GWFP: Einstein Telescope and ETpathfinder

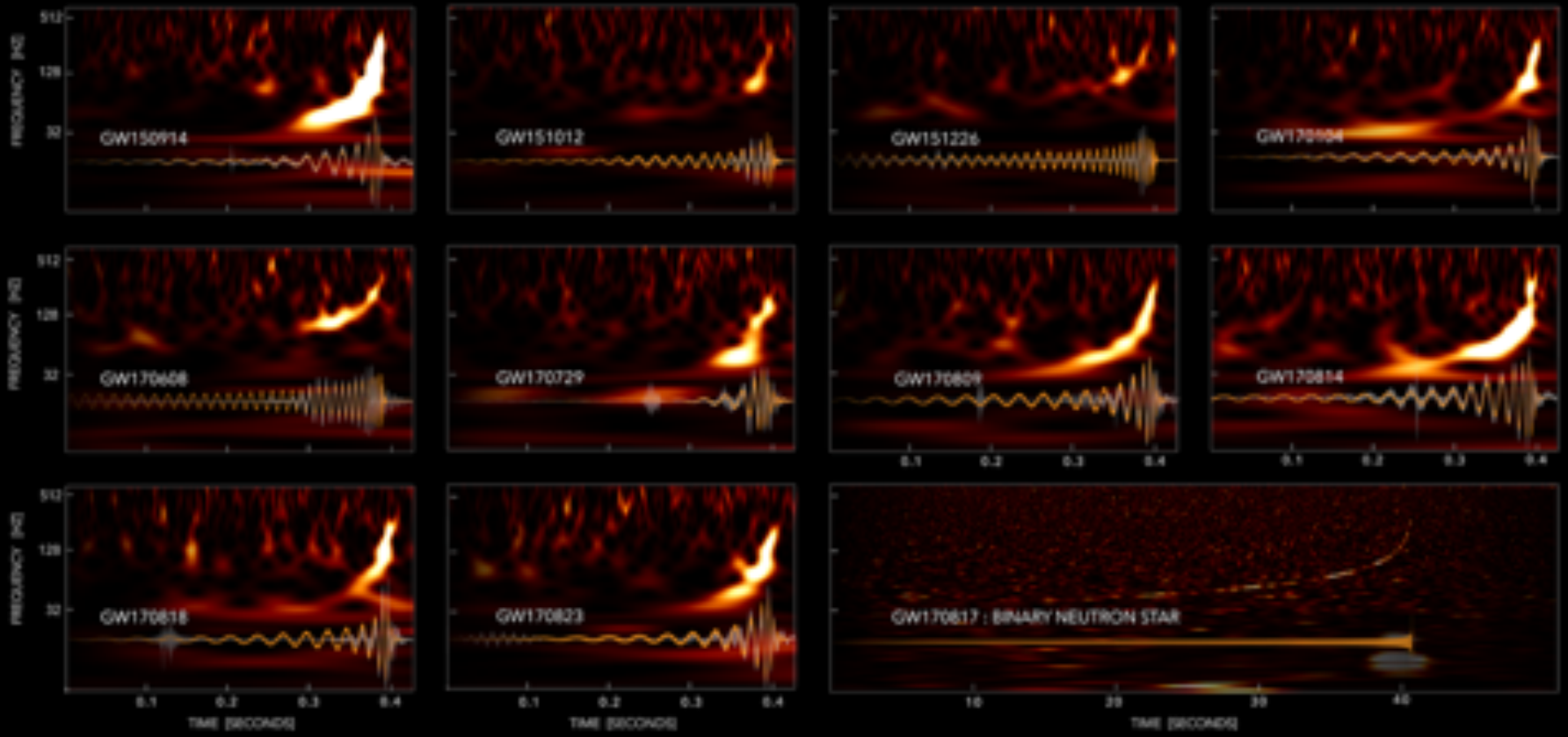
Prof. Stefan Hild, s.hild@nikhef.nl

ET EINSTEIN TELESCOPE

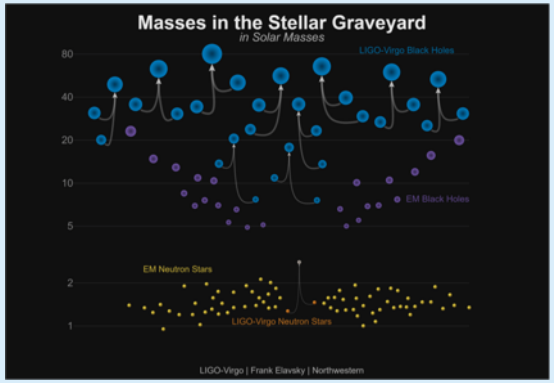
Maastricht University

Nikhef

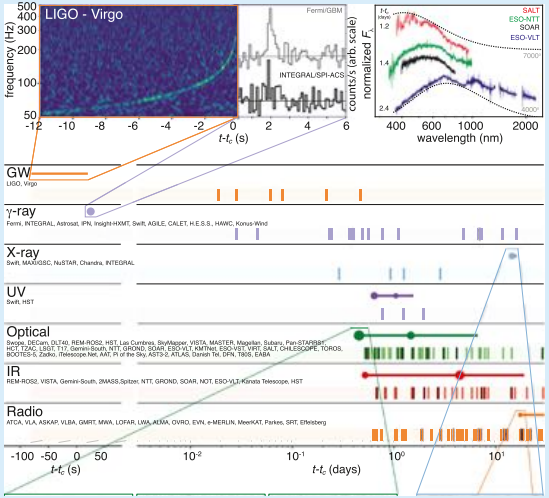
GRAVITATIONAL-WAVE TRANSIENT CATALOG-1



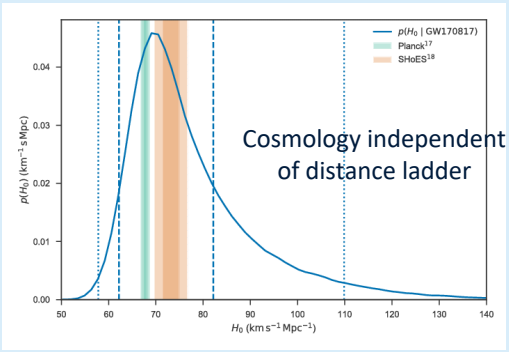
From a few seconds of signals …

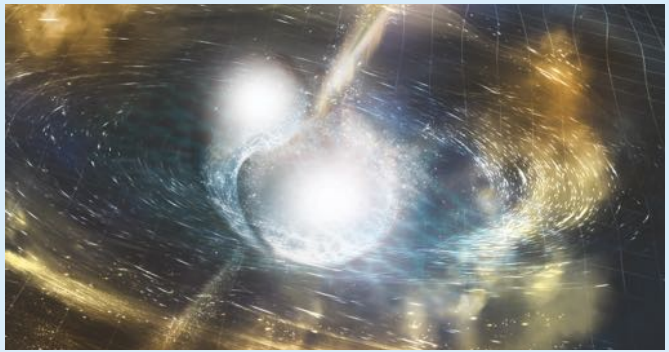


Found new class of heavy stellar mass BBH

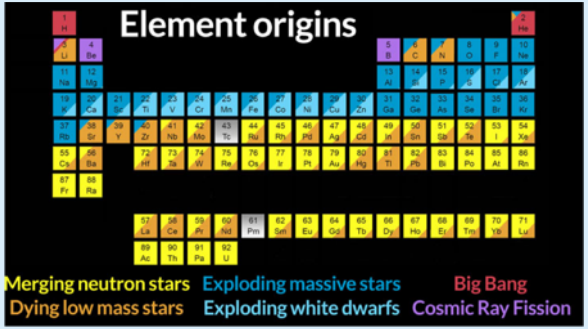


Start of GW multi-messenger astronomy



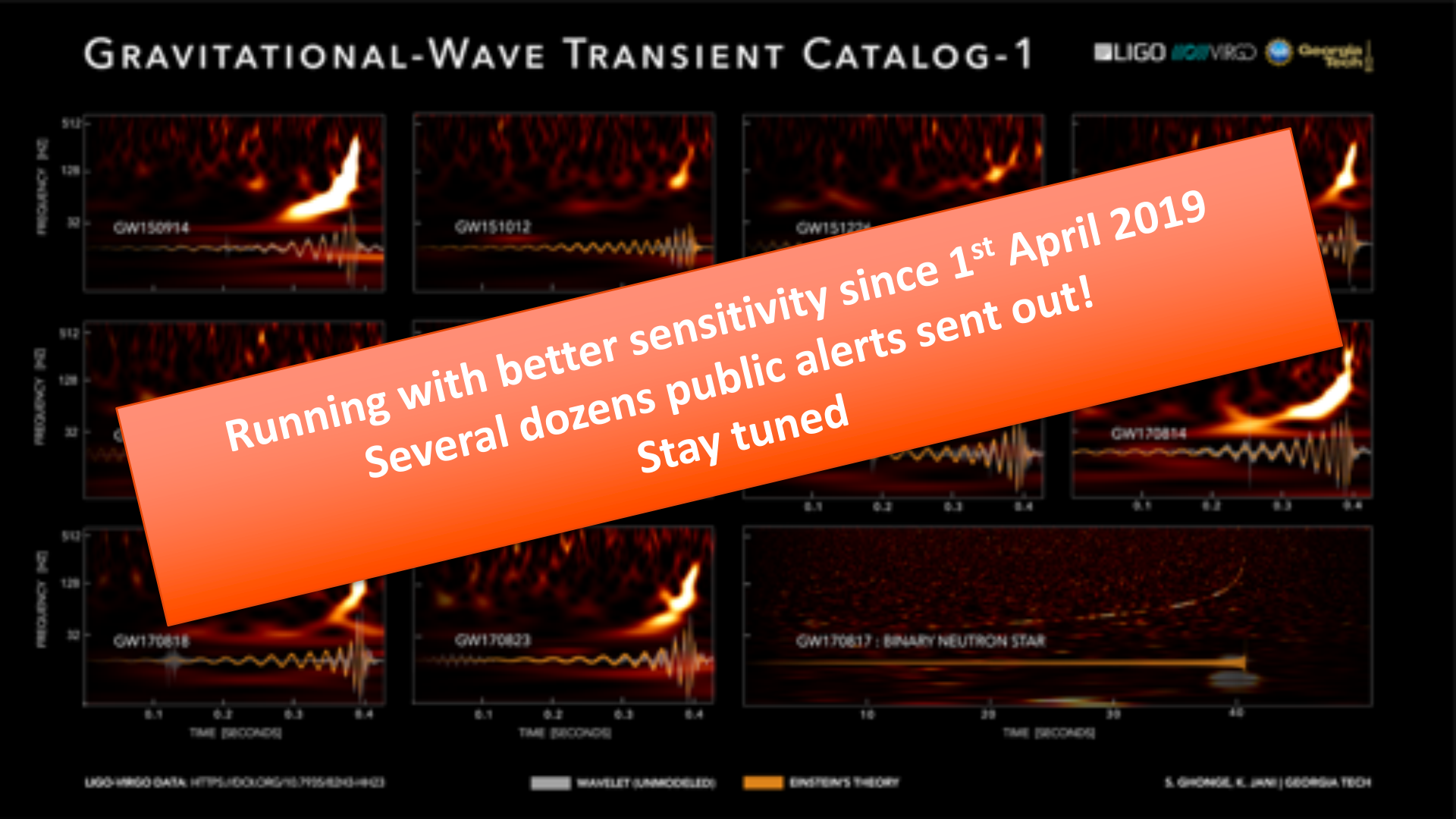


Confirmed BNS as origin for some GRBs

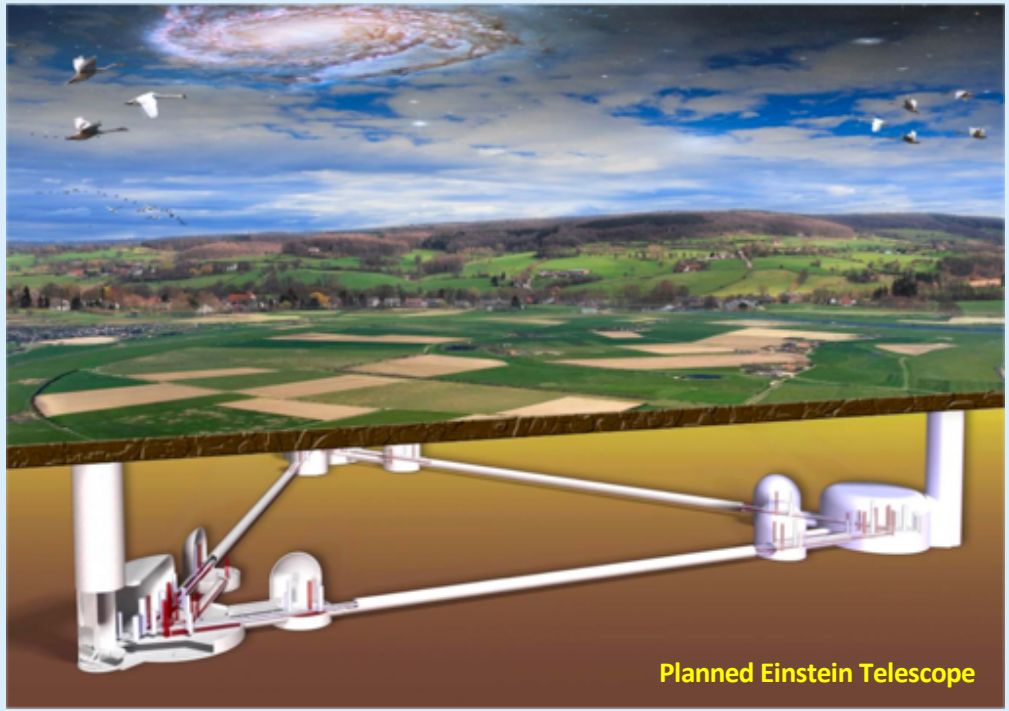


Confirmed Kilonova and R-process

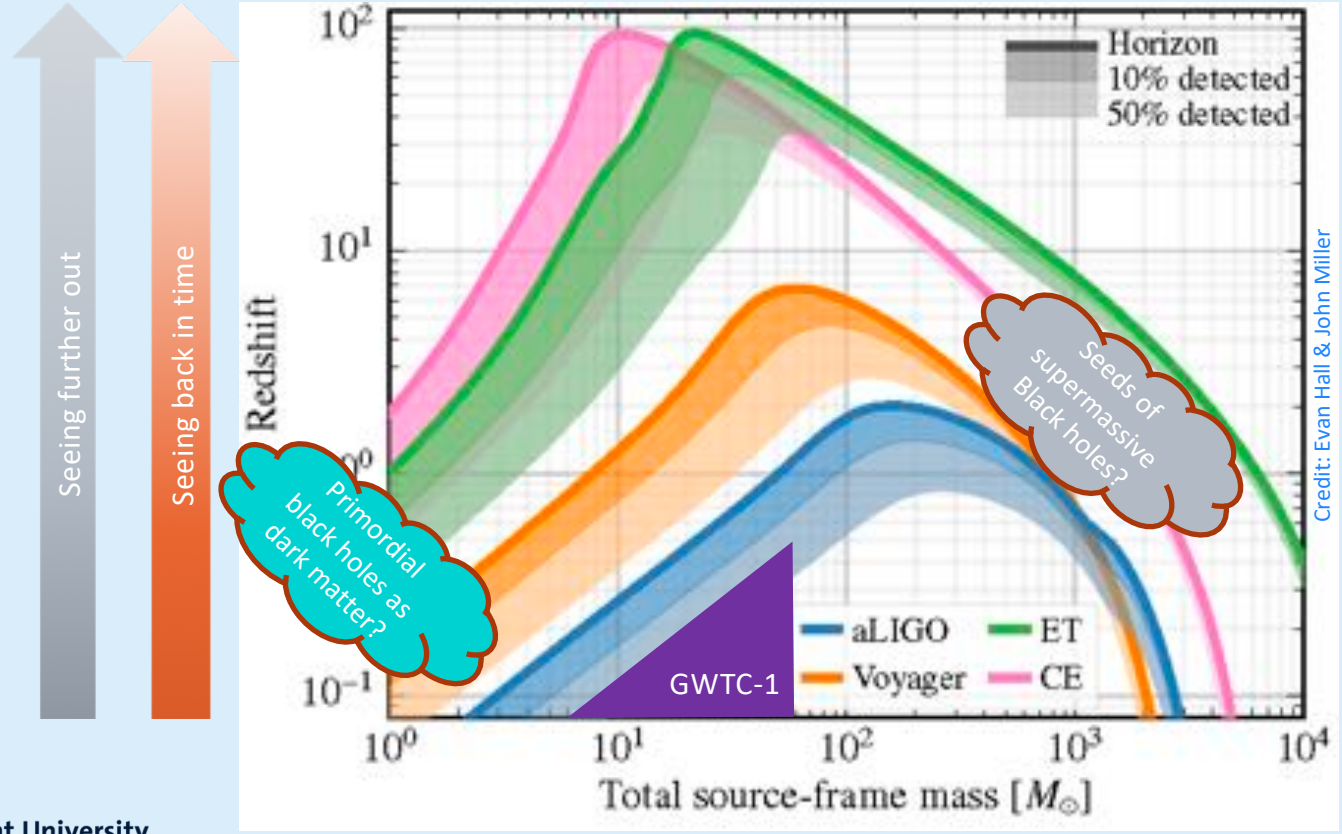
Maastricht University


GRAVITATIONAL-WAVE TRANSIENT CATALOG-1
LIGO VIRGO
Georgia Tech
GW150914
GW151012
GW170814
GW170818
GW170823
GW170817 : BINARY NEUTRON STAR
FREQUENCY [HZ]
TIME [SECONDS]
Running with better sensitivity since 1st April 2019
Several dozens public alerts sent out!
Stay tuned
LIGO-VIRGO DATA
WAVELET (UNMODELED)
EINSTEIN'S THEORY
S. GHONGE, K. JANI | GEORGIA TECH

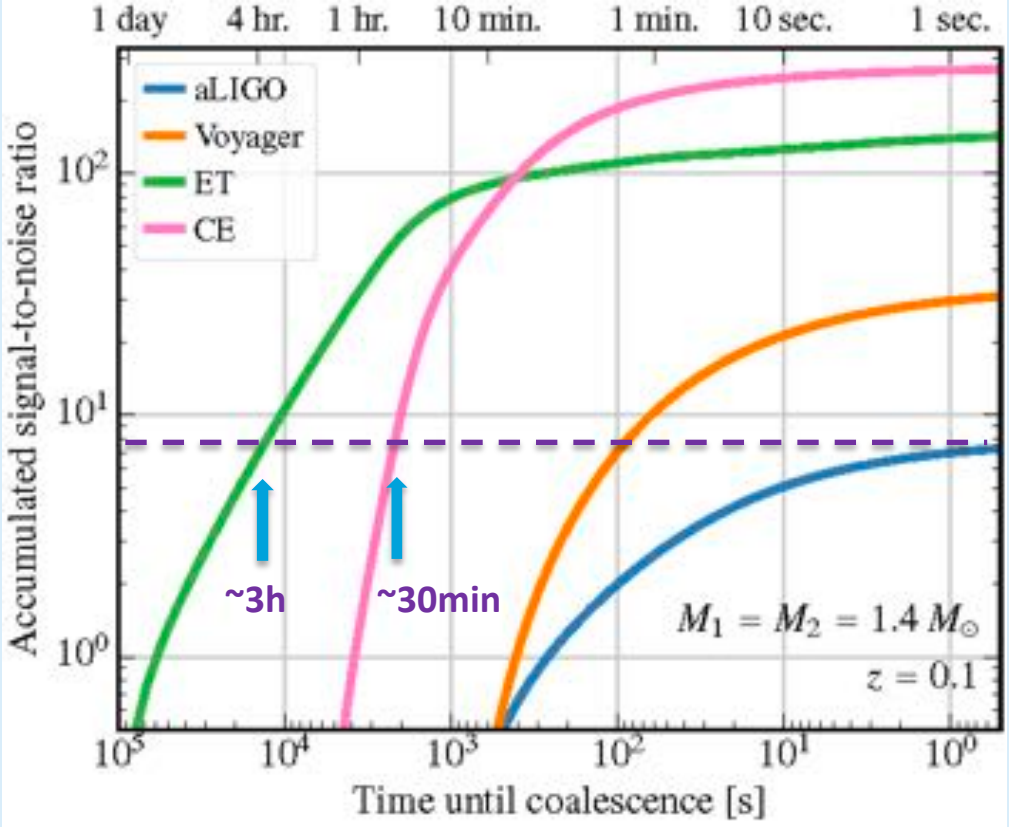
From Current Detectors to 3G/Einstein Telescope



Reaching for the full cosmos!

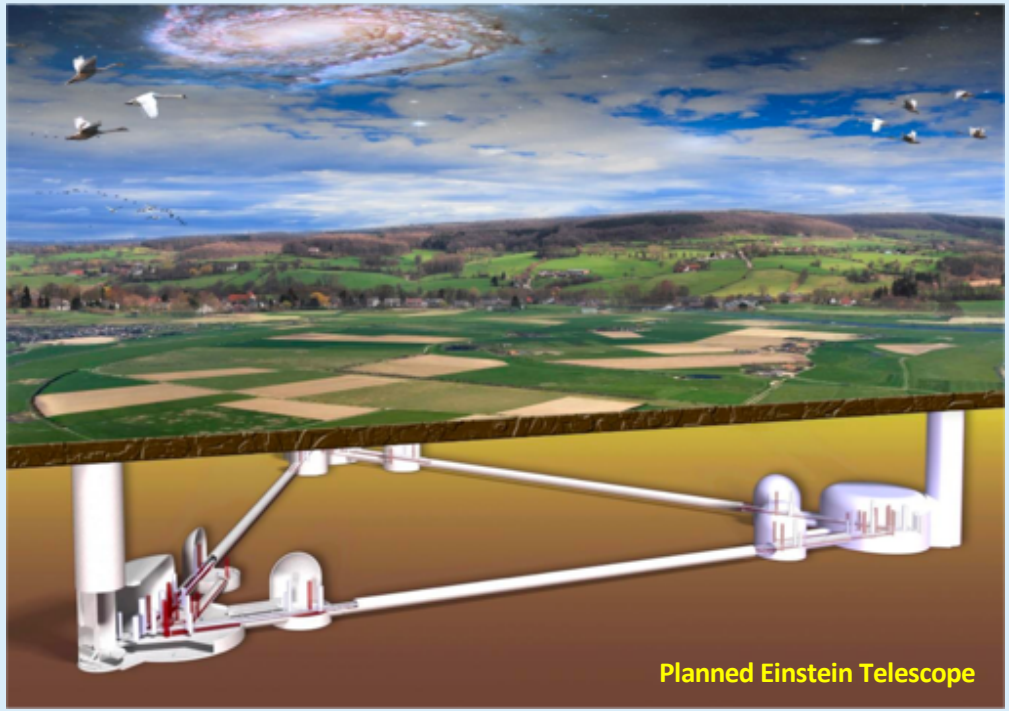


Seeing BNS in GW before merger



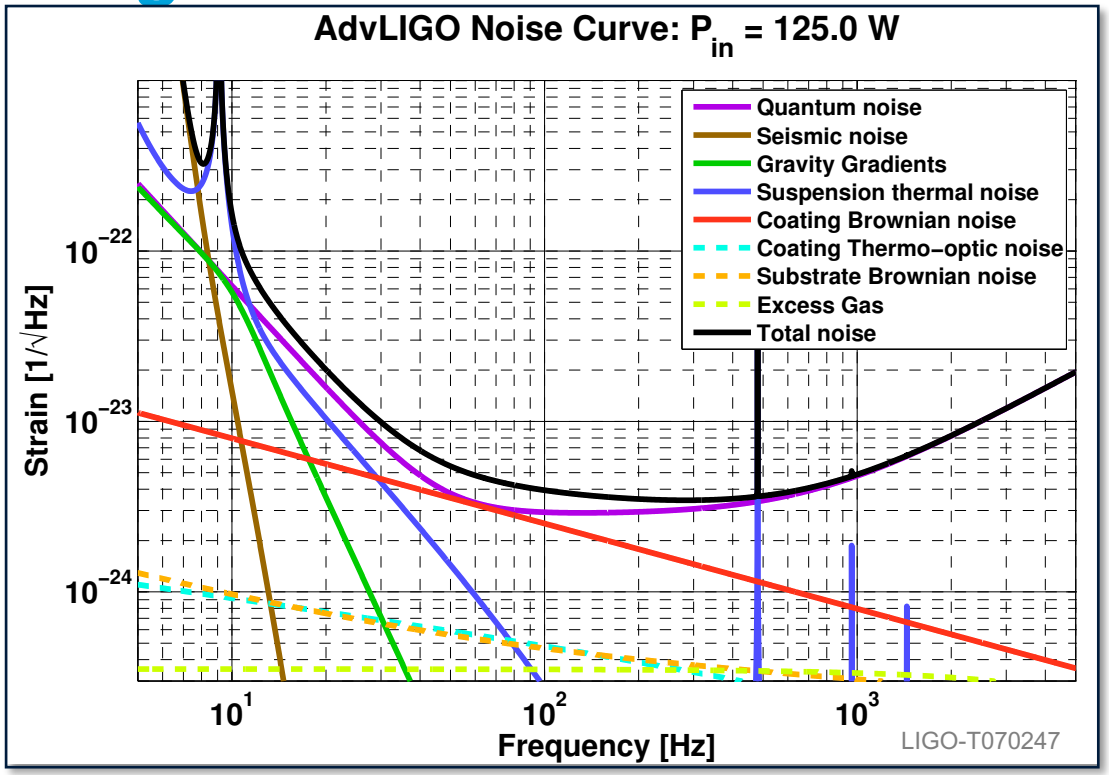
Credit: Evan Hall

From Current Detectors to 3G/Einstein Telescope

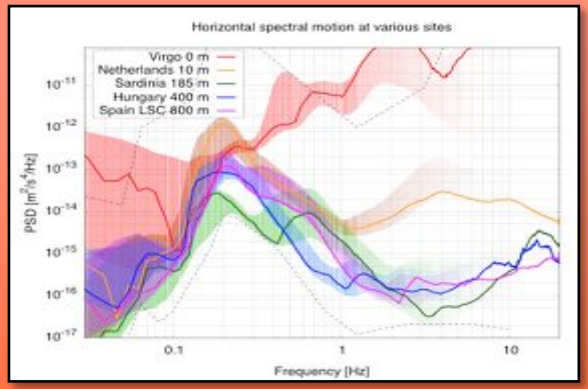


Noise Sources limiting the 2G

- **Quantum Noise** limits most of the frequency range.
- **Coating Brownian** limits in the range from 50 to 100Hz.
- Below ~15Hz we are limited by 'walls' made of **Suspension Thermal**, **Gravity Gradient** and **Seismic noise**.
- And then there are the, often not mentioned, 'technical' noise sources which trouble the commissioners so much



Key Concepts of ET in one slide



Underground location for Reduction of seismic and atmospheric GGN
+ long baseline

Composition of Seismic Fields

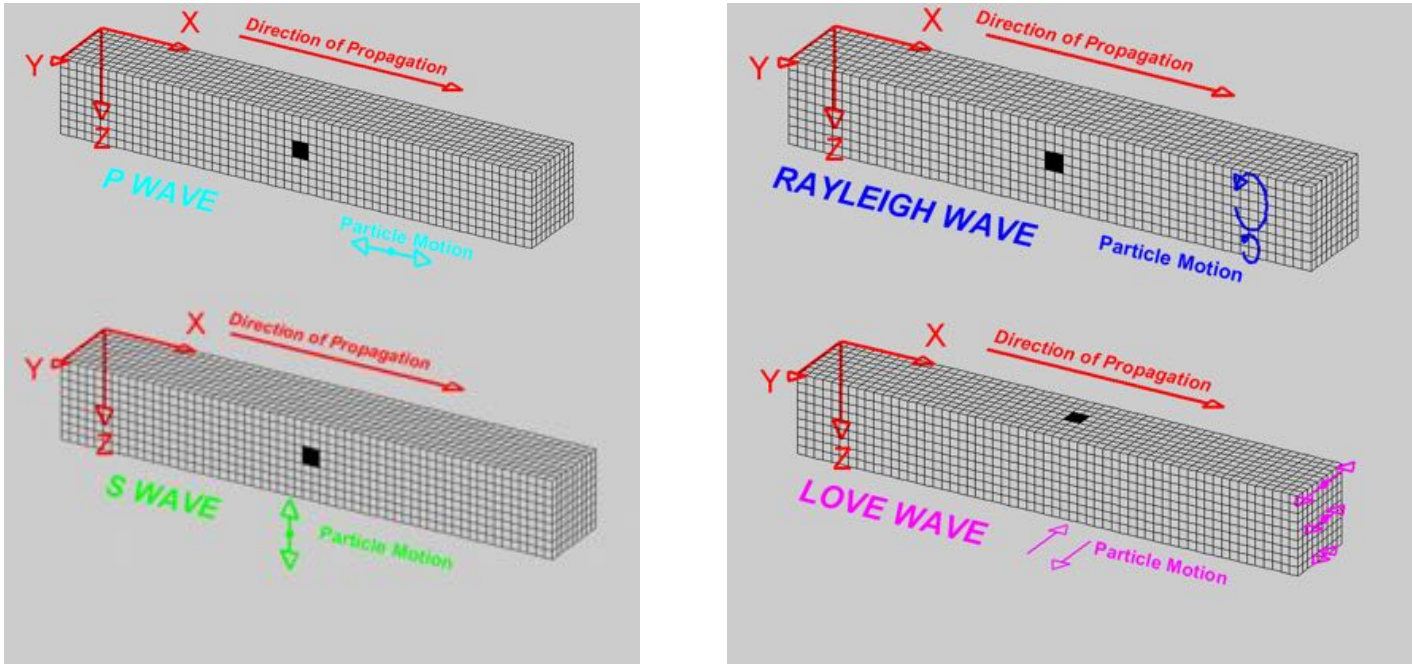
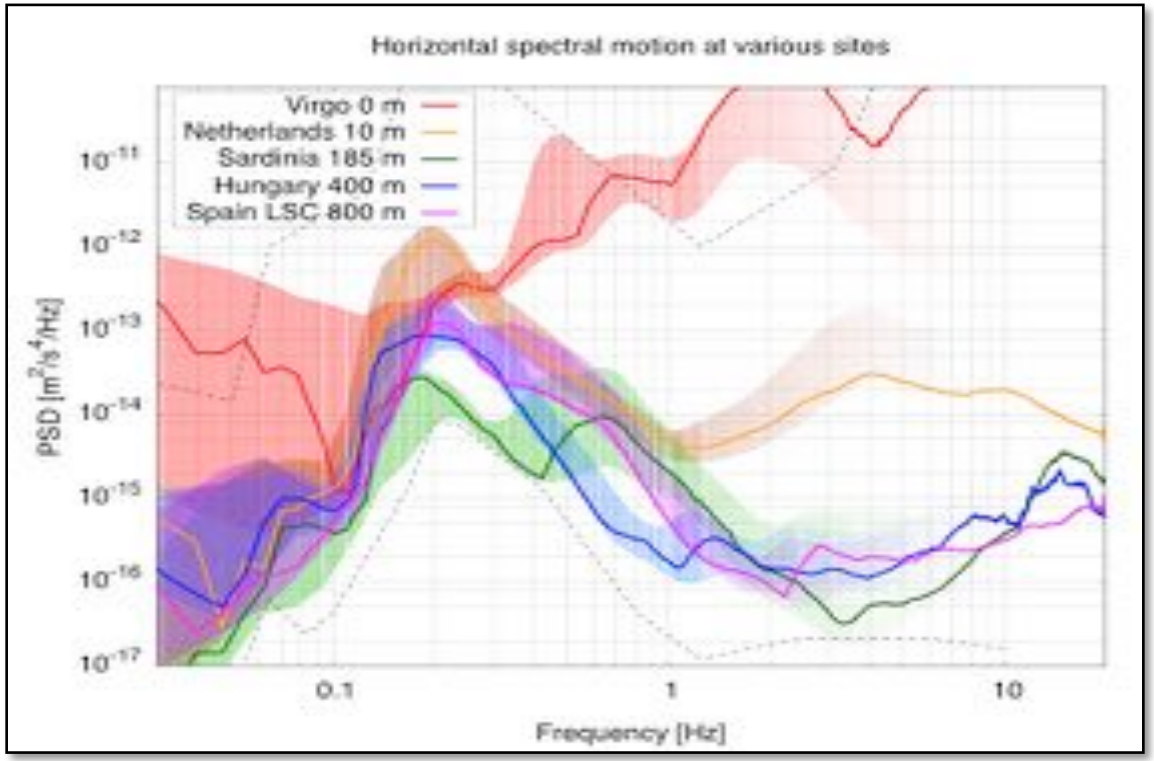


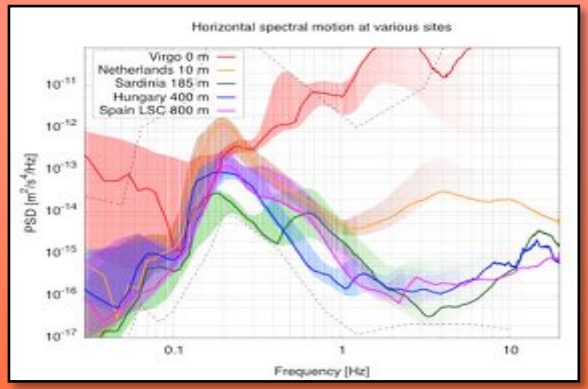
Image credits: http://www.geometrics.com/what-are-the-different-types-of-seismic-waves/

ET will ‘go underground’



ET design study document

Key Concepts of ET in one slide



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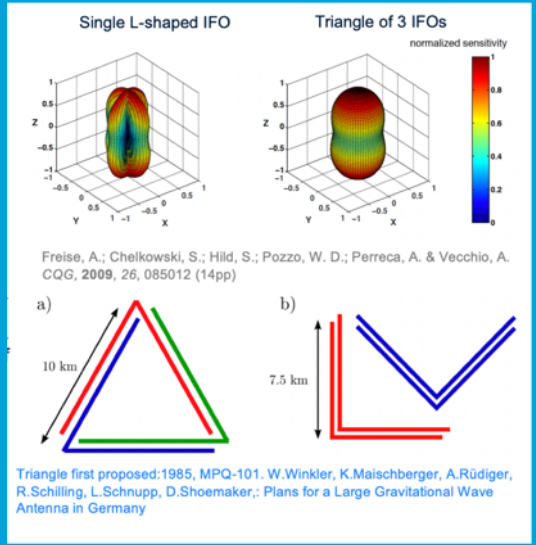
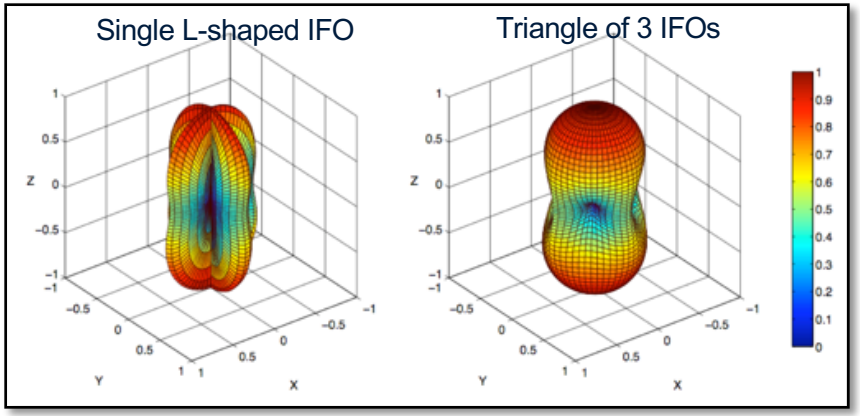
Triangular for full sky coverage and redundancy

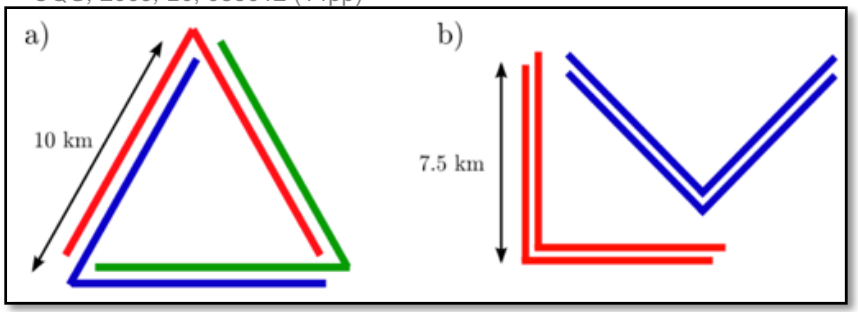


The ET Footprint

- As ET is a new infra-structure, we can start from scratch.
- What to see the full sky.
- Want to resolve both polarisations.
- Want to have redundancy.
- 1 Triangle vs 4 Ls:
  - Both have 30km integrated tunnel length
  - Both resolve both polarisations and offer redundancy.
  - Both give equivalent sensitivity.
  - Triangle reduces the number of end stations.
- **ET will be a triangle.**



Freise, A.; Chelkowski, S.; Hild, S.; Pozzo, W. D.; Perreca, A. & Vecchio, A. *CQG*, **2009**, *26*, 085012 (14pp)



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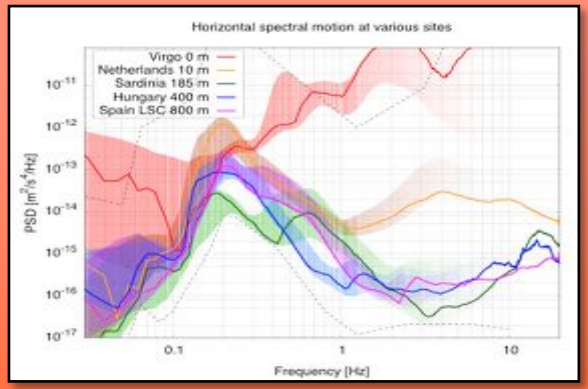

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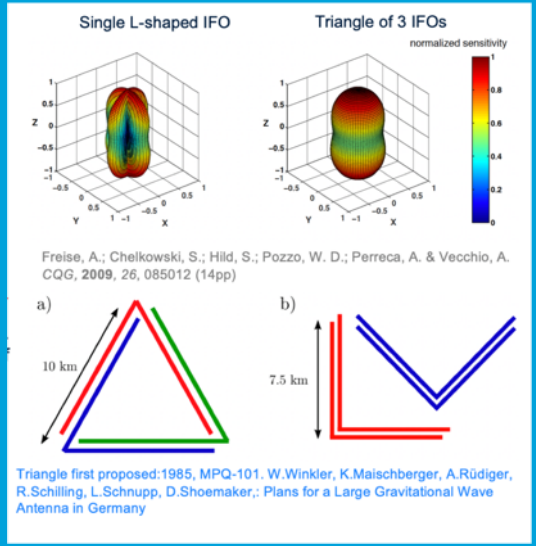
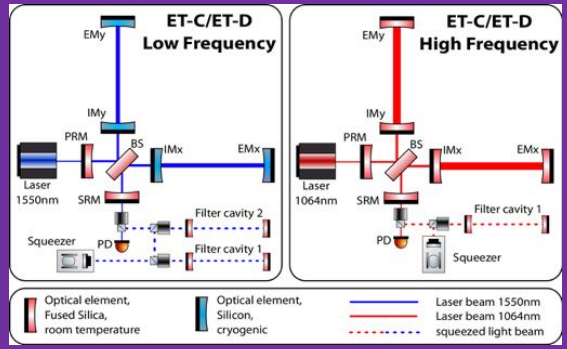




Xylophone concept

Many new technologies, like for instance cryogenic silicon mirrors

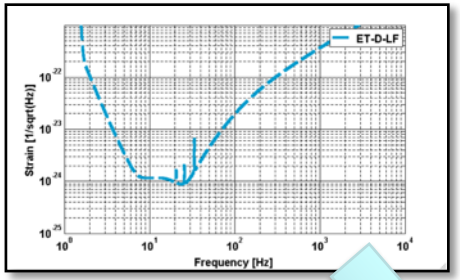
Xylophone Concept

- As our detectors become more and more complex and at the same time aim increase even further the observation bandwidth the xylophone concept becomes more and more attractive.
- The xylophone concept was originally suggested for advanced LIGO:

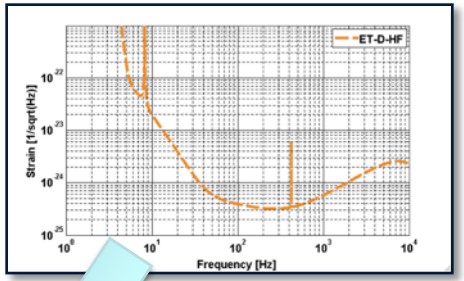
  R.DeSalvo, CQG 21 (2004) S1145-S1154
  G.Conforto and R.DeSalvo, Nuc. Instruments 518 (2004) 228 - 232
  D.Shoemaker, presentation at Aspen meeting (2001), http://www.ligo.caltech.edu/docs/G/G010026-00.pdf

- Allows to overcome 'contradicting' requirements in the technical detector design:
  - To reduce shot noise you have to increase the light power, which in turn will reduce the sensitivity at low frequencies due to higher radiation pressure noise.
  - Need cryogenic mirrors for low frequency sensitivity. However, due to residual absorption it is hard to combine cryogenic mirrors with high power interferometers.
- For ET we choose the conservative approach (designing an infrastructure) and went for a 2-band xylophone: low-power, cryogenic low-frequency detector and a high-power, room-temperature high-frequency detector.

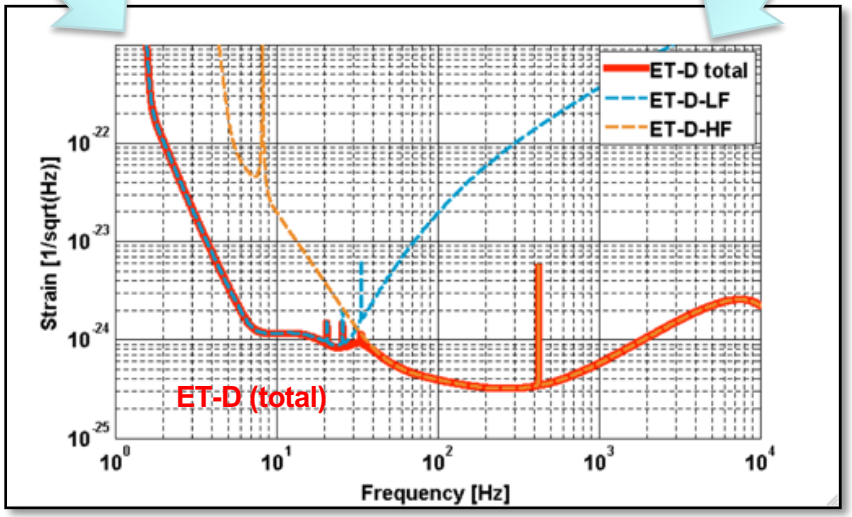
Combining 2 IFOs



ET-D-LF



ET-D-HF



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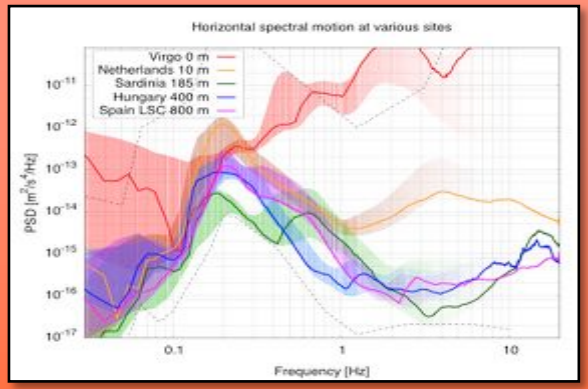

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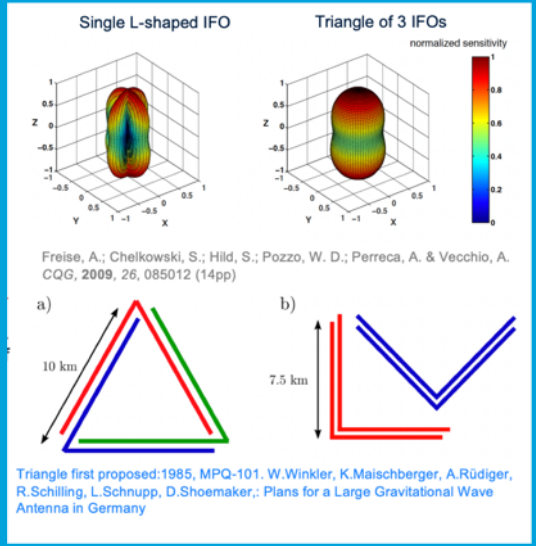

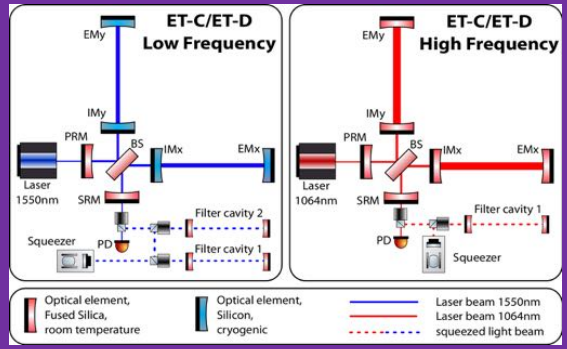

Xylophone concept

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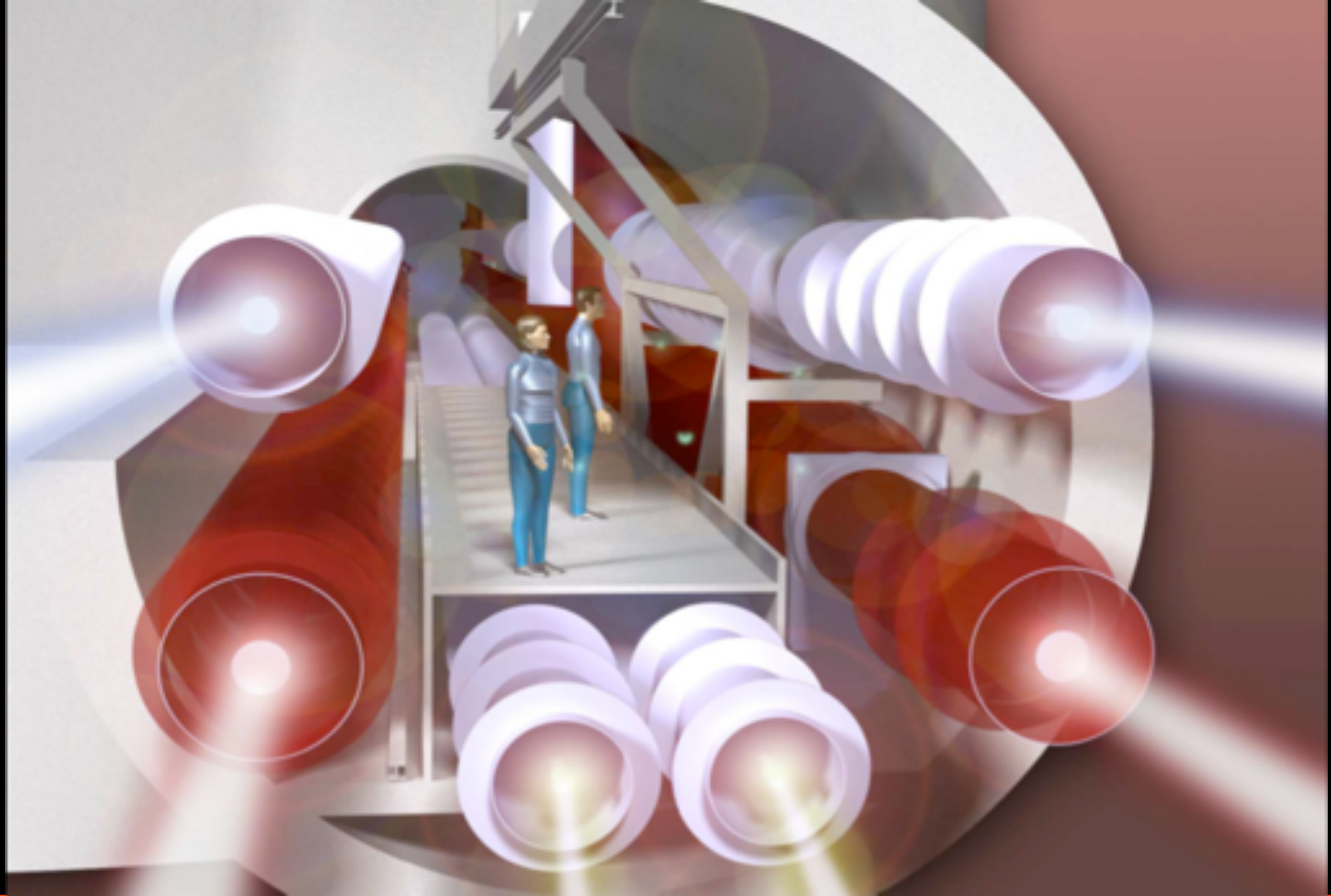
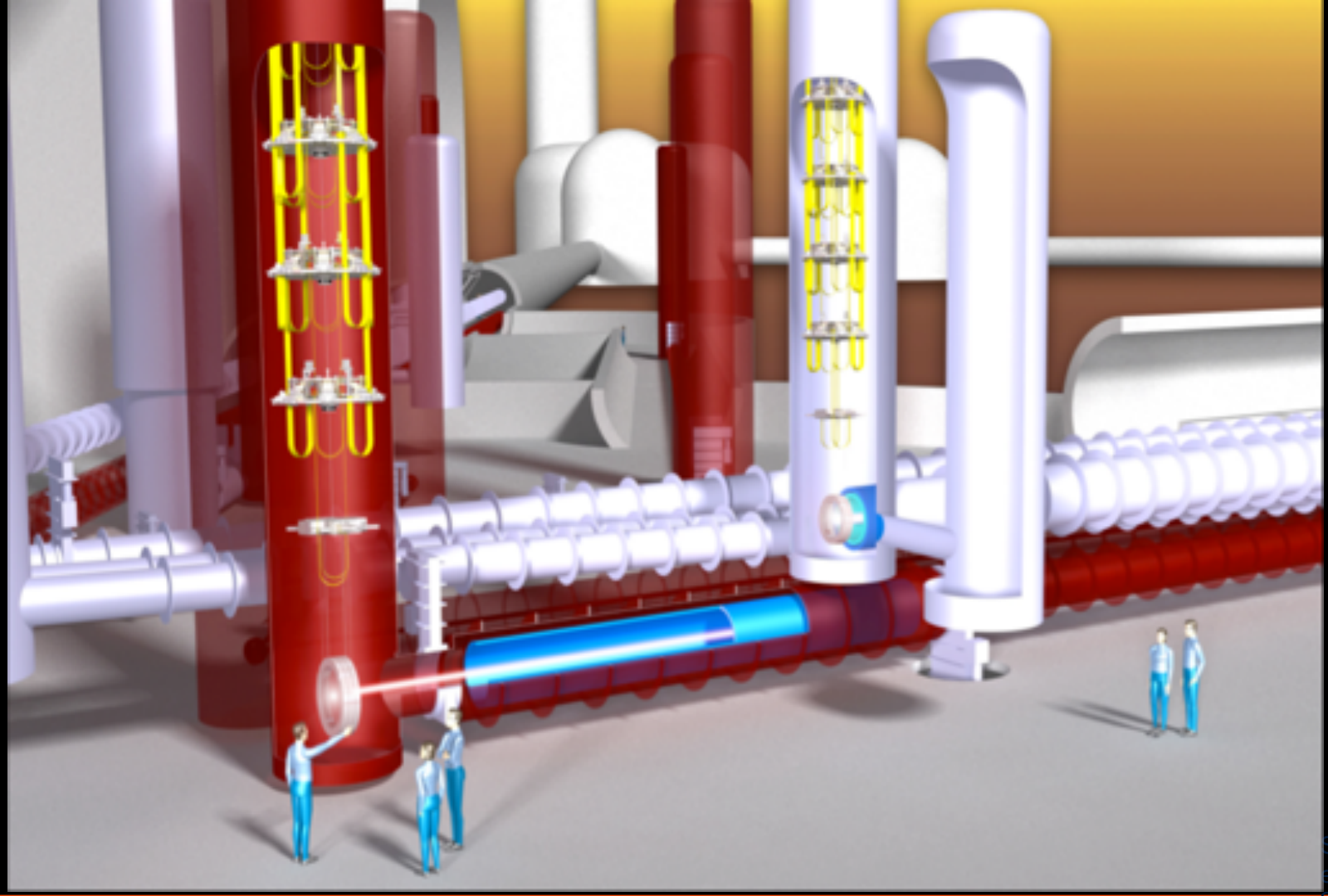
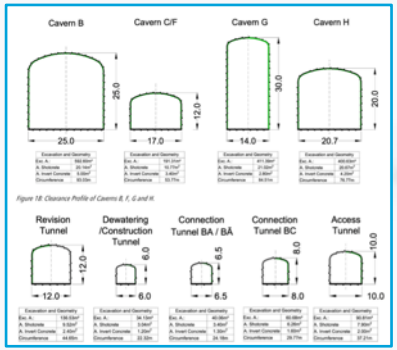
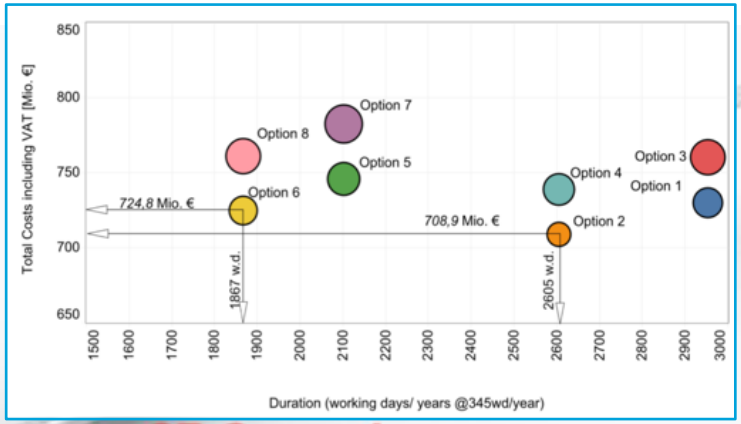




Going Underground

Refining construction of Infrastructure



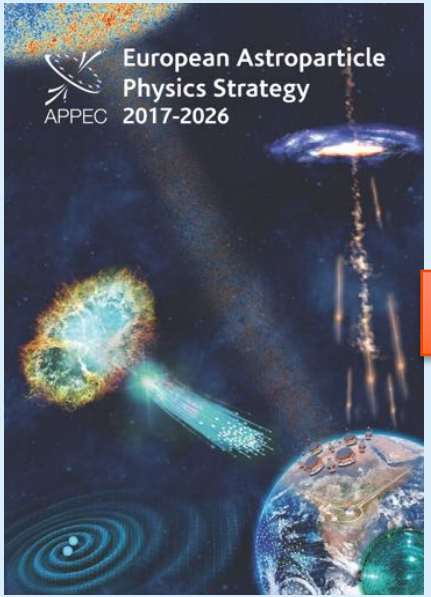


Roadmap to Einstein Telescope

Current candidate locations:

- **Sardinia**, supported by Italy
- **South Limburg**, supported by a consortium from the Netherlands, Belgium and Germany

Decision scheduled for 2022.



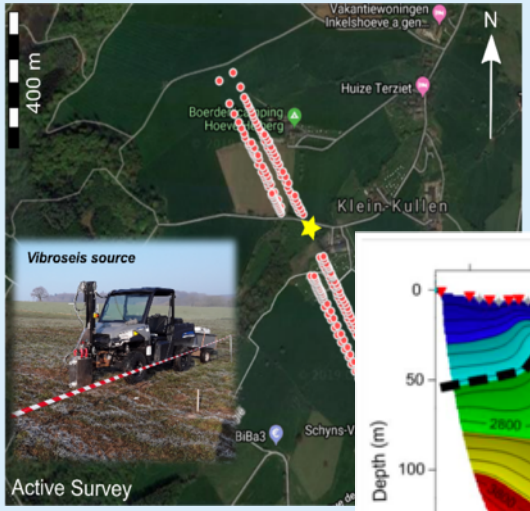
Sardinia

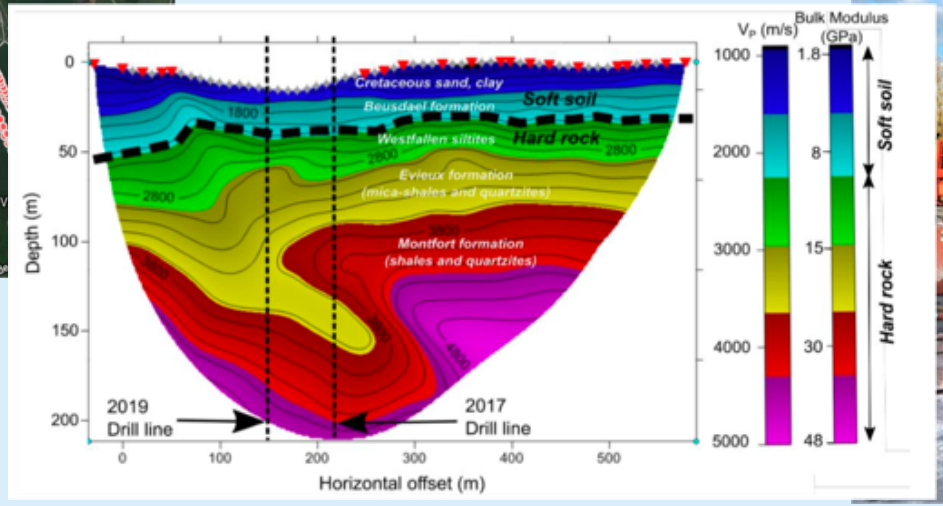
LOCAL GEOPHYSICS

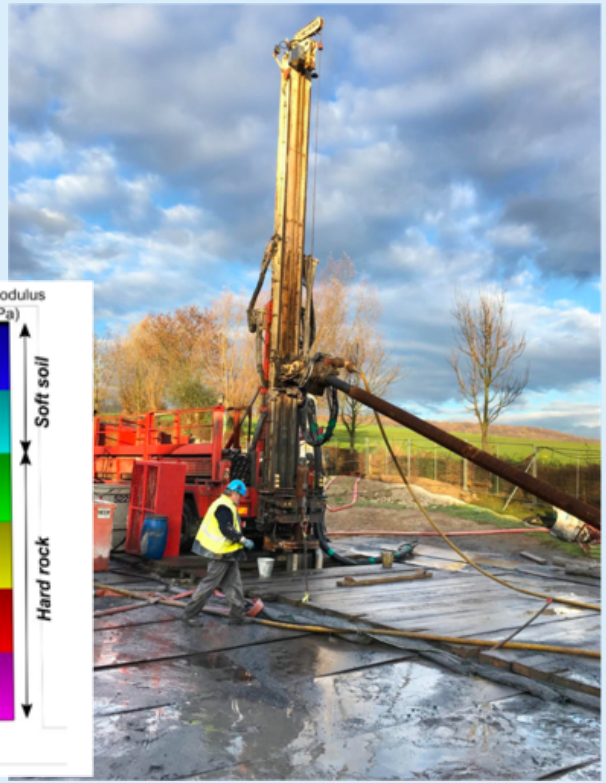
- Excellent geology
- Strong local (universities) and national support (INFN)

Ancient rocks, European continental landmass: seismically quiet

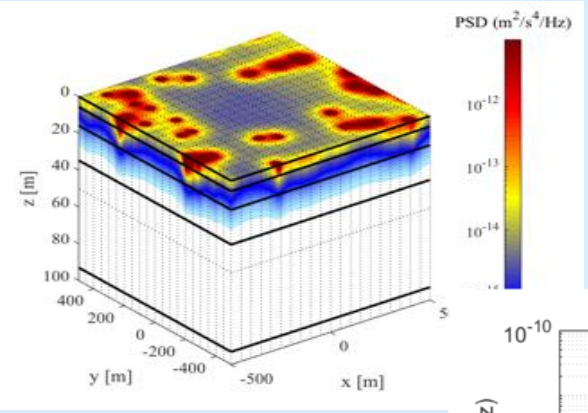
Why ET in EUREGIO?

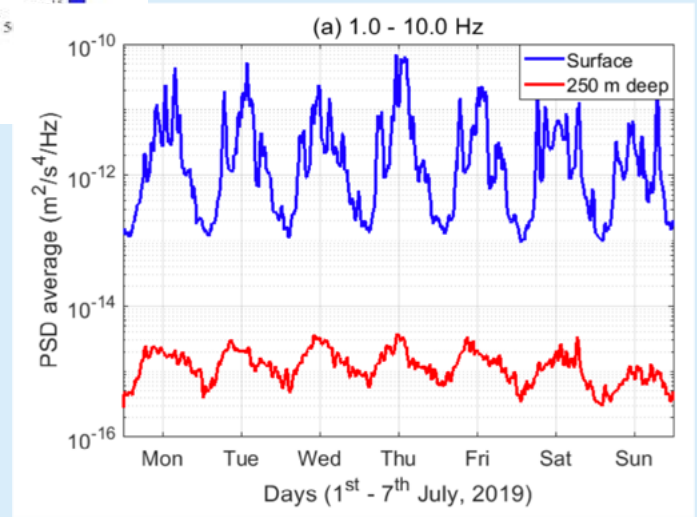






Underground!





SEISMIC CHARACTERIZATION OF THE EUREGIO MEUSE-RHINE IN VIEW OF EINSTEIN TELESCOPE

13 September 2019

First results of seismic studies of the Belgian-Dutch-German site for Einstein Telescope

Soumen Koley[1], Maria Bader[1],
Alessandro Bertolini[1], Jo van den Brand[1,2], Henk Jan Bulten[1,3],
Stefan Hild[1,2], Frank Linde[1,4], Bas Swinkels[1], Bjorn Vink[5]

1. Nikhef, National Institute for Subatomic Physics, Amsterdam, The Netherlands
2. Maastricht University, Maastricht, The Netherlands
3. VU University Amsterdam, Amsterdam, The Netherlands
4. University of Amsterdam, Amsterdam, The Netherlands
5. Antea Group, Maastricht, The Netherlands

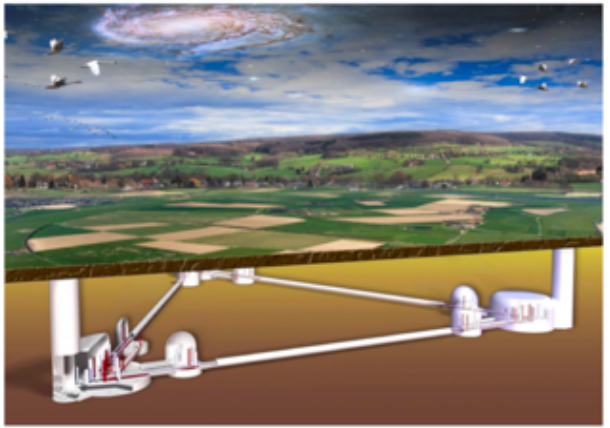
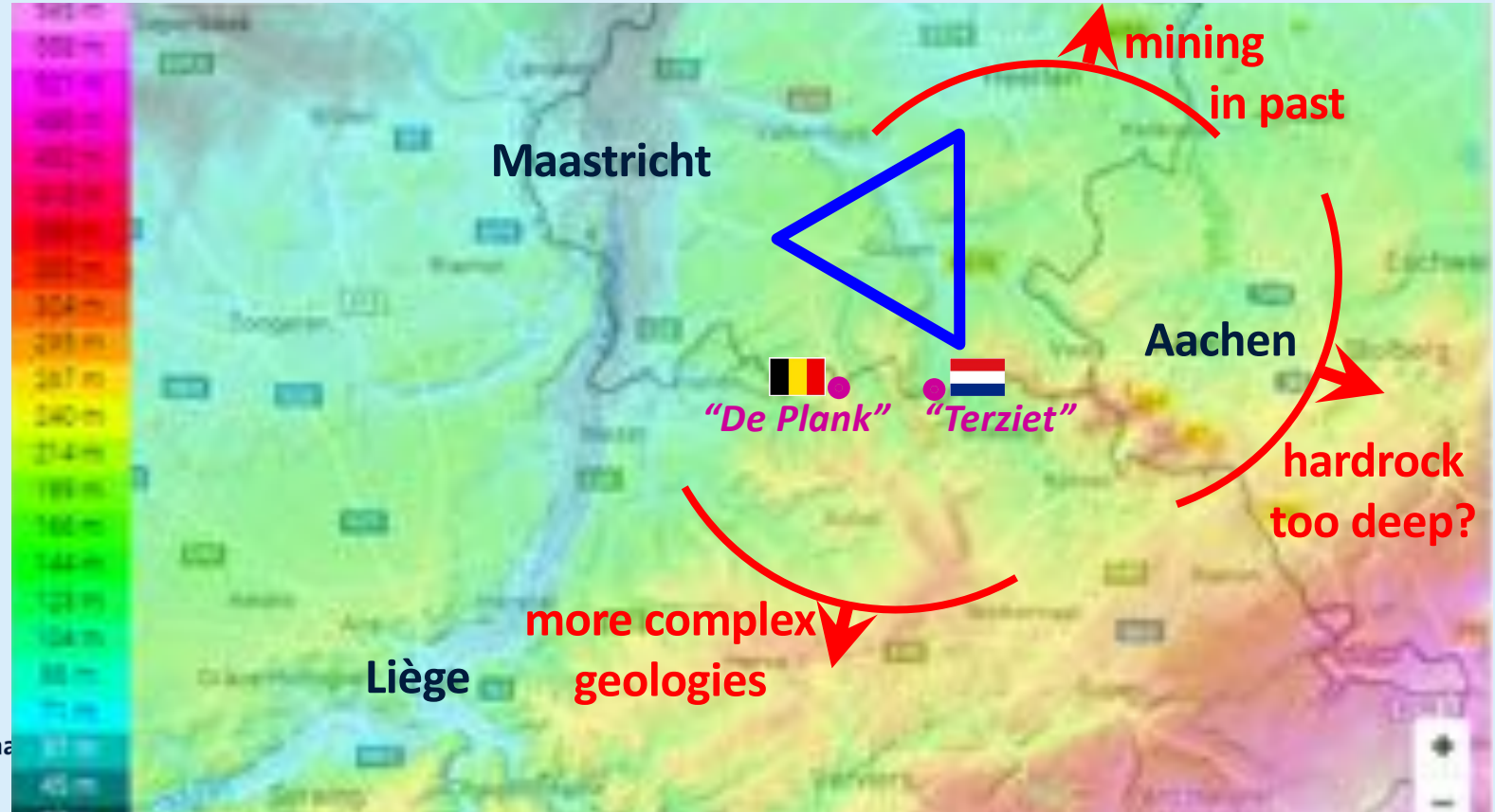


Figure 1: Artist impression of the Einstein Telescope gravitational wave observatory situated at a depth of 200-300 meters in the Euregio Meuse-Rhine landscape. The triangular topology with 10 kilometers long arms allows for the installation of multiple so-called laser interferometers. Each of which can detect ripples in the fabric of space-time – the unique signature of a gravitational wave – as minute relative movements of the mirrors hanging at the bottom of the red and white towers indicated in the illustration at the corners of the triangle.

Seimsic studies in EUREGIO



Dutch-Belgium-German Efforts

Homework done to qualify site in Euregion:

- Positive geological studies
- Positive economic impact studies
- Strong effort across borders (MOU just refreshed)


technopolis (group)

Impact assessment of the Einstein Telescope

Final report, 28/09/2018

Impact assessment of the Einstein Telescope

Final report, 28/09/2018

technopolis (group) September 2018

Joost van Barneveld
Lisanne Saes
Ivette Ontanon
Geert van der Veen


Cellule Socran

HEC LIÈGE RESEARCH

Étude d'impact socio-économique en Région wallonne de l'implantation du Télescope Einstein en Euregio

Juin 2019

Auteurs :

A. Boerboom, Chargée d'études, CIDE-SOCRAN
M. Mottet, Chargée d'études, CIDE-SOCRAN
N. Schils, Chargé d'études, CIDE-SOCRAN
D. Van Caillie, Professeur ordinaire, HEC ULIEGE
M. Anand, Assistante de recherche, HEC ULIEGE

ETpathfinder comes to Maastricht

Interreg
Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling

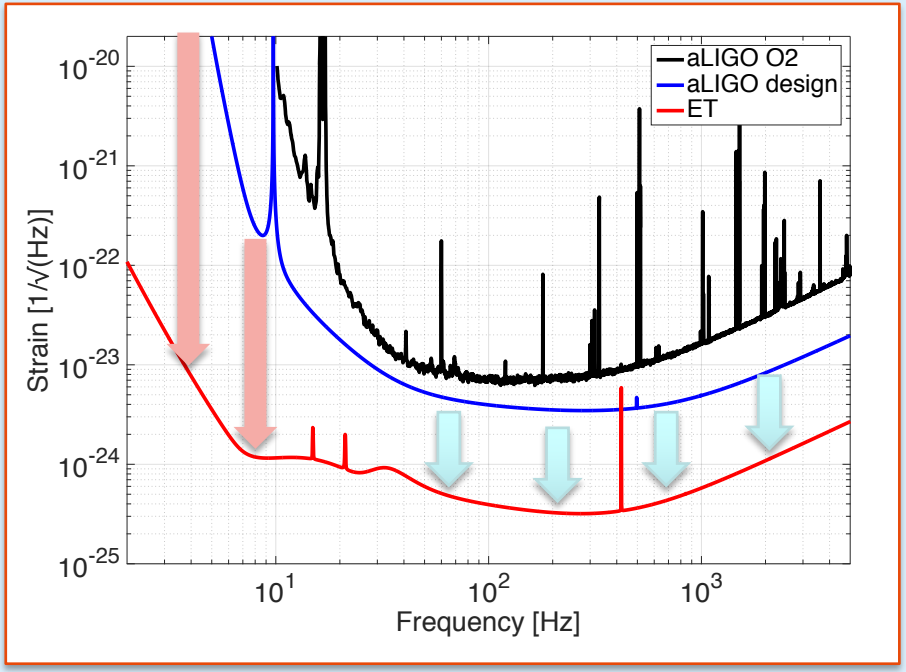
Maastricht University

ETpathfinder comes to Maastricht

Low Frequency Challenge

At mid and high frequency we aim for factor ~10 improvement.
At low frequency we are aiming for factors 100, 1000 and more improvement. ->

Need to do fundamental changes in technology and concepts



New Technologies

ET requires technological advances on all fronts:

- New temperature => 10-20K
- New mirror material => Silicon
- New laser wavelength => 1.5-2.1 microns
- Advanced quantum-noise-reduction schemes

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- **New mirror material => Silicon**
- **New temperature => 10-20K**
- **New laser wavelength => 1.5-2.1 microns**
- **Advanced quantum-noise-reduction schemes**

ETpathfinder = Collaborative Effort!

1. *Nikhef*
2. *Maastricht University*
3. *Eindhoven University of Technology*
4. *University of Leuven*
5. *Ghent University*
6. *University of Antwerp*
7. *University of Hasselt*
8. *University of Liège*
9. *Vrije Universiteit Brussel*
10. *Université catholique de Louvain*
11. *Fraunhofer Institute for Laser Technology (ILT)*
12. *RWTH Aachen University*
13. *University of Twente*
14. *Flemish Institute for Technological Research (VITO), Mol*
15. *Netherlands Organisation for Applied Scientific Research (TNO), Delft*

plus contributions from AEI, Australia, Italy, the UK, etc.

€14.5m capital investment (Interreg, institutions, governments, provinces)

Committed manpower of 100+ man years (scientists and engineers) over the next 5 years

Collaboration with relevant local and national industry partners

ETpathfinder longterm ambition

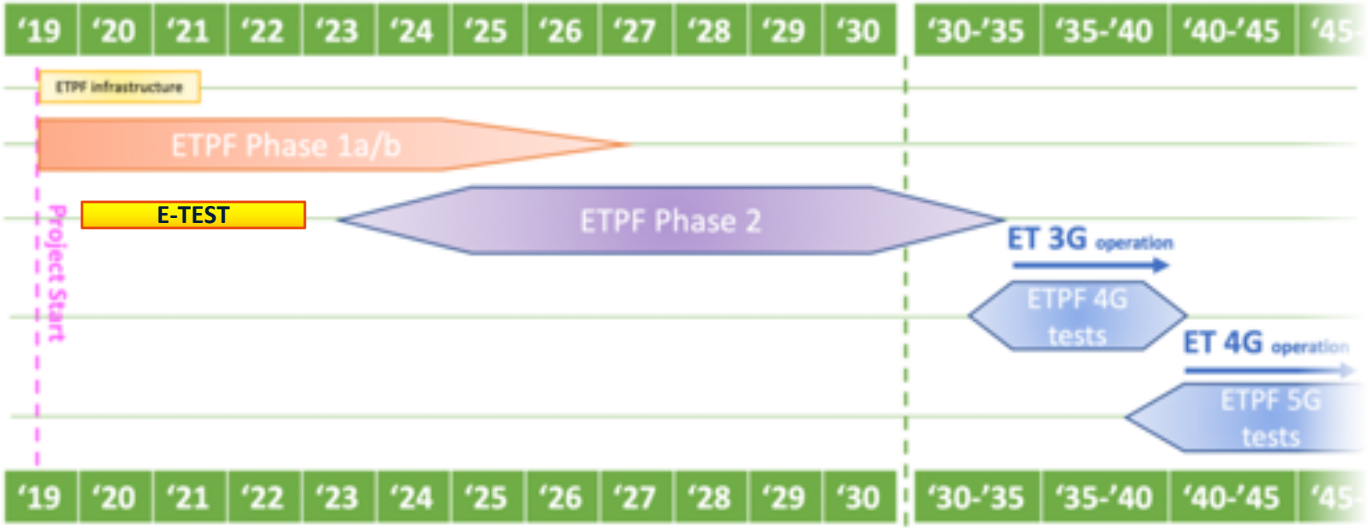

Figure 1.1: Rough overview of the estimated ETpathfinder timelines. After completion of Phase 1 and Phase 2 (see description in text), it is anticipated that while ET is running in observation mode with generation X technology, that ETpathfinder will contribute to prototyping generation $X + 1$ technologies.

NEWS: E-TEST approved

1. *University of Liège*
2. *Fraunhofer Institute for Laser Technology*
3. *RWTH Aachen University*
4. *University of Hasselt*
5. *Katholieke Universiteit Leuven*
6. *NWO-I / Nikhef*
7. *Rheinische Friedrich-Wilhelms-Universitaet Bonn*
8. *NMWP Management GmbH*
9. *Koninklijk Nederlands Meteorologisch Instituut*
10. *Maastricht University*
11. *Université catholique de Louvain*

Boreholes + geological studies (determining ET site in EMR region) + Large cryogenic silicon mirror

WP	Lead	Funds
T1: Seismic and Cooling	Nikhef	3832 k
T2: Optical engineering	Fraunhofer	3215 k
T3: EMR underground observatory	Liege	1507 k
T4: Cross-border geological model	RWTH	5412 k

Maastricht University

Thank you for your attention

Image Credit: NASA/Hubble Telescope, Lueck AEI