries. Virgo has more that doubled its size in the last few years. See https://www.virgo-gw.eu/

European Gravitational Observatory EGO

- EGO Council: CNRS, INFN and Nikhef
- EGO hosts the Virgo detector

Virgo Steering Committee

- 34 groups with 32 full members and 2 first-year members
- Representation from 9 countries

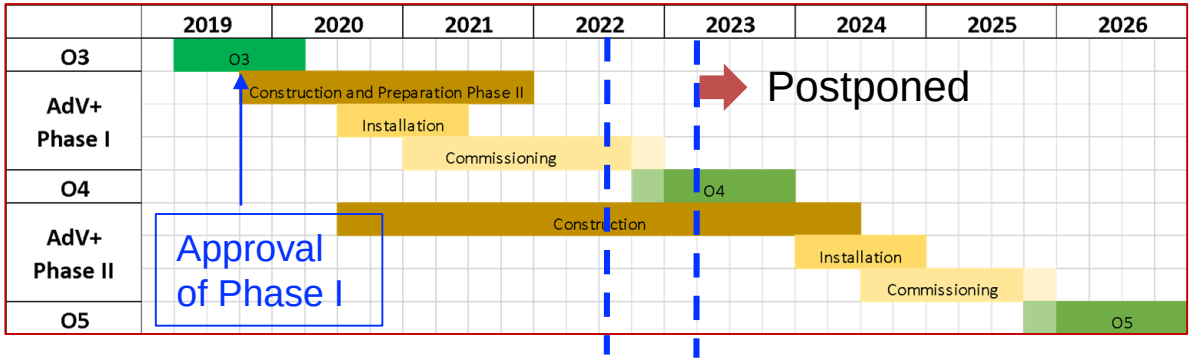
Advanced Virgo Plus AdV+ is a two-phase project

Phase I (before O4 run/2022-23)

- Upgrade to reduce quantum noise: no mirrors change
- Reduction of technical noises
- Preparation of Phase II

Phase II (before O5 run/2025-26)

- Upgrade to reduce thermal noise: mirrors change



Virgo Collaboration

Post-O5 Virgo foresees a set of challenging upgrades with a significant improvement in sensitivity identified: BNS range ~2x with respected to O5 low

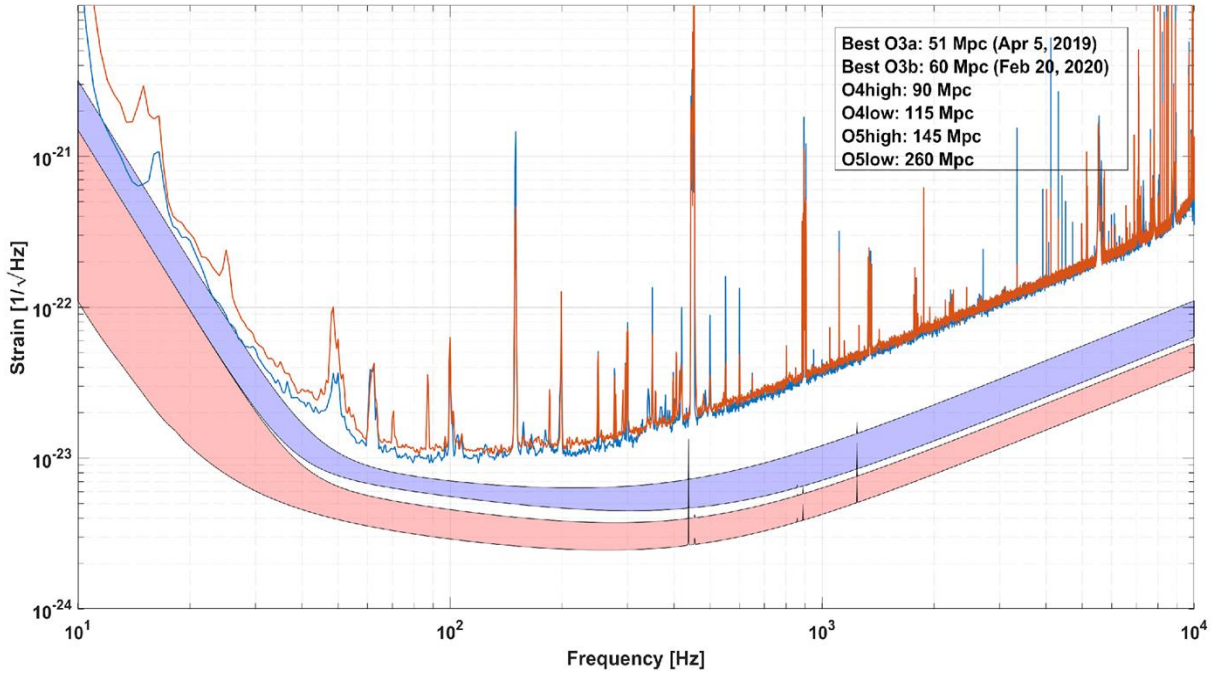
AdV+ and projections for O4 and O5

- O4: project sensitivity between 90 and 115 Mpc
- O5: project sensitivity between 145 and 260 Mpc

Post-O5

- >O5: project sensitivity in excess of 290 Mpc
- Risk reduction for 3G technologies

Concept study to be released to funding agencies



KAGRA

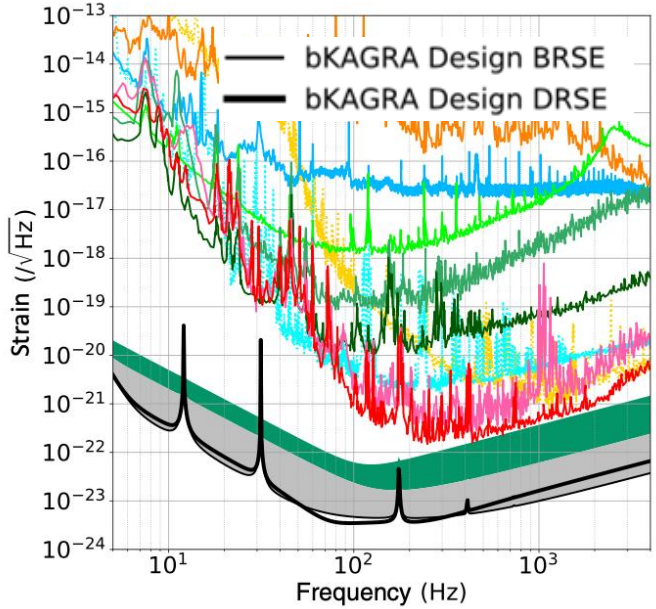
Large-scale Cryogenic Gravitational wave Telescope underground in Kamioka, Hida-city, Gifu, Japan.
KAGRA joined LV O3b run in March 2020. See http://gwcenter.icrr.u-tokyo.ac.jp/en/

Host institutions

- ICRR (Institute for Cosmic Ray Research, U. Tokyo)
- NAOJ (National Astronomical Observatory of Japan)
- KEK (High Energy Accelerator Research Organization)

International collaboration (as of August 2021)

- 505 members in 14 countries and regions
- 200 authorship holders, 112 research groups
- KAGRA joined LIGO-Virgo MOA in October 2019



Preparation for O4

- Install anti-frosting heater to remove frost on the mirrors
- Install baffles for stray light mitigation
- Improve suspension system with more sensors and better control systems
- Separate vacuum areas for easy access to the output optics system to suppress shot noises

Plan for O4 (start in March 2023)

- Join O4a for about a month with PRFPMI @ room temperature with BNS range 1-3 Mpc
- After an extended break, join O4b with cryogenic PRFPMI with about 10 Mpc sensitivity

LIGO Virgo KAGRA - LVK Collaboration

LIGO, Virgo and KAGRA formally collaborate through an MOA since October 2019

Run planning framework

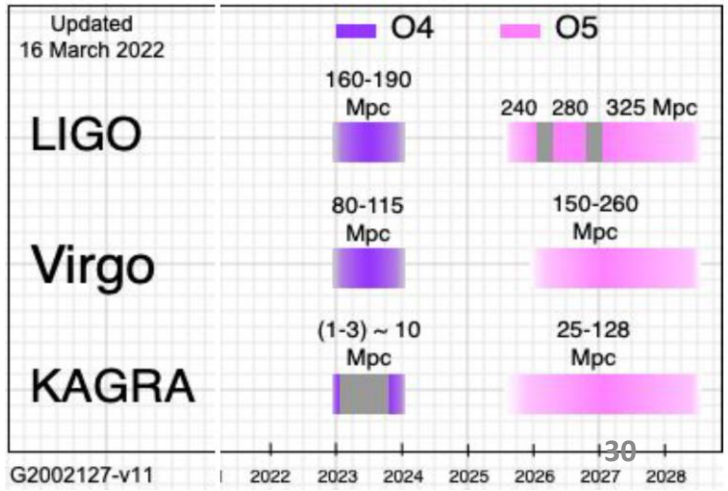
- Joint run planning committee: digests information from LVK on quarterly basis and documents plans for public release
- LVK leadership (spokespeople and Lab directors) exchange information on instrument status weekly to align upgrade work to allow observation runs as a network
- Virtual town hall meetings in the summer to present technical information about alert distribution, etc.
- Restart OpenLV(K)EM meetings in preparation for O4

International Gravitational-Wave observatory Network (IGWN)

- Defines the organizational structure of IGWN, identifies its functions, and establishes criteria for membership
- LIGO, VIRGO and KAGRA jointly establish IGWN
- IGWN would supersede the LVK Memorandum of Agreement

Looking forward to O4, O5 and beyond

- O4 expected to start March 2023



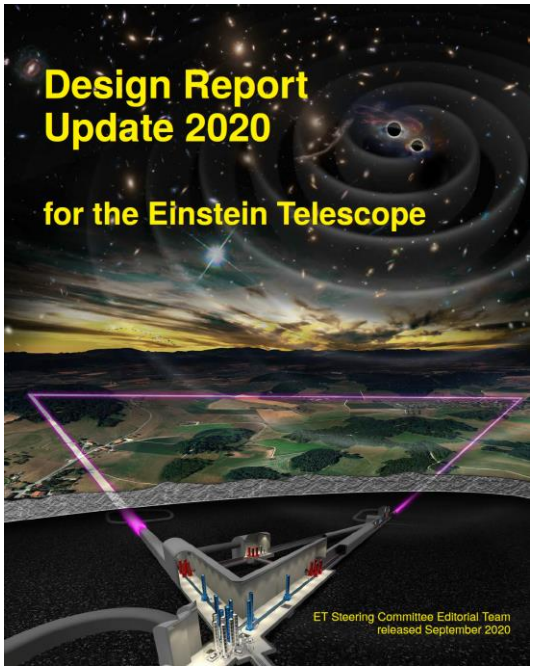
Mental Health Survey

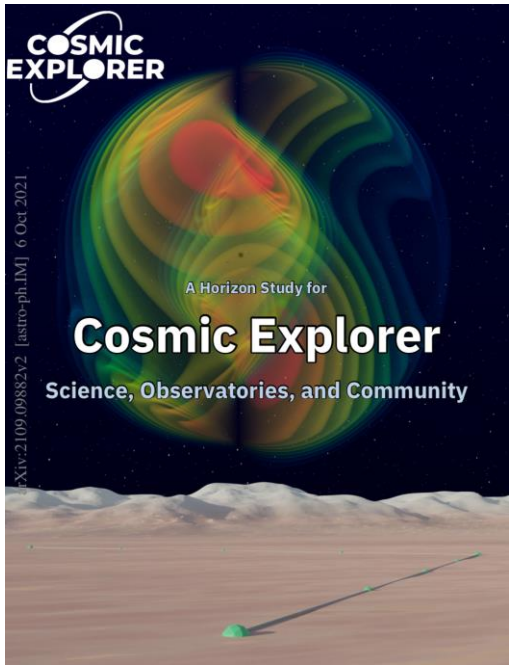
- See differences between the Collaborations
- Room for improvement

Overview

Topics for today

1. Introduction: GWIC member projects and collaborations
2. Scientific highlights
3. Overview of GW activities
4. **Next Generation Gravitational-Wave Observatories: Einstein Telescope and Cosmic Explorer**
5. Summary



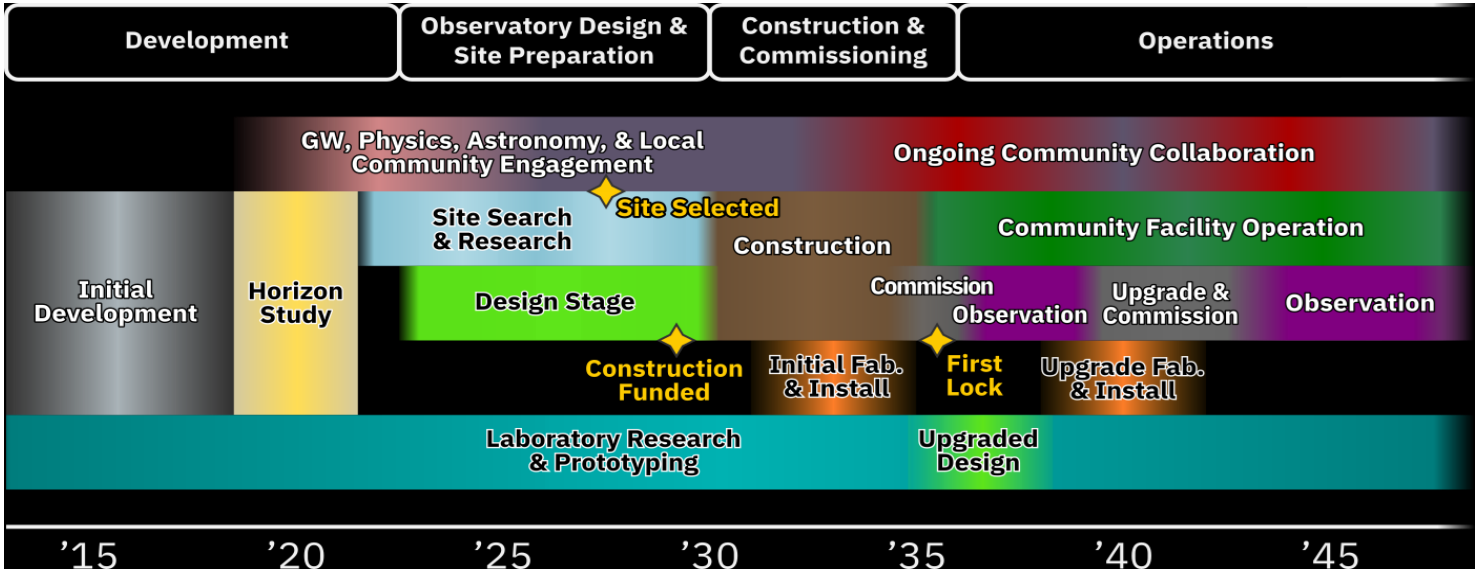


Cosmic Explorer

CE is the planned U.S. contribution to the global third-generation ground-based gravitational-wave detector network. See https://cosmicexplorer.org/

Quick reminder

- US concept for next-generation GW detectors
- Two ‘L’ sites, one 40 km, one 20 km, on the Earth’s surface
- Using incrementally-improved LIGO detector designs for the first detectors
- Plan to match Einstein Telescope’s planned schedule with joint observing in the 2030’s

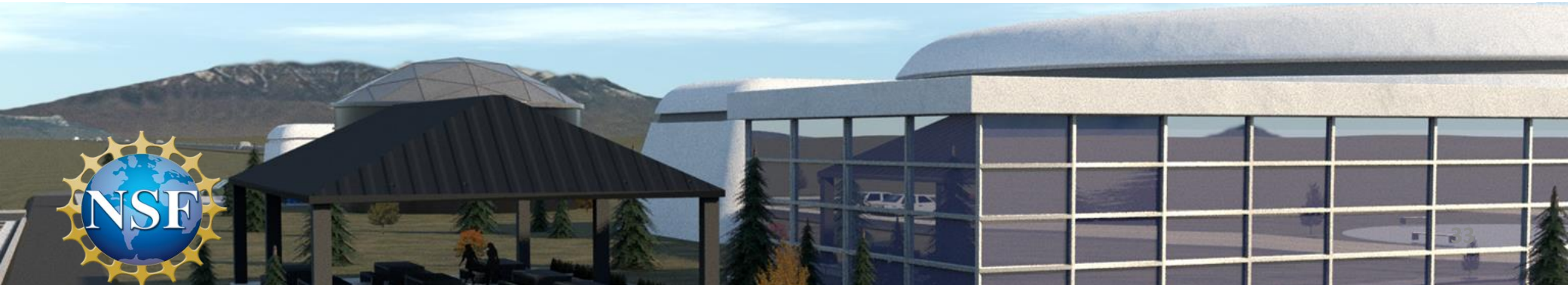


Cosmic Explorer: key steps forward in the last year

Significant progress in organization of the Cosmic Explorer Project and in community building

Key steps forward

- The Cosmic Explorer Horizon Study https://cosmicexplorer.org/ submitted to NSF
- The Dawn VI community meeting focused on CE, the Horizon study, and connections to the broader MMA community
  - Consensus that Cosmic Explorer is a valid path forward
  - Dawn VI Report: https://gwic-documents.s3.us-west-2.amazonaws.com/dawn/Dawn-VI-report.pdf
- Astro Decadal report strongly supportive of GWs, MMA, and CE
  - Astro Decadal Report: https://www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020
- White papers on science and detectors from the community as input
- Formation of a Project organization with both Project and Technical meetings
- First draft of a proposal for the Conceptual Design; first meeting of the CE Project Advisory Committee and review of the draft proposal



Cosmic Explorer: current focus

Funding is needed to maintain momentum

Current focus

- Growing the institutional depth, geographical distribution for the core team
  - About 12 universities in the US, plus Canada, Germany, UK, Australia
- Working to engage the community widely for a range of technical activities
  - Detector design; strong overlap with LIGO ‘Post-O5’ design effort
  - In discussions with ETpathfinder, AEI, Australian labs for shared activities
- Finding a path to successful identification of sites
  - See establishing relationships with Indigenous peoples central to success of the Project
- Continued development of the Project organization
  - Guided by the very detailed NSF Research Infrastructure Guide and the Program Advisory Committee
  - For NSF RIG: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf21107&org=CMMI
- Refinement of the Conceptual Design Proposal
  - Second review by PAC in September; submission to NSF planned for Fall 2022

Einstein Telescope

Einstein Telescope appeared on the ESFRI Roadmap June 30, 2021. See http://www.et-gw.eu/

ESFRI proposal

- Submitted by: Italy, Belgium, Netherlands, Poland and Spain

Project and collaboration also include agencies and institutions belonging to

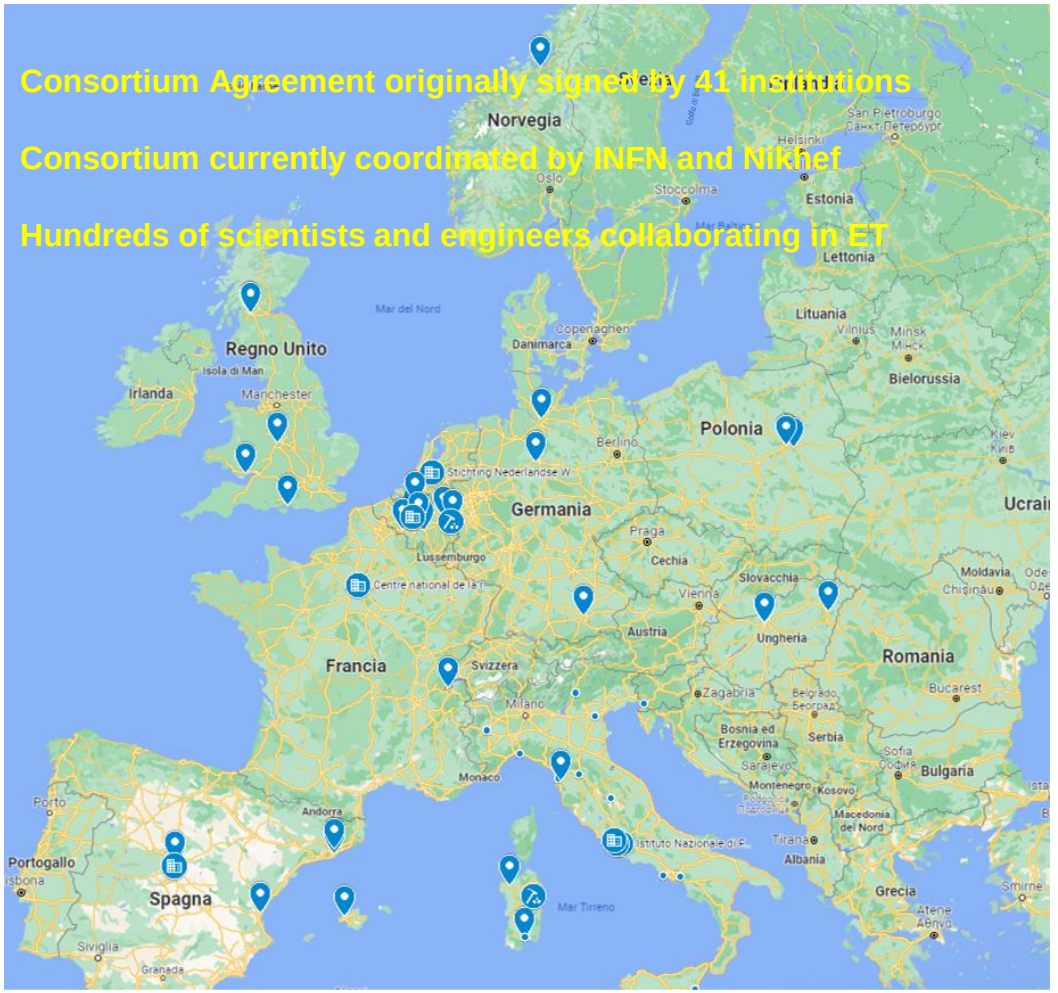
- Austria, France, Germany, Hungary, Switzerland and UK

Funds

- Preparatory funds available in some countries (IT, NL, …)
- EU INFRA-DEV proposal approved with a grant of 3.45 M€
- EU INFRA-TECH proposal just submitted

Site candidates

- Studies ongoing in Sardinia in Italy, B-G-NL border region, and Saxony in Germany



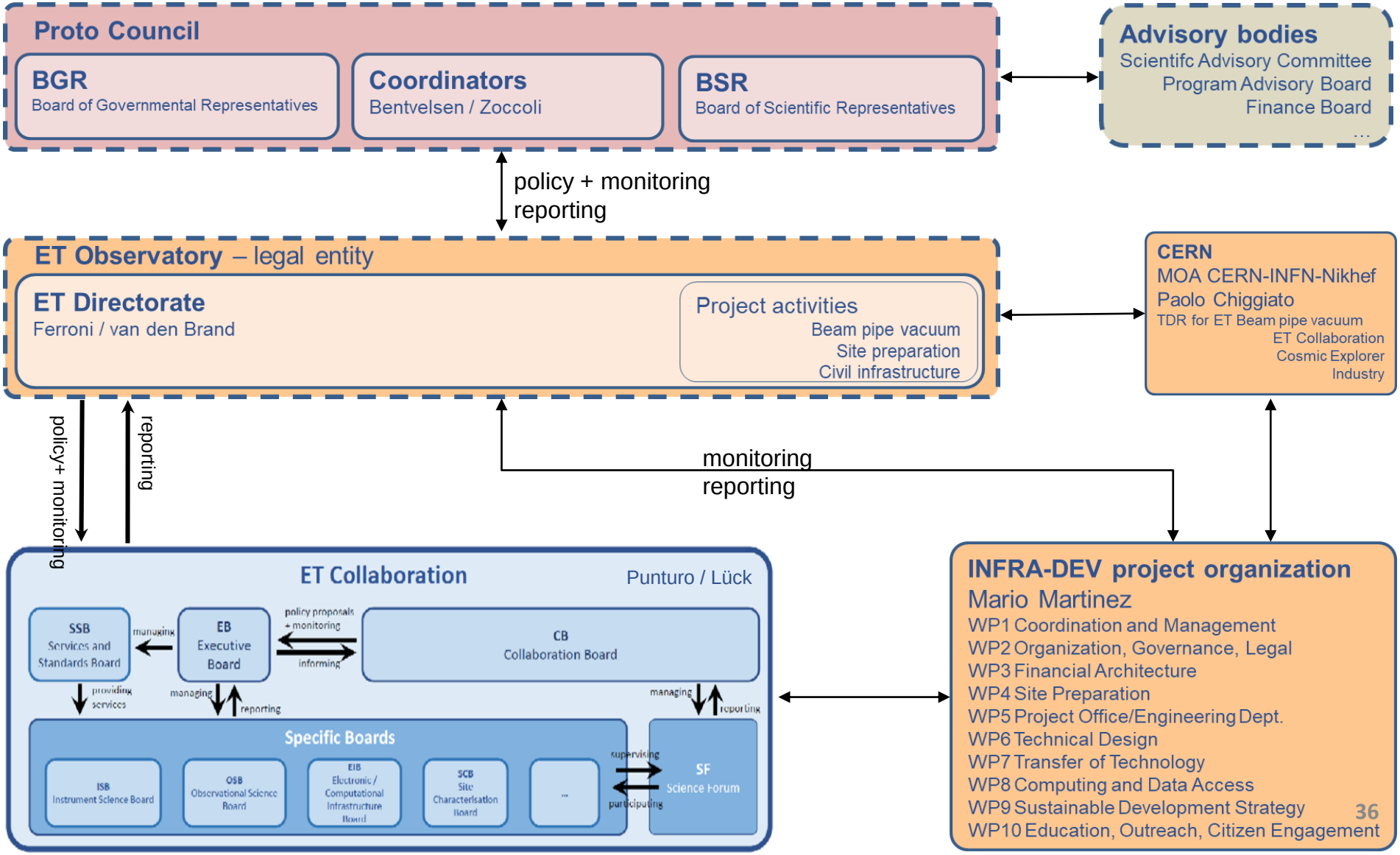
ESFRI ROADMAP 2021

European Strategy Forum on Research Infrastructures

ET EINSTEIN TELESCOPE

Governance in evolution

Entities enclosed in solid boxes have been instantiated. Dashed boxes represent work in progress
Large part of activities is now covered by ET Collaboration. Focus on build-up of ET Observatory



ETIC – Einstein Telescope Infrastructure Consortium

Next Generation EU investment proposed of 100 M€ focused on ET enabling technology and Sardinian site candidature support

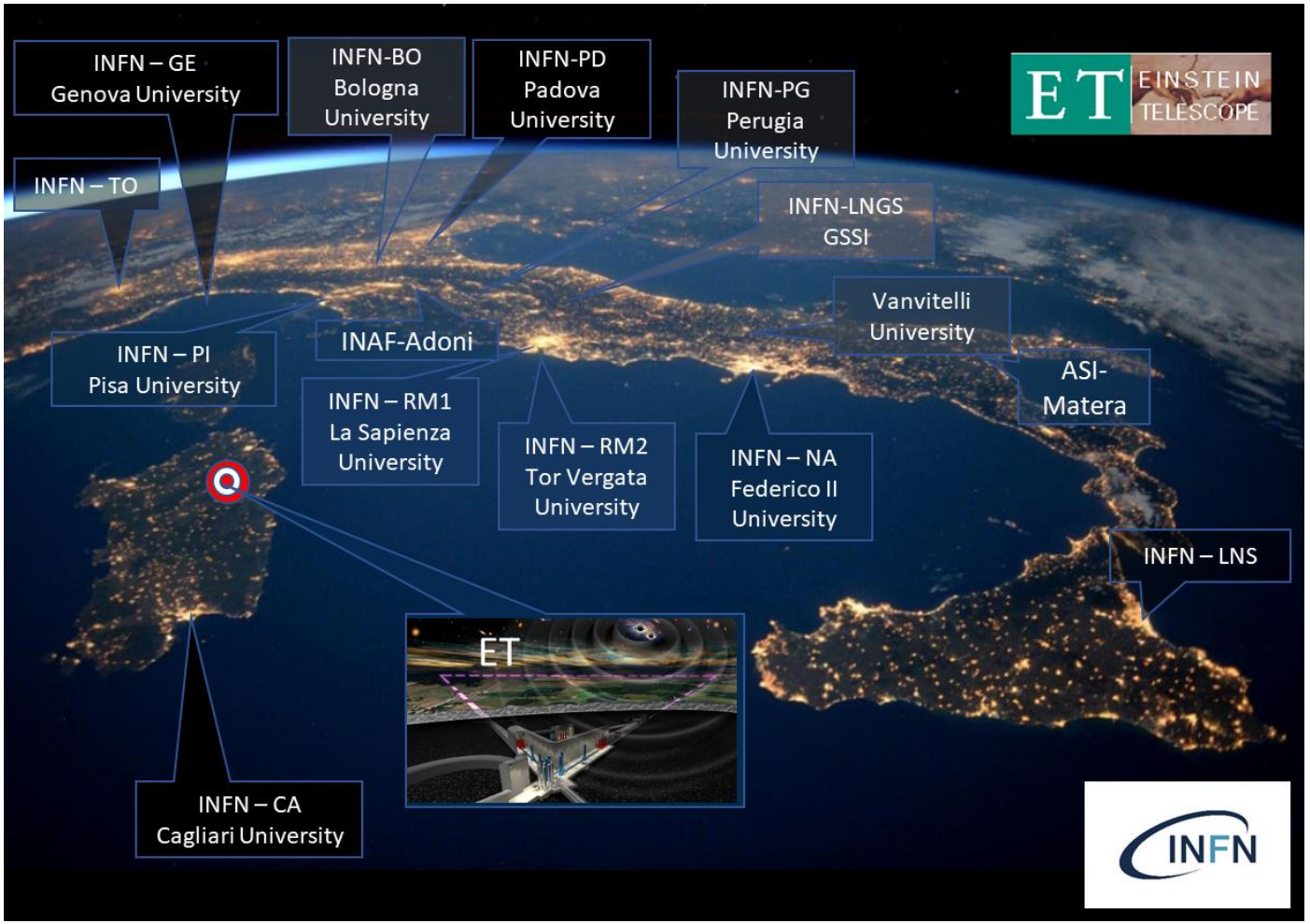
Support for

- 8% Human resources
- 30% Scientific apparatuses
- 12% Distributed infrastructures
- 28% ET design
- 12% Training

Additional 5 M€ funding on the same framework for the site characterization

Feedback expected soon

Discussion ongoing on an Italian share toward ET realization

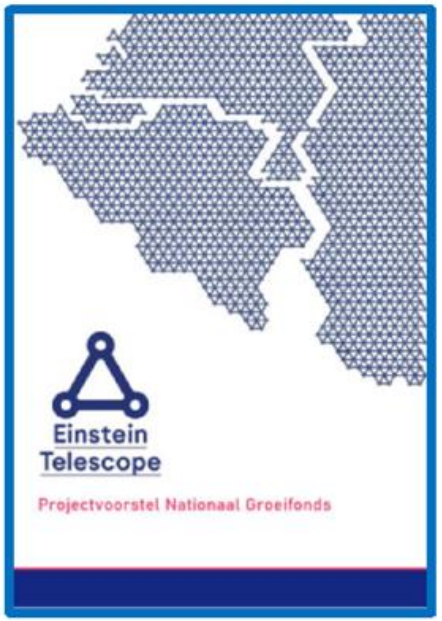


Einstein Telescope in Euregio Meuse-Rhine (EMR)

Einstein Telescope approved by Dutch National Growth Fund on April 14, 2022. Development funds of M€ 42 available to prepare bid book, while M€ 870 will be available in case EMR region hosts ET

Connected institutions in:
Belgium,
Germany &
the Netherlands

Nationaal Groeifonds (the Netherlands)



Emphasis on potential socio-economic Impact

Submitted by OCW Ministry
(EZK Ministry support)

Supported by ~70 Dutch Industries/institutions

In October 2021 the Netherlands submitted large funding proposal within context of the *'Nationaal Groeifonds'*. Decision in April 2022.

Includes 42 M€ for geology, R&D & organization
as well as possible Dutch share towards ET realization

Formal birth of the Einstein Telescope Collaboration

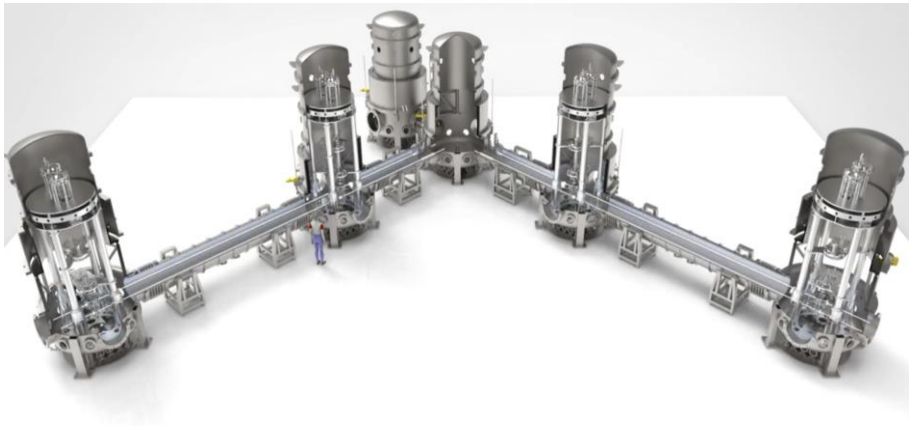
XII Einstein Telescope Symposium, Budapest June 7-8, 2022

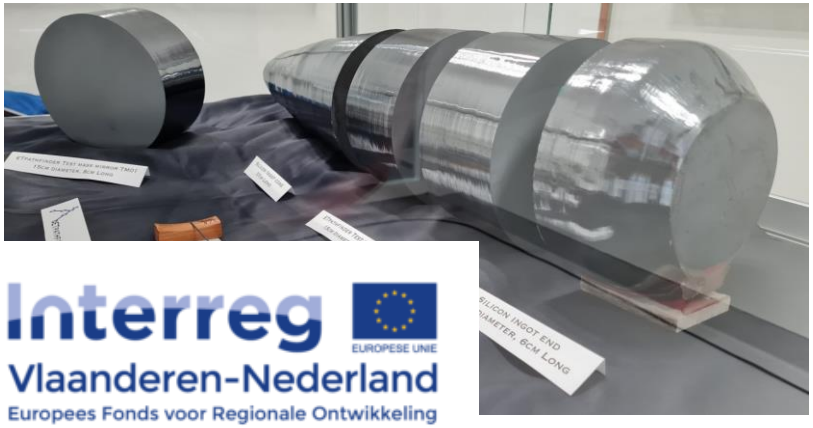
See https://indico.ego-gw.it/event/411/

ETpathfinder

ETpathfinder is a new R&D infrastructure for testing innovative concepts and technologies for future gravitational wave observatories. Open for everyone interested to join. See https://www.etpathfinder.eu

- New facility for testing ET technology in a low-noise, full-interferometer setup
- Key aspects: silicon mirrors (3 to 100+ kg), cryogenics (cryogenic liquids and sorption coolers, water/ice management), “new” wavelengths (1,550 and 2,090nm), new coatings
- Start with 2 FPMI: at 120 K and at 15 K (2022+)
- 20 partners from NL/B/G/FR/SP/UK
- Initial capital funding of 14.5 M€
- Detailed Design Report available at https://apps.et-gw.eu/tds/?content=3&r=17177





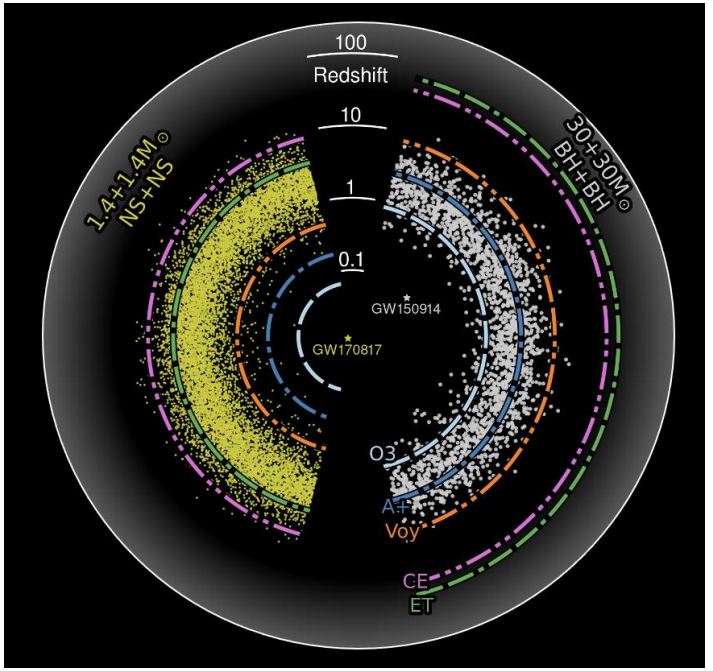
Interreg
EUROPESE UNIE
Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling

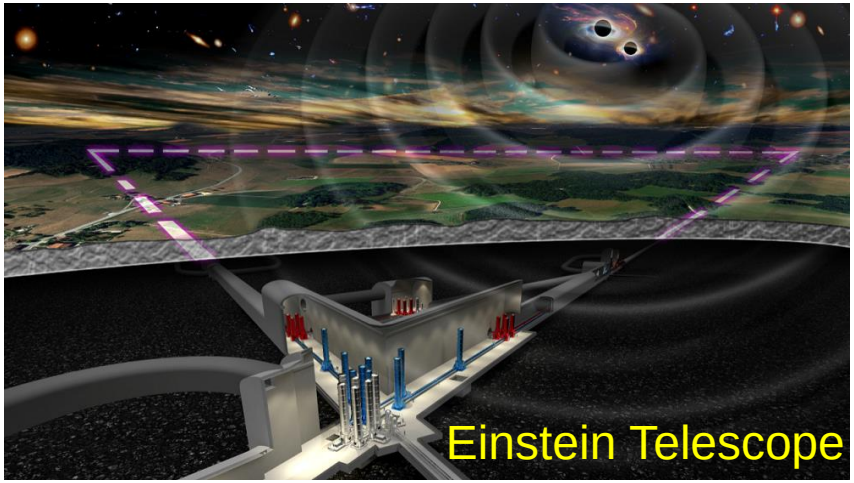
Building a Global Next-Generation Observatory Network

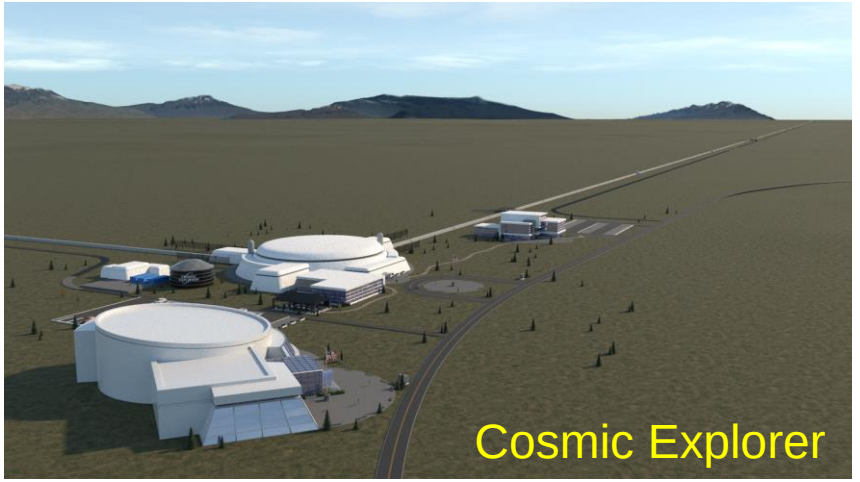
Realization of 3G observatories will profit from collaboration and a coordinated effort

Points of attention

- The most science and best use of infrastructures will come from a fully coordinated effort
- There are initial differences in project maturity, funding status
- Wish to take advantage of a coherent effort world-wide
  - Shared observational science basis
  - Shared R&D for detector and infrastructure
  - …networked observing







Summary

Issues of importance to APPEC GA

LIGO-Virgo-KAGRA

- IGWN as an initiative to bring more structure to the LVK Consortium: joint running, computing, …
- OpenLV(K)EM meetings to align with the astronomy community in preparation for O4
- Impact and opportunities: 2G versus 3G

Close interaction between various stakeholders is needed

- Facilitating international collaboration and exchange visits of scientists involved in ET, LVK and CE
  - Enormous potential to increase productivity, grow careers, and reduce the ‘reinvention of the wheel’
- Give advice on how to communicate at all relevant levels of the relevant government (White Papers, one-pagers, information cards, presentations…)
- Einstein Telescope: regular communication via Board of Governmental Representatives (BGR)

Gravitational-wave research is growing rapidly

- Upgrades of 2G facilities and preparation for 3G observatories
- Fast increase in event rate expected

Resources and priority should also grow to allow our community to handle these challenges effectively and to serve a broad community

Reference material

What is GWIC (Gravitational Wave International Committee)?

Organization formed in 1997 to facilitate international collaboration and cooperation in the construction, operation and use of the major gravitational wave detection facilities worldwide

GWIC

Affiliated with the International Union of Pure and Applied Physics (Working Group WG.11). Through this, GWIC is connected with the International Society on General Relativity and Gravitation (IUPAP's Affiliated Commission AC.2), its Commission C19 (Astrophysics), and another Working Group, the AstroParticle Physics International Committee (APPIC)

Current Chair: Jo van den Brand
Executive Secretary: David Shoemaker

The membership of GWIC represents all of the world's active gravitational wave projects*, as well as other relevant communities, covering gravitational wave frequencies from nanohertz to kilohertz

- **Pulsar timing arrays, covering low-frequency nanohertz GW sources**
- **Space based detectors, covering the micro – mHz band**
- **Ground-based detectors, covering the Hz – kHz band**

*no Cosmic Microwave Background Community membership

Complementary approaches **essential to maximizing the scientific potential of the field**

Full membership and more information at: https://gwic.ligo.org/

GWIC Goals and Missions

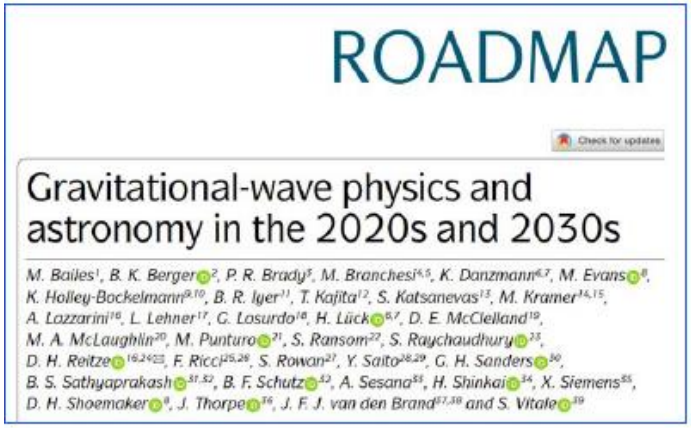
Organization formed in 1997 to facilitate international collaboration and cooperation in the construction, operation and use of the major gravitational wave detection facilities worldwide

- Promote international cooperation in all phases of construction and scientific exploitation of gravitational-wave detectors → **GWIC 3G Subcommittee**
- Coordinate and support long-range planning for new instrument proposals, or proposals for instrument upgrades → **GWIC 3G Subcommittee**
- Promote the development of gravitational-wave detection as an astronomical tool, exploiting especially the potential for multi-messenger astrophysics → Updated GWIC Roadmap
- Organize regular, world-inclusive meetings and workshops for the study of problems related to the development and exploitation of new or enhanced gravitational-wave detectors, and foster research and development of new technology → **Amaldi Meeting**
- Represent the gravitational-wave detection community internationally, acting as its advocate → **GWAC**
- Provide a forum for project leaders to regularly meet, discuss, and jointly plan the operations and direction of their detectors and experimental gravitational-wave physics generally → **Annual GWIC Meeting**

More at https://gwic.ligo.org/

GWIC Goals and Missions

GWIC Roadmap "Gravitational-wave physics and astronomy in the 2020s and 2030s" was published in Nature Reviews Physics 3, 344-366 (2021)


ROADMAP

Gravitational-wave physics and astronomy in the 2020s and 2030s

M. Bailes[1], B. K. Berger[2], P. R. Brady[3], M. Branchesi[4,5], K. Danzmann[6,7], M. Evans[8], K. Holley-Bockelmann[9,10], B. R. Iyer[11], T. Kajita[12], S. Katsanevas[13], M. Kramer[14,15], A. Lazzarini[16], L. Lehner[17], G. Losurdo[18], H. Lück[6,7], D. E. McClelland[19], M. A. McLaughlin[20], M. Punturo[21], S. Ransom[22], S. Raychaudhury[23], D. H. Reitze[16,24,25], F. Ricci[25,26], S. Rowan[27], Y. Saito[28,29], G. H. Sanders[30], B. S. Sathyaprakash[31,32], B. F. Schutz[33], A. Sesana[34], H. Shinkai[35], X. Siemens[36], D. H. Shoemaker[8], J. Thorpe[16], J. F. J. van den Brand[37,38] and S. Vitale[39]

GWIC Ground-based Third Generation Subcommittee Reports https://gwic.ligo.org/3Gsubcomm/