Time constraints and opportunities in Europe

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Dawn V, Cascina, May 26, 2019

LSC LIGO Scientific Collaboration

Advanced Virgo

Virgo Collaboration

Virgo is a European collaboration with about 400 members from about 80 institutes

Advanced Virgo (AdV) and AdV+: upgrades of the Virgo interferometric detector

Participation by scientists from France, Italy, Belgium, The Netherlands, Poland, Hungary, Spain, Germany

- Institutes in Virgo Steering Committee
  - APC Paris
  - ARTEMIS Nice
  - IFAE Barcelona
  - INFN Firenze-Urbino
  - INFN Genova
  - INFN Napoli
  - INFN Perugia
  - INFN Pisa
  - INFN Roma La Sapienza
  - INFN Roma Tor Vergata
  - INFN Trento-Padova
  - LAL Orsay – ESPCI Paris
  - LAPP Annecy
  - LKB Paris
  - LMA Lyon
  - Nikhef Amsterdam
  - POLGRAW(Poland)
  - RADBOUD Uni. Nijmegen
  - RMKI Budapest
  - UCLouvain, ULiege
  - Univ. of Barcelona
  - University of Sannio
  - Univ. of Valencia
  - University of Jena

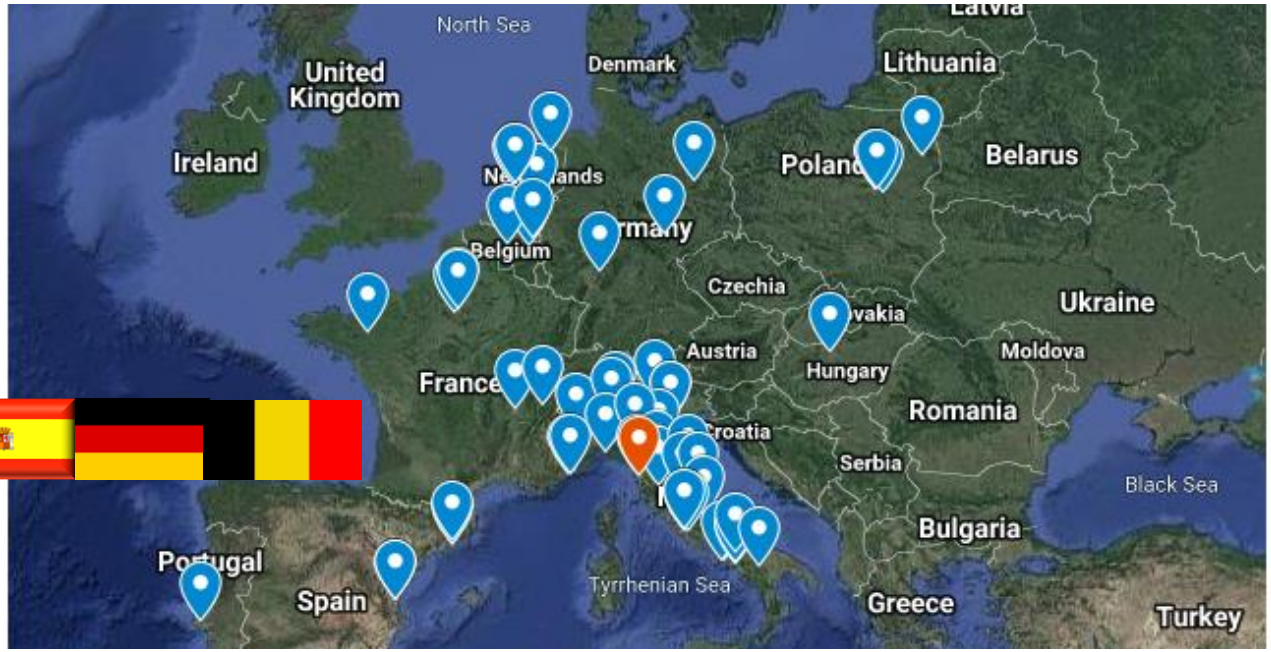
Advanced Virgo project has been formally completed on July 31, 2017

Part of the international network of 2nd generation detectors

Joined the O2 run on August 1, 2017

LIGO and Virgo running of O3

8 European countries



2018: IFAE and UBarcelona, ULiège and UCLouvain

New groups strengthen Virgo in areas as Computing and Stray Light Mitigation

2019: USannio/UniSA and Jena Univ.

Groups from UTorino, USardinia, UMaastricht joined Virgo indirectly

UMaastricht, ULBrussels, UAntwerp, UGhent, UUtrecht, KULeuven, KIT, … in discussion

Scientific impact of gravitational wave science

A broad community is relying of detection of gravitational waves. HEP interest shown in red

Fundamental physics

Access to dynamic strong field regime, new tests of General Relativity
Black hole science: inspiral, merger, ringdown, quasi-normal modes, echo's
Lorentz-invariance, equivalence principle, polarization, parity violation, axions

Astrophysics

First observation for binary neutron star merger, relation to sGRB
Evidence for a kilonova, explanation for creation of elements heavier than iron

Astronomy

Start of gravitational wave astronomy, population studies, formation of progenitors, remnant studies

Cosmology

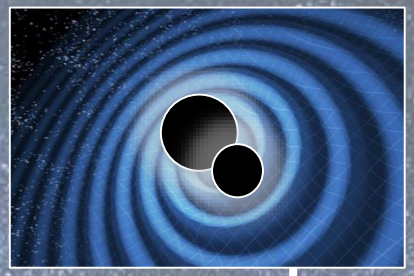
Binary neutron stars and black holes can be used as standard “sirens”
Dark Matter and Dark Energy, primordial black holes

Nuclear physics

Tidal interactions between neutron stars get imprinted on gravitational waves
Access to equation of state

GW is firmly on the “radar” of the HEP community and CERN HEP Strategy discussion

January 4, 2017

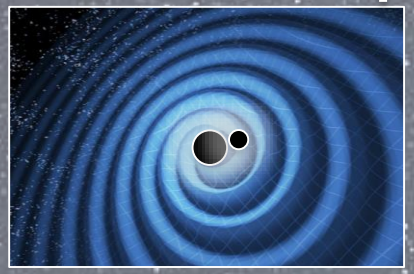


August 1, 2017

Advanced LIGO's Second Observing Run

Virgo turns on

Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	May 2017	Jun 2017	Jul 2017	Aug 2017



June 6, 2017

Table of O1 and O2 triggers with source properties

See https://dcc.ligo.org/LIGO-G1801864

Virgo data contributed to Parameter Estimation of 5 events

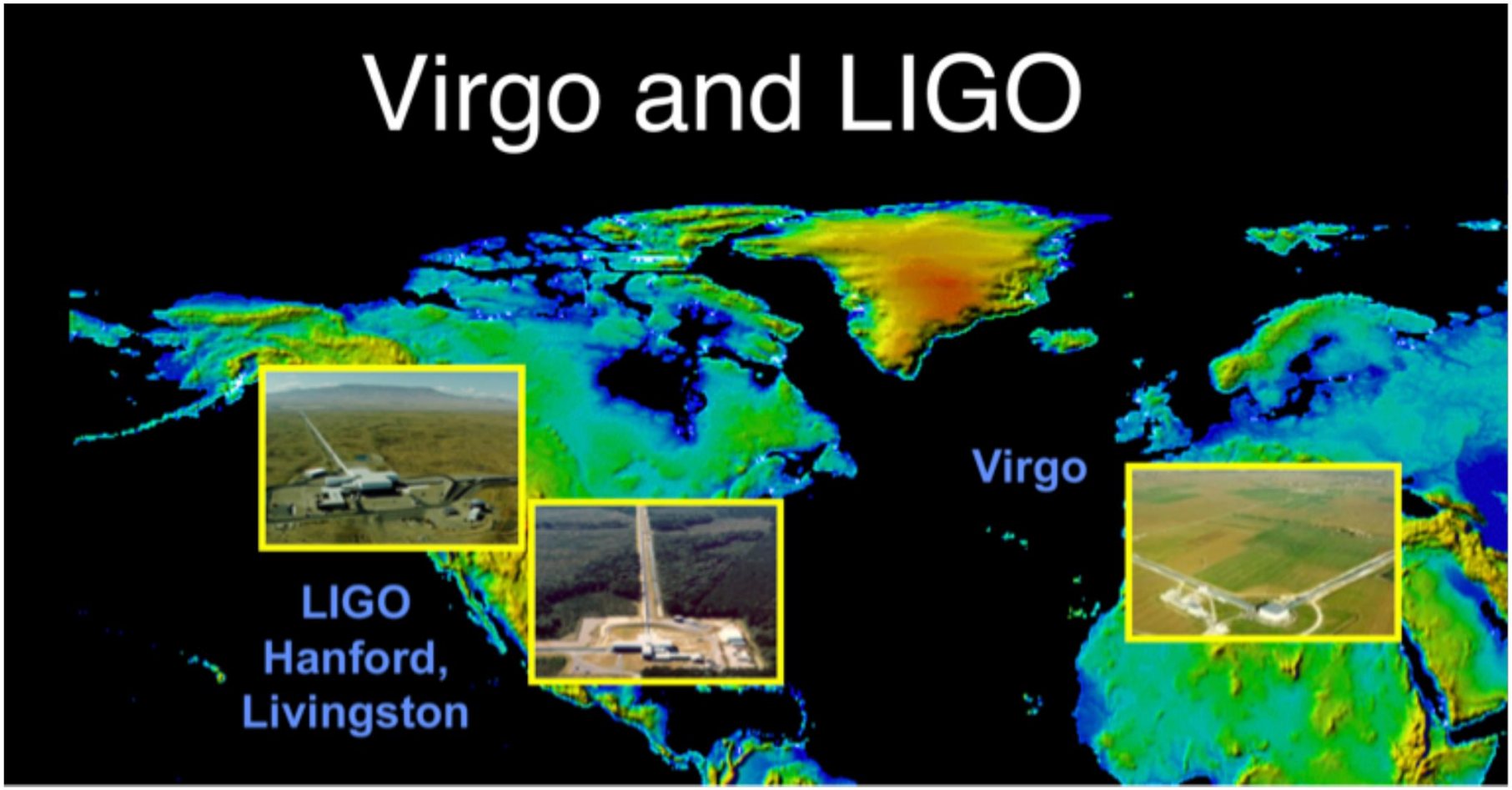
Event	$m_1/M_\odot$	$m_2/M_\odot$	$\mathcal{M}/M_\odot$	$\chi_{\rm eff}$	$M_{\rm f}/M_\odot$	$a_{\rm f}$	$E_{\rm rad}/(M_\odot c^2)$	$\ell_{\rm peak}/({\rm erg\ s^{-1}})$	$D_{\rm L}/{\rm Mpc}$	z	$\Delta\Omega/{\rm deg}^2$
GW150914	$35.6^{+4.8}_{-3.0}$	$30.6^{+3.0}_{-4.4}$	$28.6^{+1.6}_{-1.5}$	$-0.01^{+0.12}_{-0.13}$	$63.1^{+3.3}_{-3.0}$	$0.69^{+0.05}_{-0.04}$	$3.1^{+0.4}_{-0.4}$	$3.6^{+0.4}_{-0.4}\times10^{56}$	430^{+150}_{-170}	$0.09^{+0.03}_{-0.03}$	194
GW151012	$23.2^{+14.0}_{-5.4}$	$13.6^{+4.1}_{-4.8}$	$15.2^{+2.0}_{-1.2}$	$0.04^{+0.28}_{-0.19}$	$35.7^{+9.9}_{-3.7}$	$0.67^{+0.13}_{-0.11}$	$1.5^{+0.5}_{-0.5}$	$3.2^{+0.8}_{-1.7}\times10^{56}$	1060^{+540}_{-480}	$0.21^{+0.09}_{-0.09}$	1491
GW151226	$13.7^{+8.8}_{-3.2}$	$7.7^{+2.2}_{-2.6}$	$8.9^{+0.3}_{-0.3}$	$0.18^{+0.20}_{-0.12}$	$20.5^{+6.4}_{-1.5}$	$0.74^{+0.07}_{-0.05}$	$1.0^{+0.1}_{-0.2}$	$3.4^{+0.7}_{-1.7}\times10^{56}$	440^{+180}_{-190}	$0.09^{+0.04}_{-0.04}$	1075
GW170104	$31.0^{+7.2}_{-5.6}$	$20.1^{+4.9}_{-4.5}$	$21.5^{+2.1}_{-1.7}$	$-0.04^{+0.17}_{-0.20}$	$49.4^{+5.2}_{-3.9}$	$0.66^{+0.09}_{-0.11}$	$2.2^{+0.5}_{-0.5}$	$3.2^{+0.7}_{-1.0}\times10^{56}$	960^{+430}_{-410}	$0.19^{+0.07}_{-0.08}$	912
GW170608	$11.2^{+5.4}_{-1.9}$	$7.5^{+1.5}_{-2.1}$	$7.9^{+0.2}_{-0.2}$	$0.04^{+0.19}_{-0.06}$	$17.9^{+3.4}_{-0.7}$	$0.69^{+0.04}_{-0.04}$	$0.8^{+0.1}_{-0.1}$	$3.4^{+0.5}_{-1.3}\times10^{56}$	320^{+120}_{-110}	$0.07^{+0.02}_{-0.02}$	524
GW170729	$50.7^{+16.3}_{-10.2}$	$34.4^{+8.9}_{-10.2}$	$35.8^{+6.3}_{-4.9}$	$0.37^{+0.21}_{-0.26}$	$80.3^{+14.5}_{-10.3}$	$0.81^{+0.07}_{-0.13}$	$4.9^{+1.6}_{-1.7}$	$4.2^{+0.8}_{-1.5}\times10^{56}$	2760^{+1290}_{-1350}	$0.48^{+0.18}_{-0.21}$	1069
GW170809	$35.2^{+8.3}_{-5.9}$	$23.8^{+5.2}_{-5.1}$	$25.0^{+2.1}_{-1.6}$	$0.07^{+0.17}_{-0.16}$	$56.4^{+5.2}_{-3.7}$	$0.70^{+0.08}_{-0.09}$	$2.7^{+0.6}_{-0.6}$	$3.5^{+0.6}_{-0.9}\times10^{56}$	990^{+320}_{-380}	$0.20^{+0.05}_{-0.07}$	310
GW170814	$30.7^{+5.5}_{-2.9}$	$25.6^{+2.8}_{-4.0}$	$24.3^{+1.4}_{-1.1}$	$0.07^{+0.12}_{-0.11}$	$53.6^{+3.2}_{-2.5}$	$0.73^{+0.07}_{-0.05}$	$2.8^{+0.4}_{-0.3}$	$3.7^{+0.5}_{-0.5}\times10^{56}$	560^{+140}_{-210}	$0.12^{+0.03}_{-0.04}$	99
GW170817	$1.46^{+0.12}_{-0.10}$	$1.27^{+0.09}_{-0.09}$	$1.186^{+0.001}_{-0.001}$	$0.00^{+0.02}_{-0.01}$	≤ 2.8	≤ 0.89	≥ 0.04	$\geq 0.1\times10^{56}$	40^{+10}_{-10}	$0.01^{+0.00}_{-0.00}$	22
GW170818	$35.5^{+7.5}_{-4.7}$	$26.9^{+4.4}_{-5.2}$	$26.7^{+2.1}_{-1.7}$	$-0.09^{+0.18}_{-0.21}$	$59.8^{+4.8}_{-3.7}$	$0.67^{+0.07}_{-0.08}$	$2.7^{+0.5}_{-0.5}$	$3.4^{+0.5}_{-0.7}\times10^{56}$	1020^{+430}_{-370}	$0.20^{+0.07}_{-0.07}$	35
GW170823	$39.5^{+10.1}_{-6.6}$	$29.4^{+6.5}_{-7.1}$	$29.3^{+4.2}_{-3.1}$	$0.08^{+0.19}_{-0.22}$	$65.6^{+9.3}_{-6.5}$	$0.71^{+0.08}_{-0.09}$	$3.3^{+0.9}_{-0.8}$	$3.6^{+0.6}_{-0.9}\times10^{56}$	1860^{+840}_{-840}	$0.34^{+0.13}_{-0.14}$	1780

LIGO EGO European Gravitational Observatory LSC LIGO Scientific Collaboration VIRGO

LIGO and Virgo

Establishing Virgo as a partner in the global GW network was a major accomplishment

LIGO and Virgo have coordinated data taking and analysis, and release joint publications
LIGO and Virgo work under an MOU already for more than a decade
KAGRA expected to join in 2019

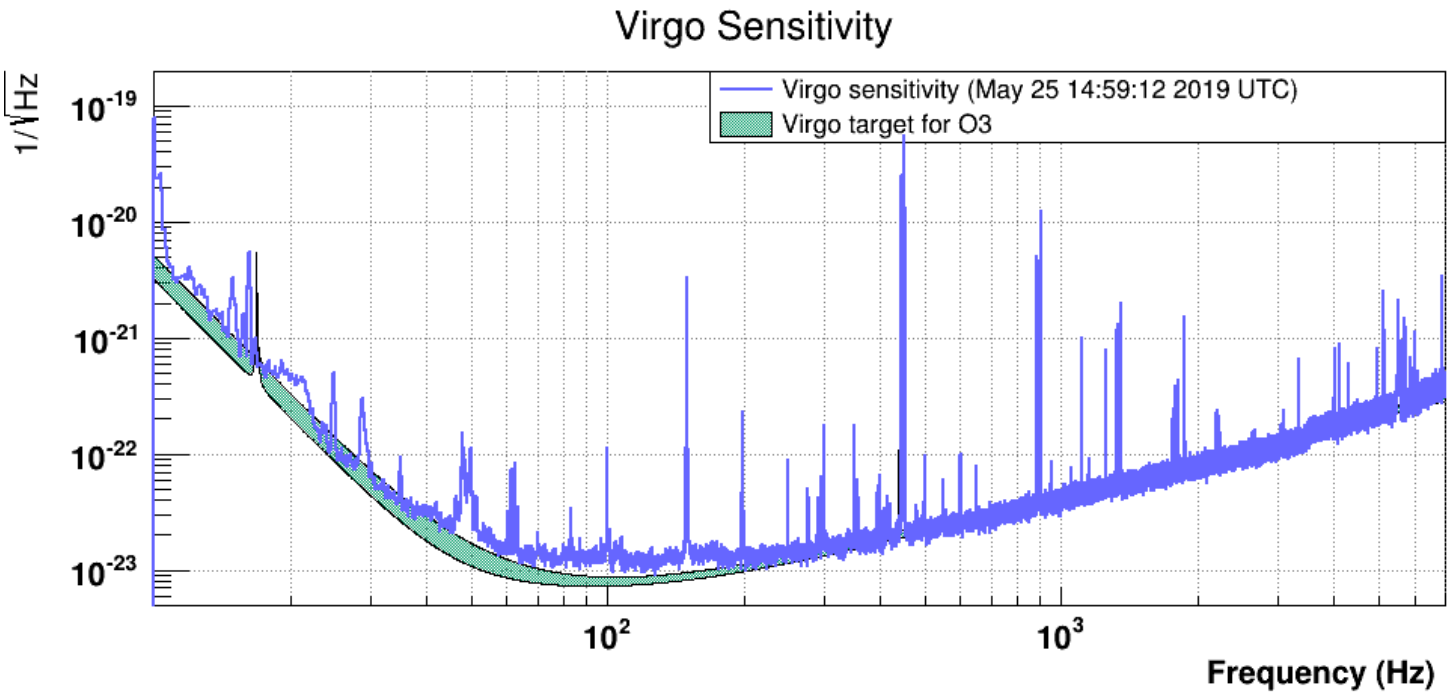


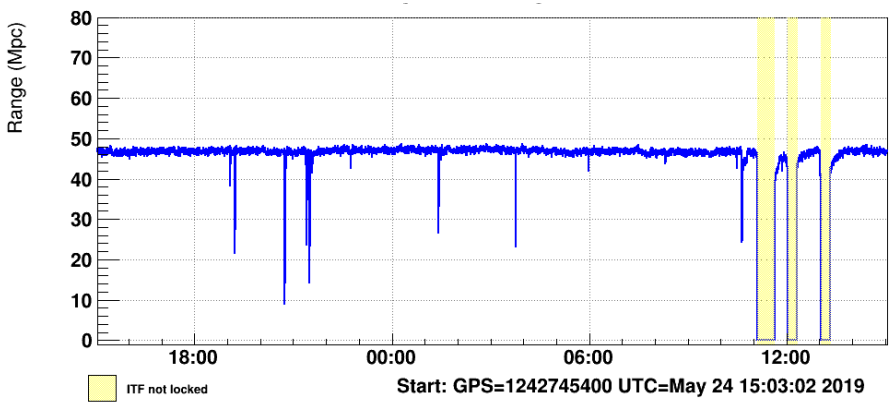
April 1, 2019: LIGO and Virgo started Observation run O3

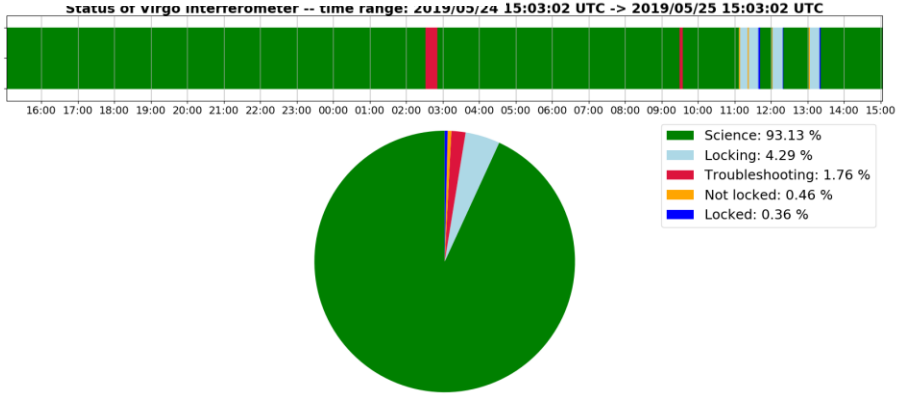
Joining O3 is another big step for Virgo

Virgo's sensitivity increased by about 85% wrt O2

Virgo's stability is good and efficiency of running amounts to about 90%







AdV+ as the next incremental step forward in sensitivity

AdV+ is the plan to maximize Virgo's sensitivity within the constrains of the EGO site. It has the potential to increase Virgo's detection rate by up to an order of magnitude

AdV+ features

Maximize science

Secure Virgo's scientific relevance

Safeguard investments by scientists and funding agencies

Implement new innovative technologies

De-risk technologies needed for third generation observatories

Attractive for groups wanting to enter the field

Upgrade activities

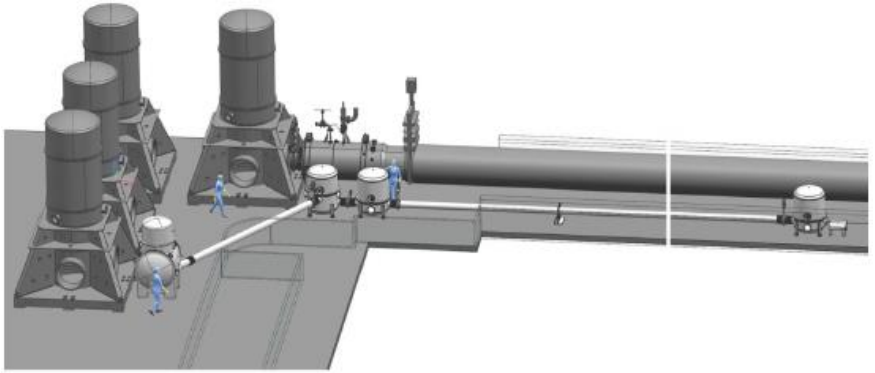
Tuned signal recycling and HPL: 120 Mpc

Frequency dependent squeezing: 150 Mpc

Newtonian noise cancellation: 160 Mpc

Larger mirrors (105 kg): 200-230 Mpc

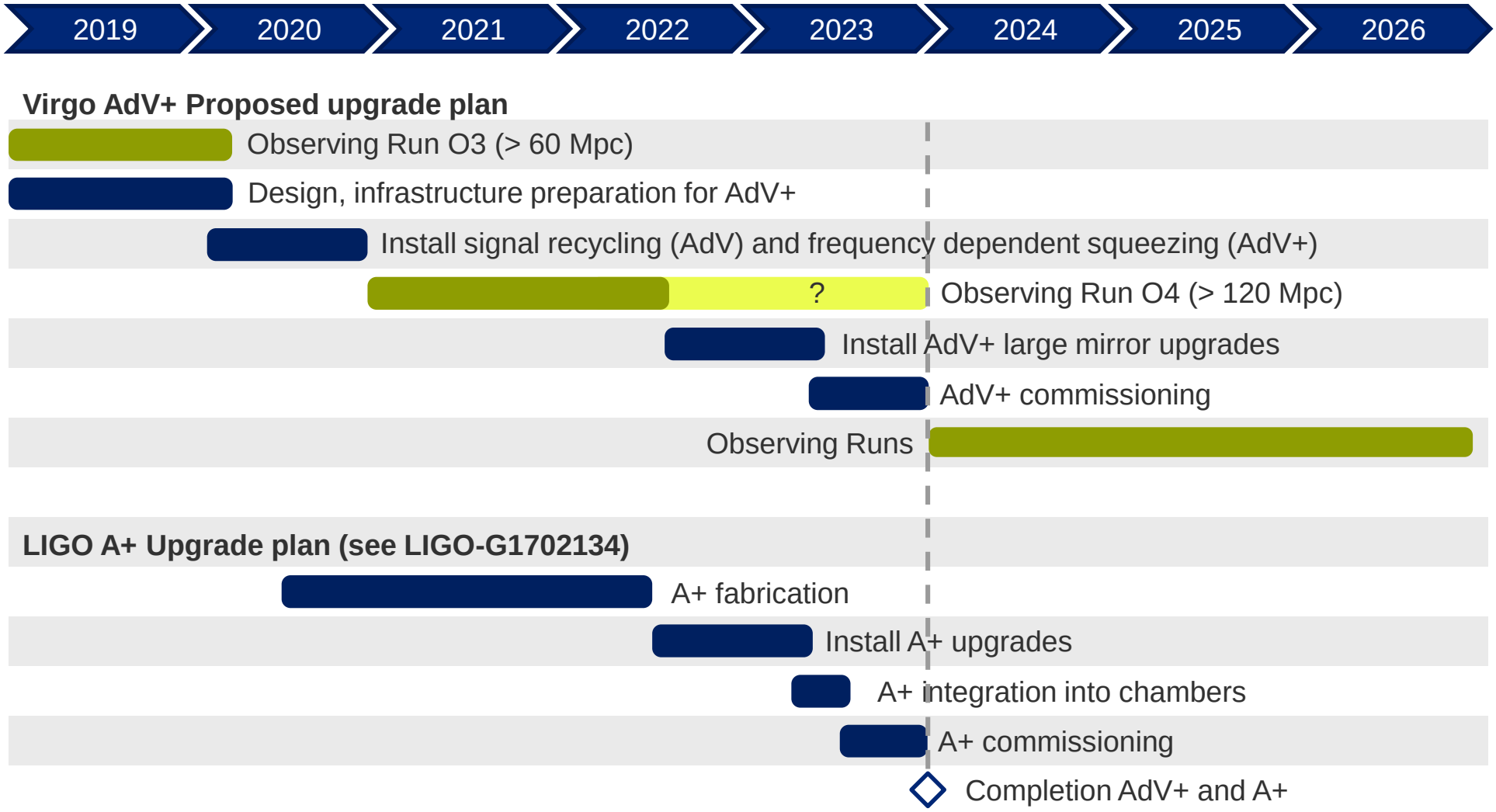
Improved coatings: 260-300 Mpc



In parallel with LIGO upgrade A+

AdV+ to be carried out in parallel with LIGO's A+ upgrade

Five year plan for observational runs, commissioning and upgrades

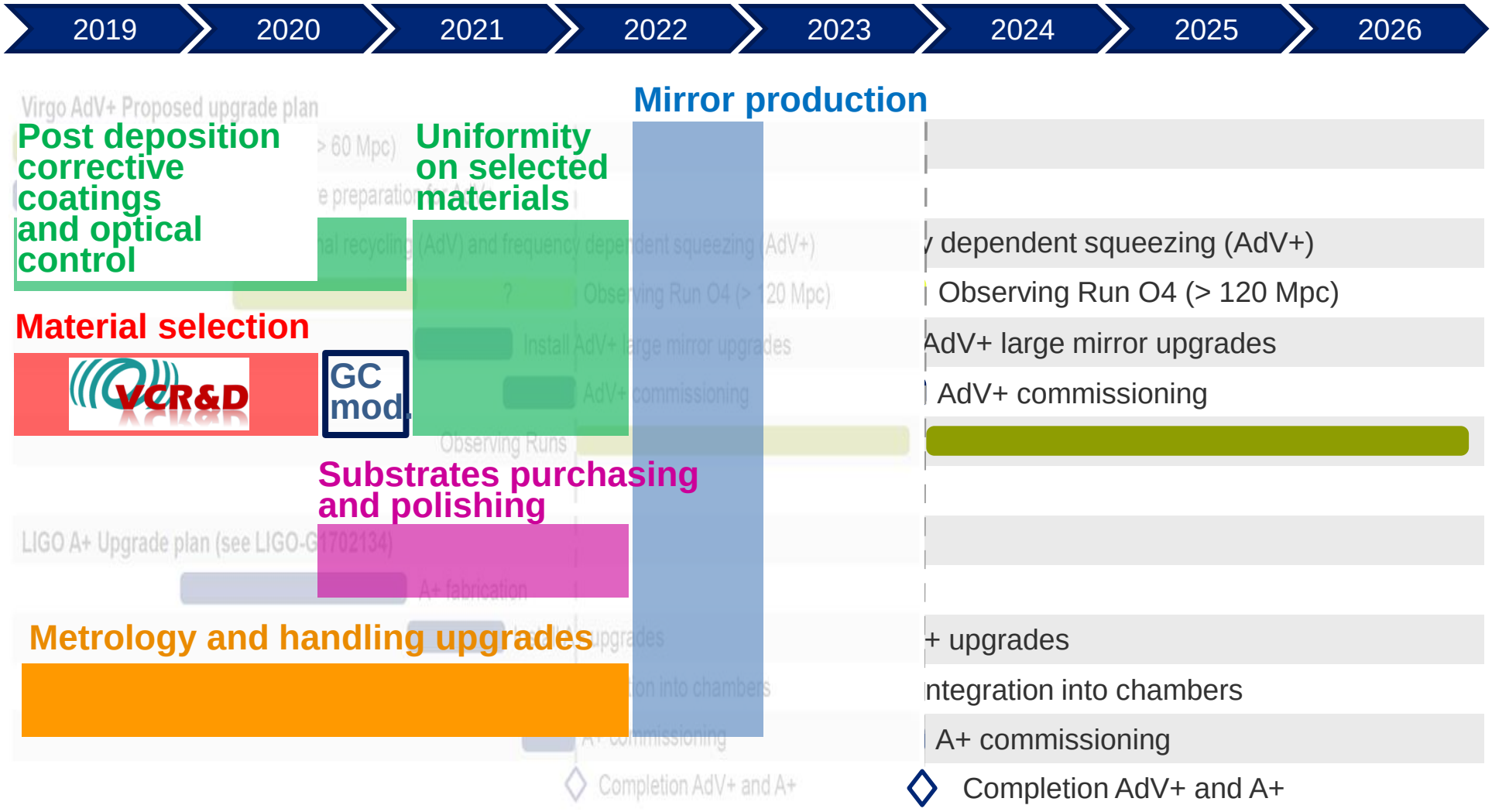


Note: Break between O3 and O4, and duration of O3 and O4 have not been decided

AdV+ is part of a strategy to go from 2nd generation to Einstein Telescope

Virgo's coating R&D secures LMA's relevance in future GW science

Tight five-year plan for observational runs, commissioning and upgrades



Note: duration of O4 has not been decided at this moment

Einstein Telescope

Einstein Telescope can observe BBH mergers to a redshift more than 20. This allows a new approach to cosmography. Access to the dark ages. Search for primordial black holes, early universe, etc.

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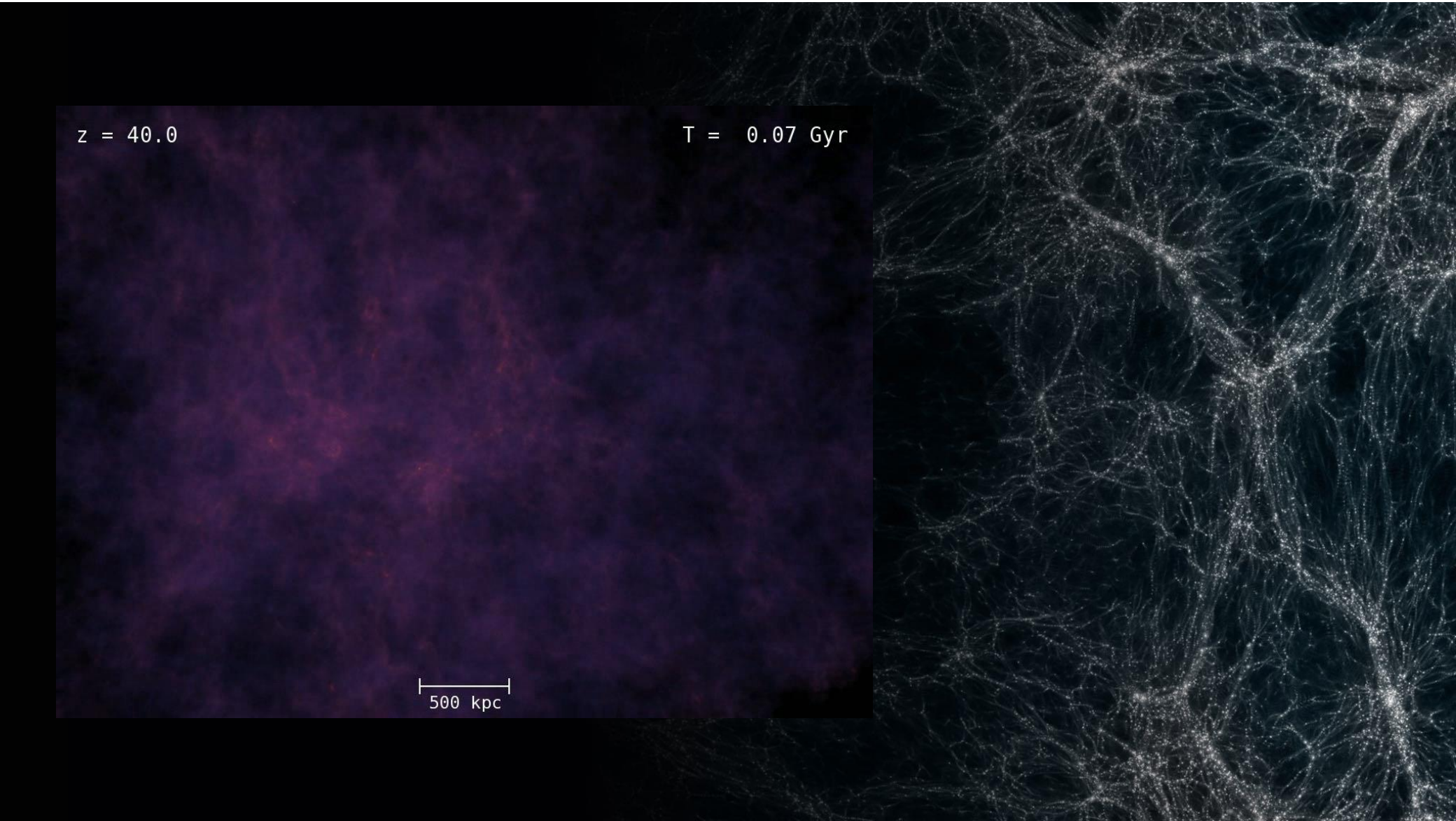
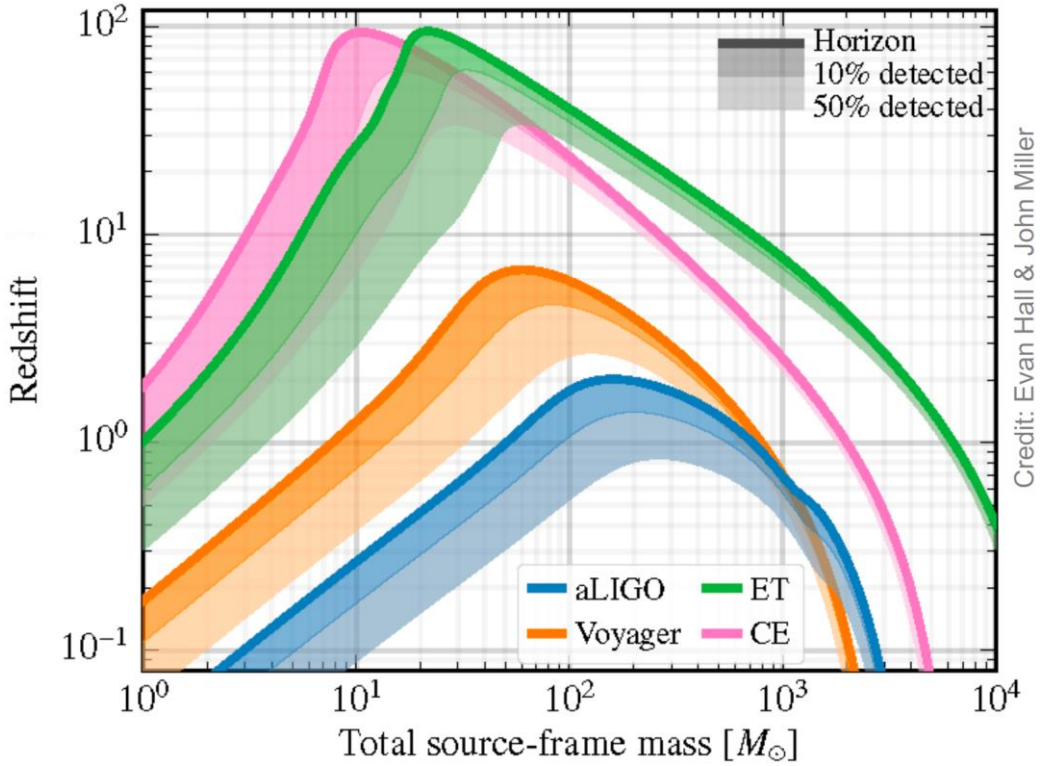


Einstein Telescope has excellent low-f sensitivity

ET as GW observatory with full sky coverage and high uptime



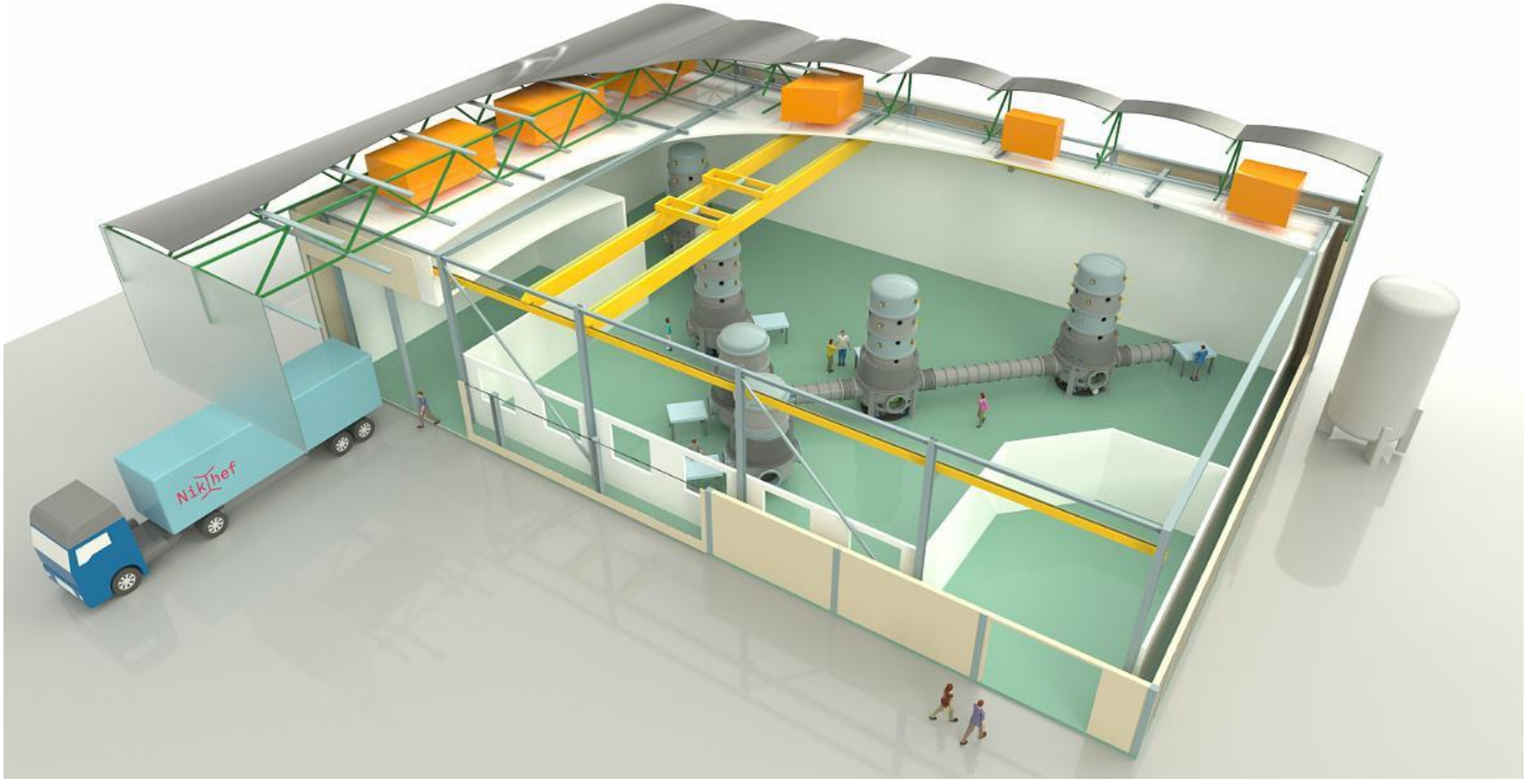
Many studies are needed: science, topology, infrastructure, cost

3G effort needs commitments from LVC groups (part of the Core Program)

Community needs a vigorous R&D program

Funding made available for 3G R&D: B-G-NL Limburg

About 14.5 M€ for the realization of a global R&D facility. This will allow de-risking of key technologies such as large scale cryogenic test masses, sensor development, new laser technology, controls, …
Also industry will be involved. Opportunity for training on GW instrumentation



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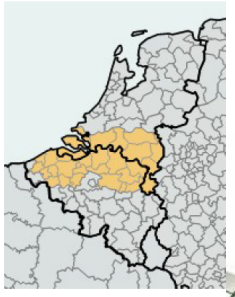
About 14.5 M€ for the realization of a global R&D facility. This will allow de-risking of key technologies such as large scale cryogenic test masses, sensor development, new laser technology, controls, … Also industry will be involved. Opportunity for training on GW instrumentation. New groups join

Funding & partners

Interreg
EUROPESE UNIE
Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling



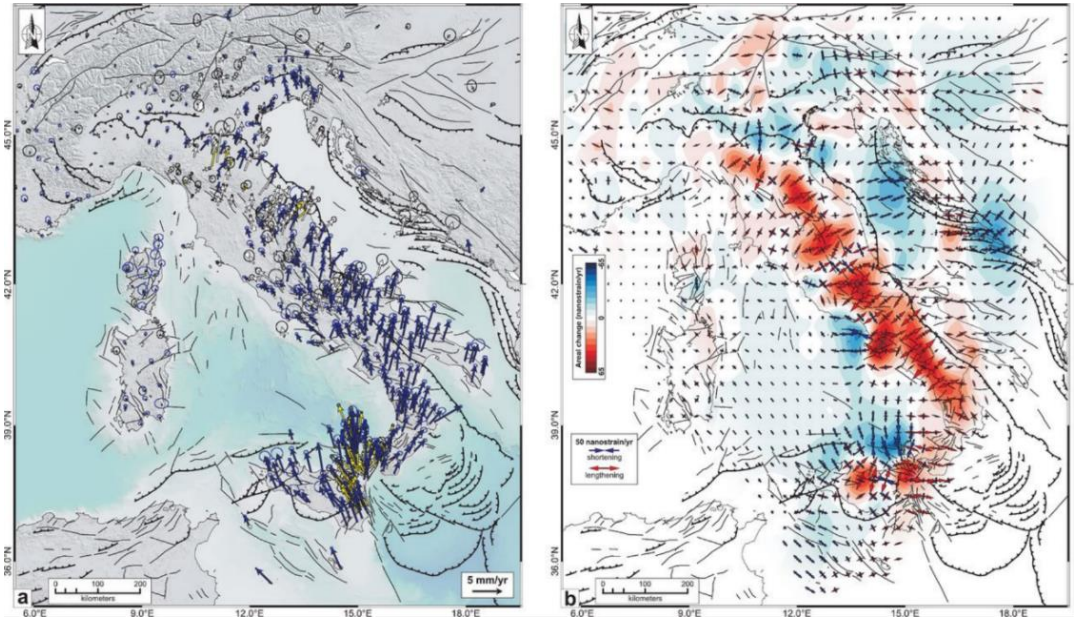
- Obtained ~14.5 MEuro funding from unconventional sources:
  - InterReg Flanders-South of NL (European fund for cross-border development)
  - Province of Limburg (NL), Dutch and Belgian national ministries
  - Matched contribution by partners
- Partners: Nikhef, universities of Antwerpen, Eindhoven, Ghent, Hasselt, Leuven, Maastrich
- Satellite partners: Aachen, Brussels, Fraunhofer, Liège, Louvain la Neuve, Twente, TNO
- Additional input from Glasgow, AEI, Perugia ...
- 100+ person-years (staff scientists and engineers) committed over the next 5 years
- New collaborators are welcome

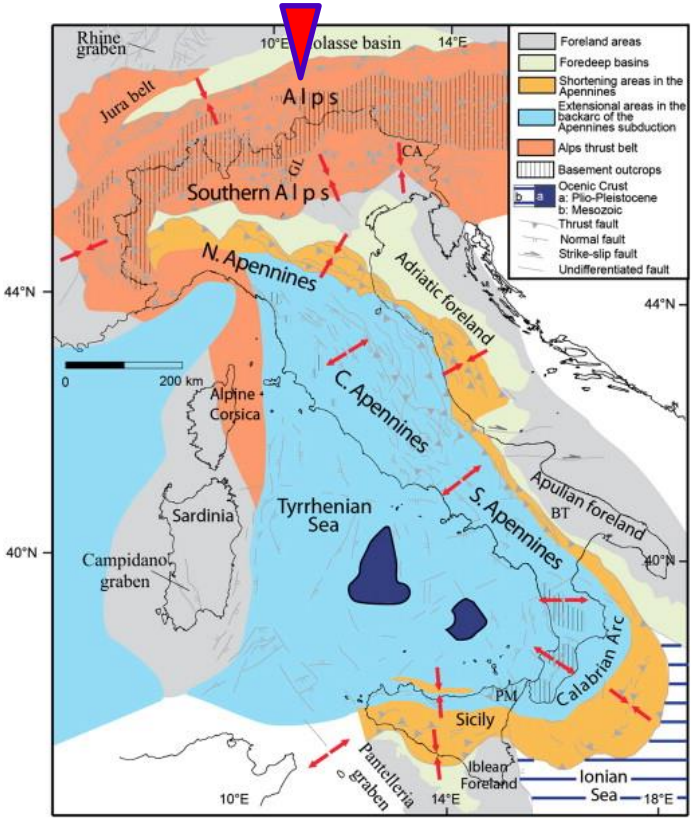
Funding made available for 3G R&D: Sardinia

About 8 M€ for the development of the Sardinia site

Support of the Italian Government: 17 M€ earmarked to support AdV+ and the ET site candidature of which 5.5 M€ allocated in 2018

2.5 M€ allocated by Sardinia region





ESFRI roadmap

Insertion of ET in the roadmap of the European Strategic Forum for Research Infrastructures (ESFRI) would be a major milestone for ET

Deadline for EU submission: April 2020

Deadline for the national submissions: January 2020

A consortium of governments must be formed, willing to support the ET proposal

Formal support must be expressed

We need to organize the *global* scientific community interested in 3G (and continuously keep them informed)

For ESFRI we need to prepare a credible plan for EU funding agencies

Next timeslot for proposal submission is at present unknown: 2022 or 2024?

Summary

There is great interest in our science

Virgo attracts many new groups, especially from HEP

Many universities are opening a program on GW science
- Several academic positions to be filled

Significant funding will be committed to AdV+
- EGO Council and in-kind contributions from the Netherlands, Poland and Spain

Sizeable funding has been made available for our 3G R&D activities
- Although in some cases from unusual sources

We need to organize the global scientific community interested in 3G
- LVC should embrace 3G activities in their Core Program
- 3G body should continuously inform their interested scientists (e.g. newsletter, website, events)
- Insufficient progress

Insertion of ET in the roadmap of the European Strategic Forum for Research Infrastructures (ESFRI) would be a major milestone for 3G
- Tremendous activity ahead