Einstein Telescope
/ NL / BE / D /

The Einstein Telescope

Science and Instrumentation

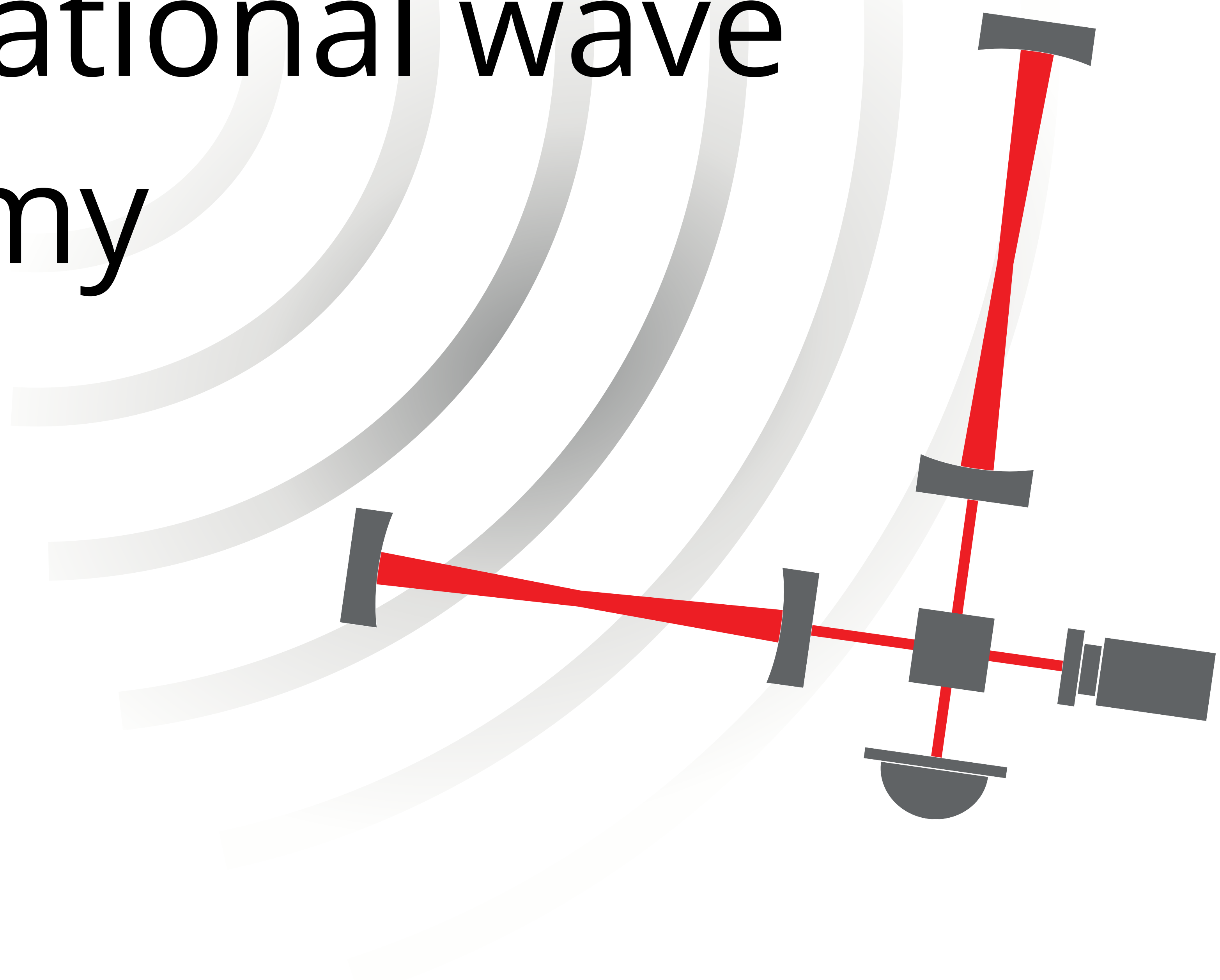
Prof. Andreas Freise

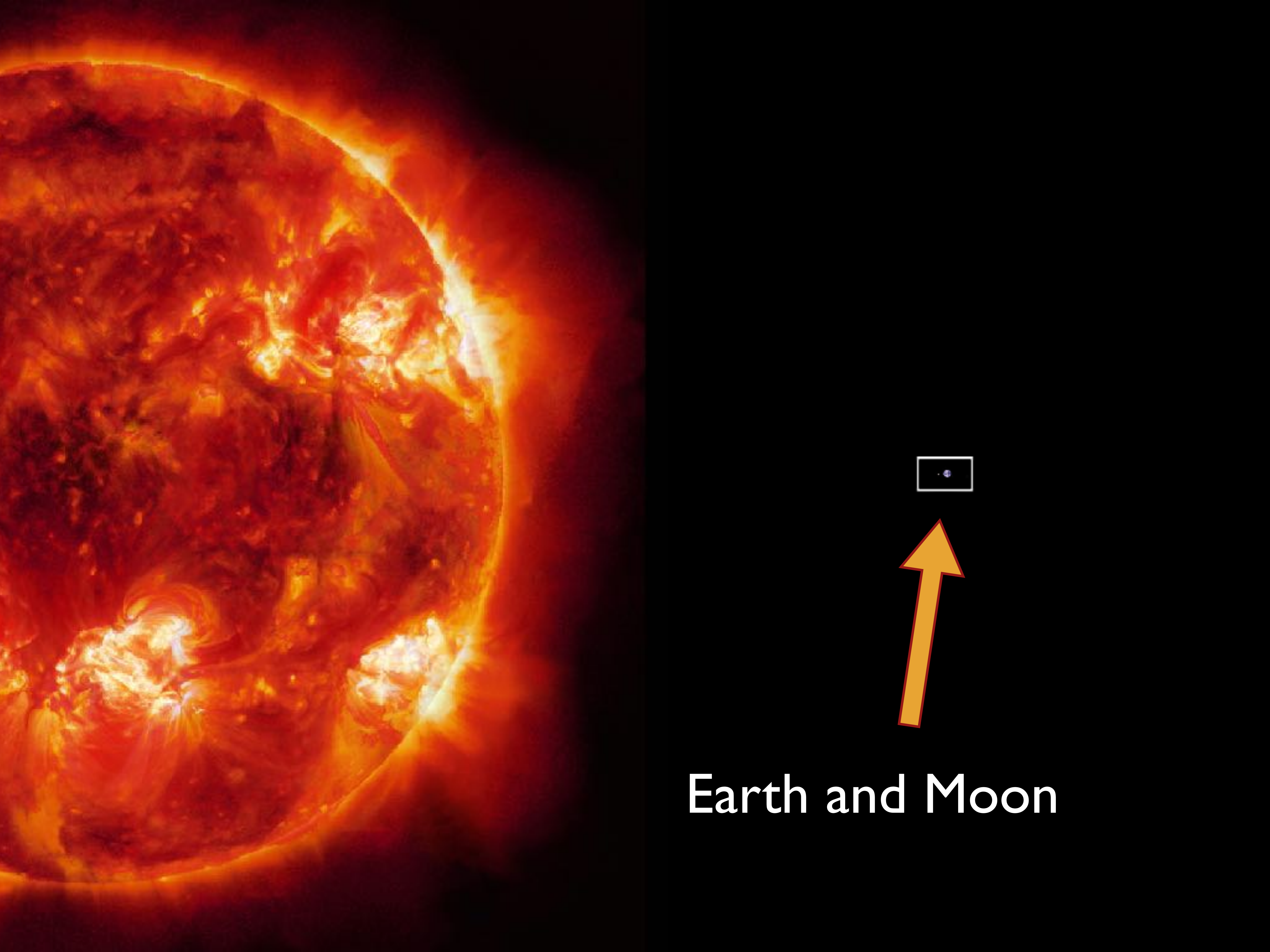
VU Vrije Universiteit Amsterdam

01.07.2020, Webinar on:
Technical challenges of the Einstein Telescope

Nikhef

A very quick introduction to gravitational wave astronomy




Earth and Moon

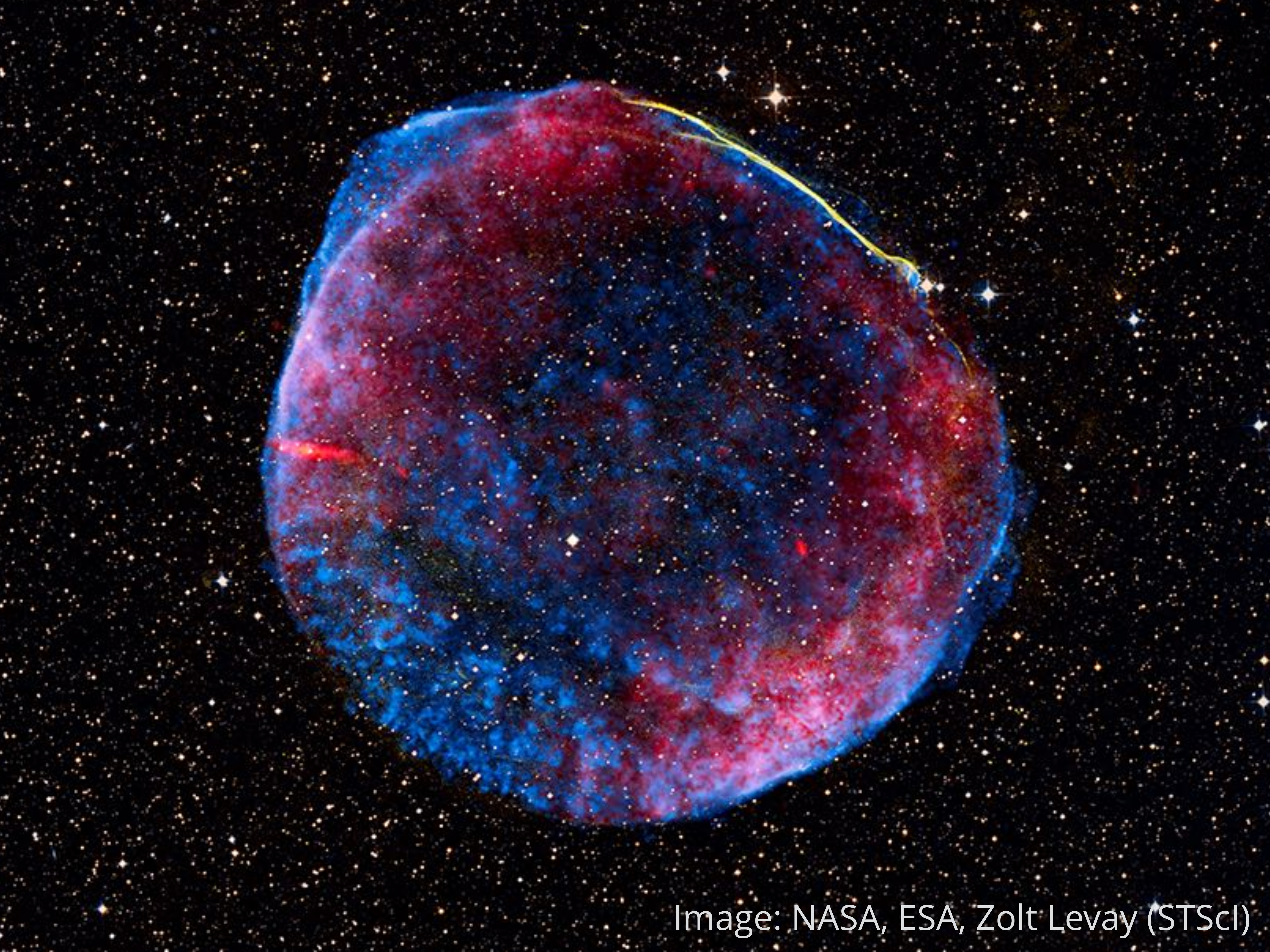
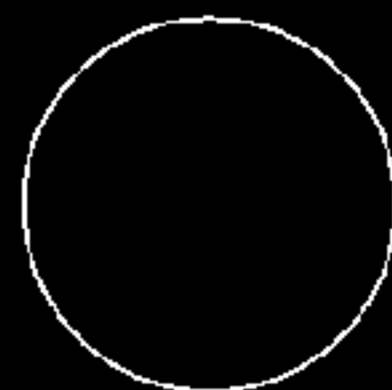


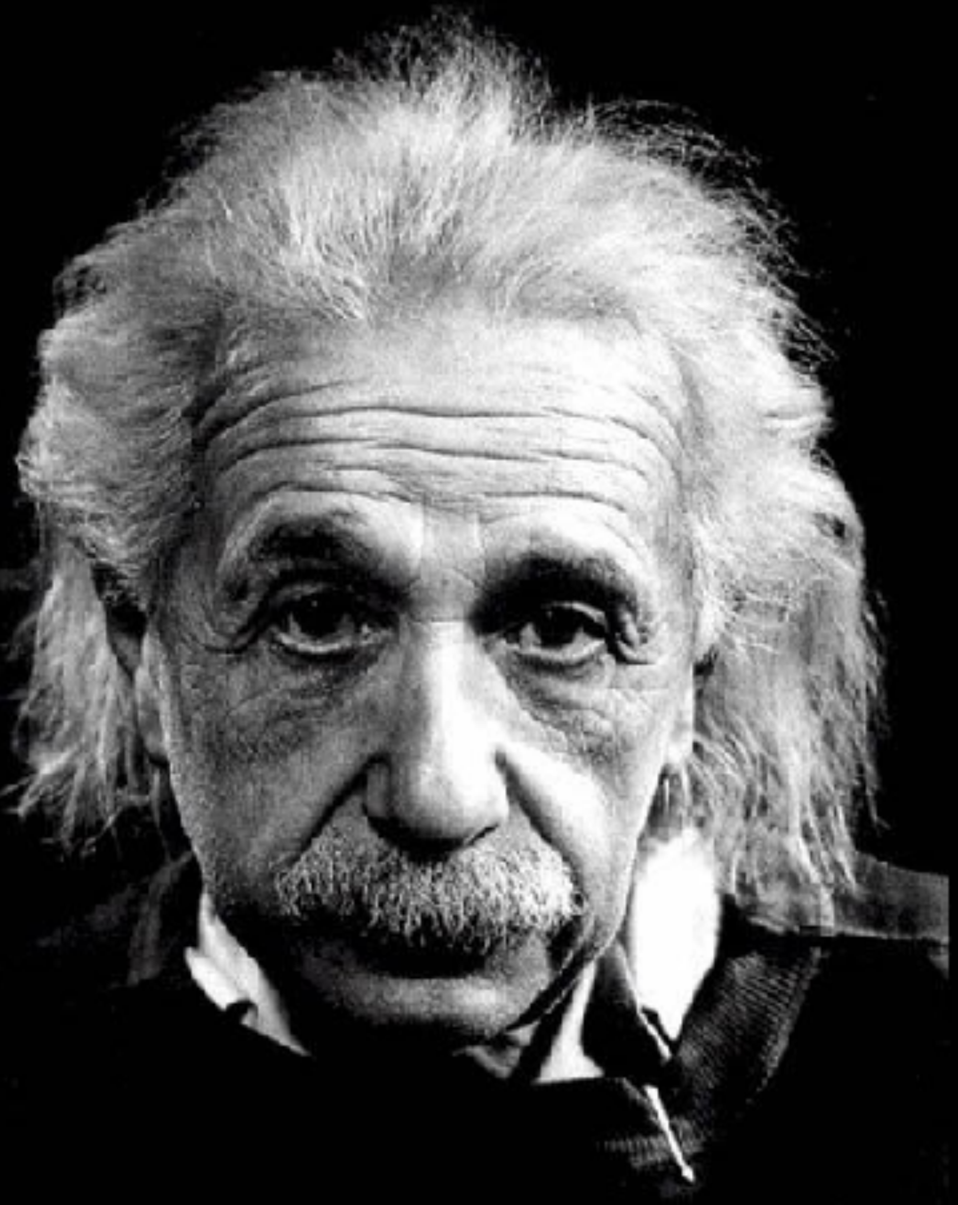
Image: NASA, ESA, Zolt Levay (STScI)

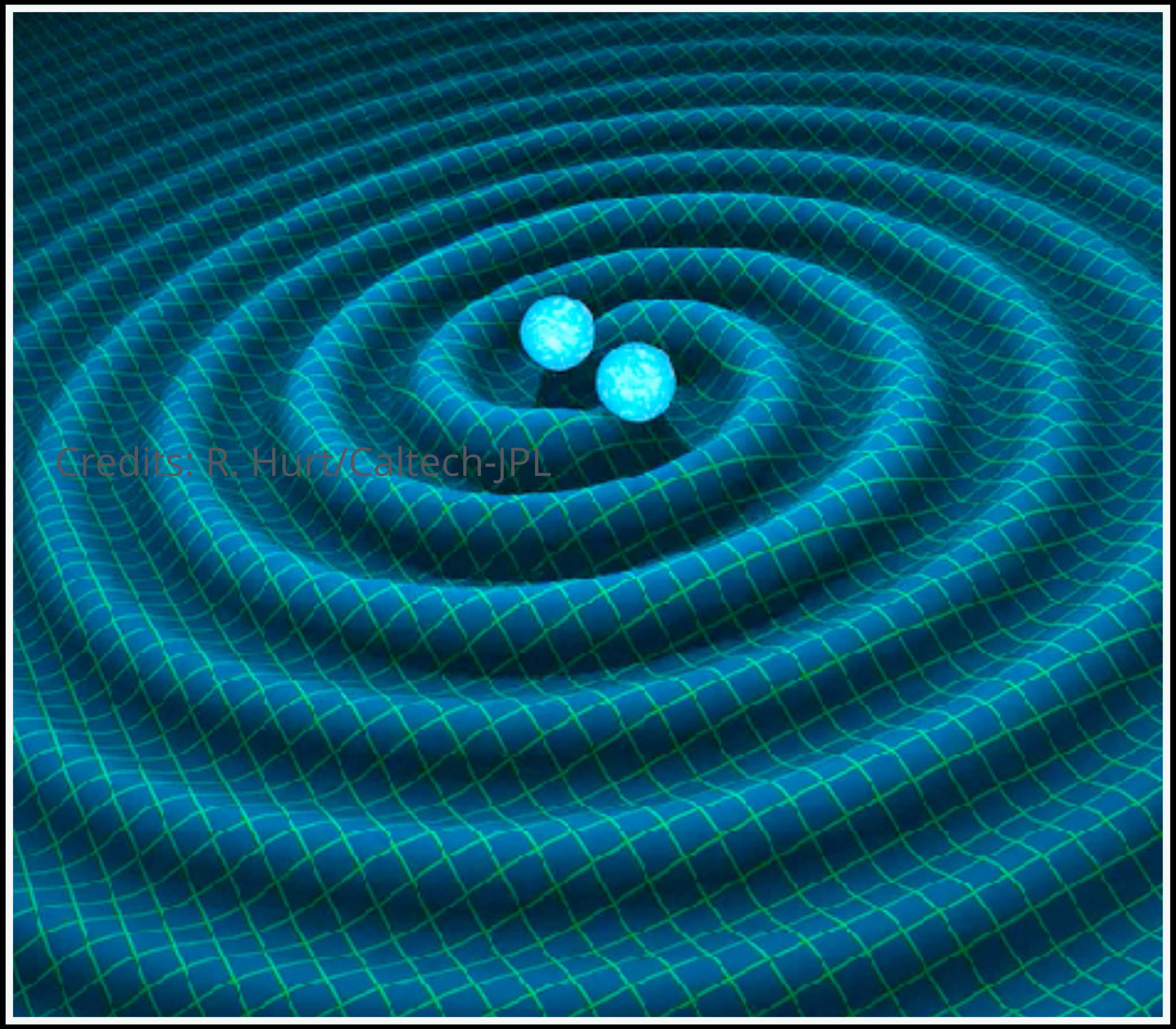
Neutron Star



Black Hole

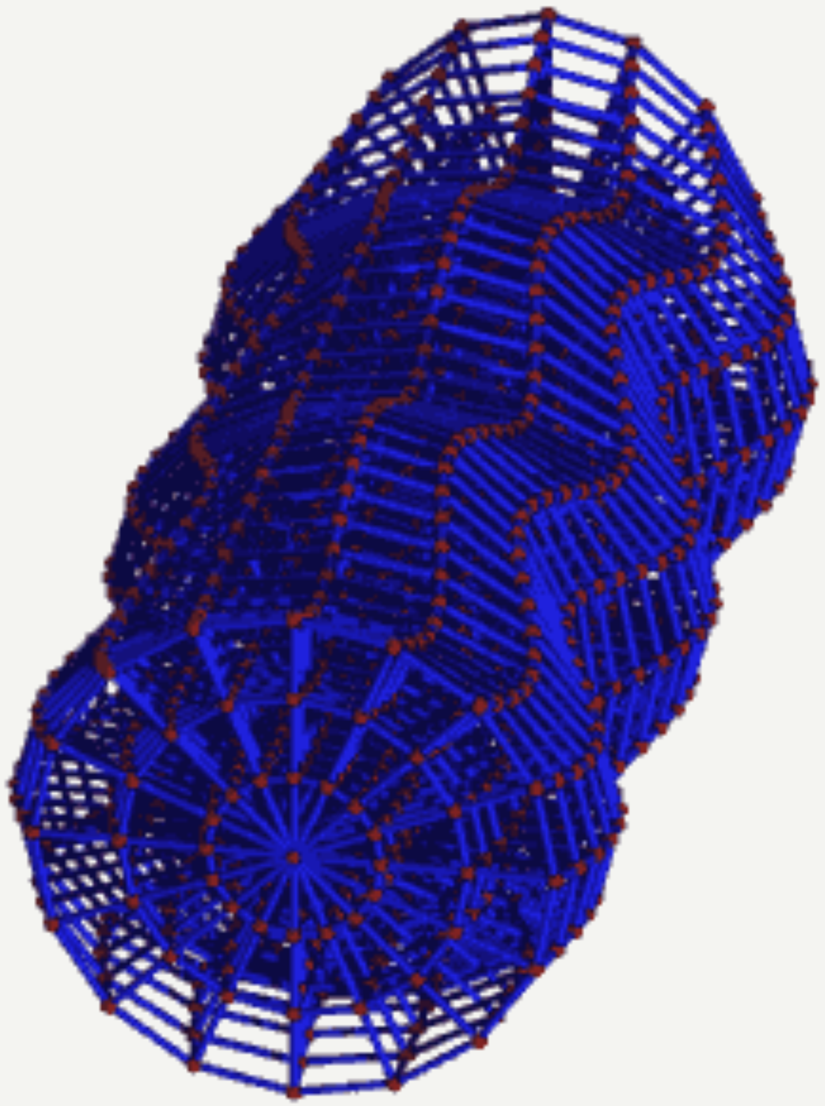
Amsterdam

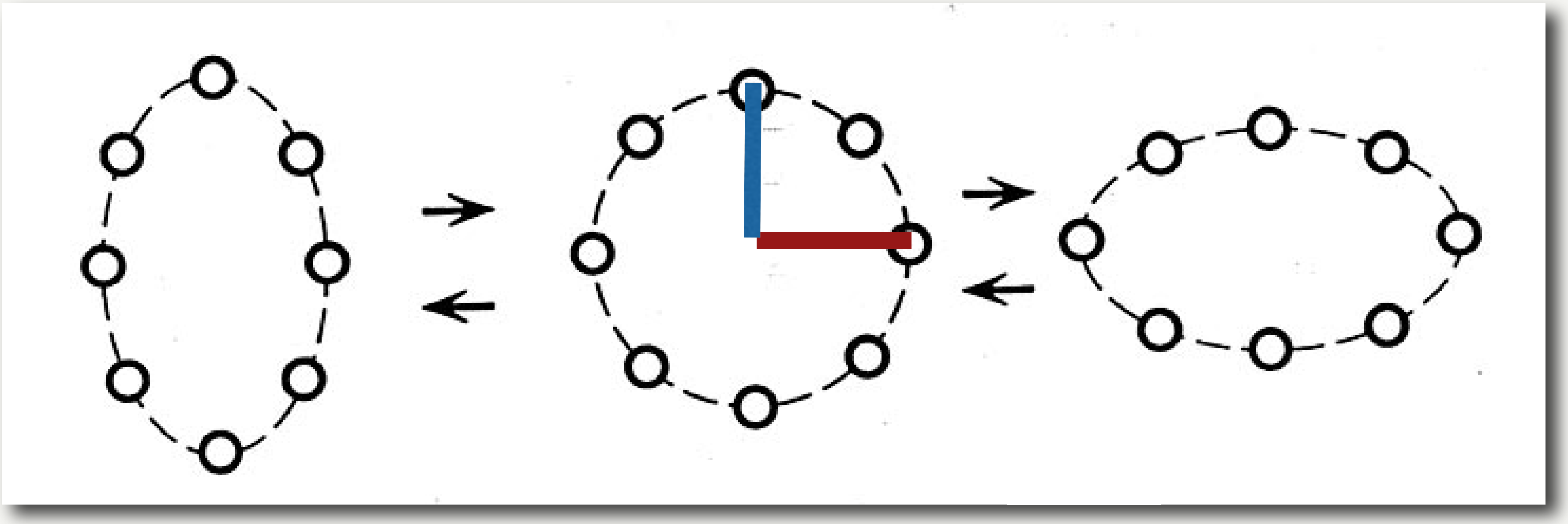




Credits: R. Hurt/Caltech-JPL

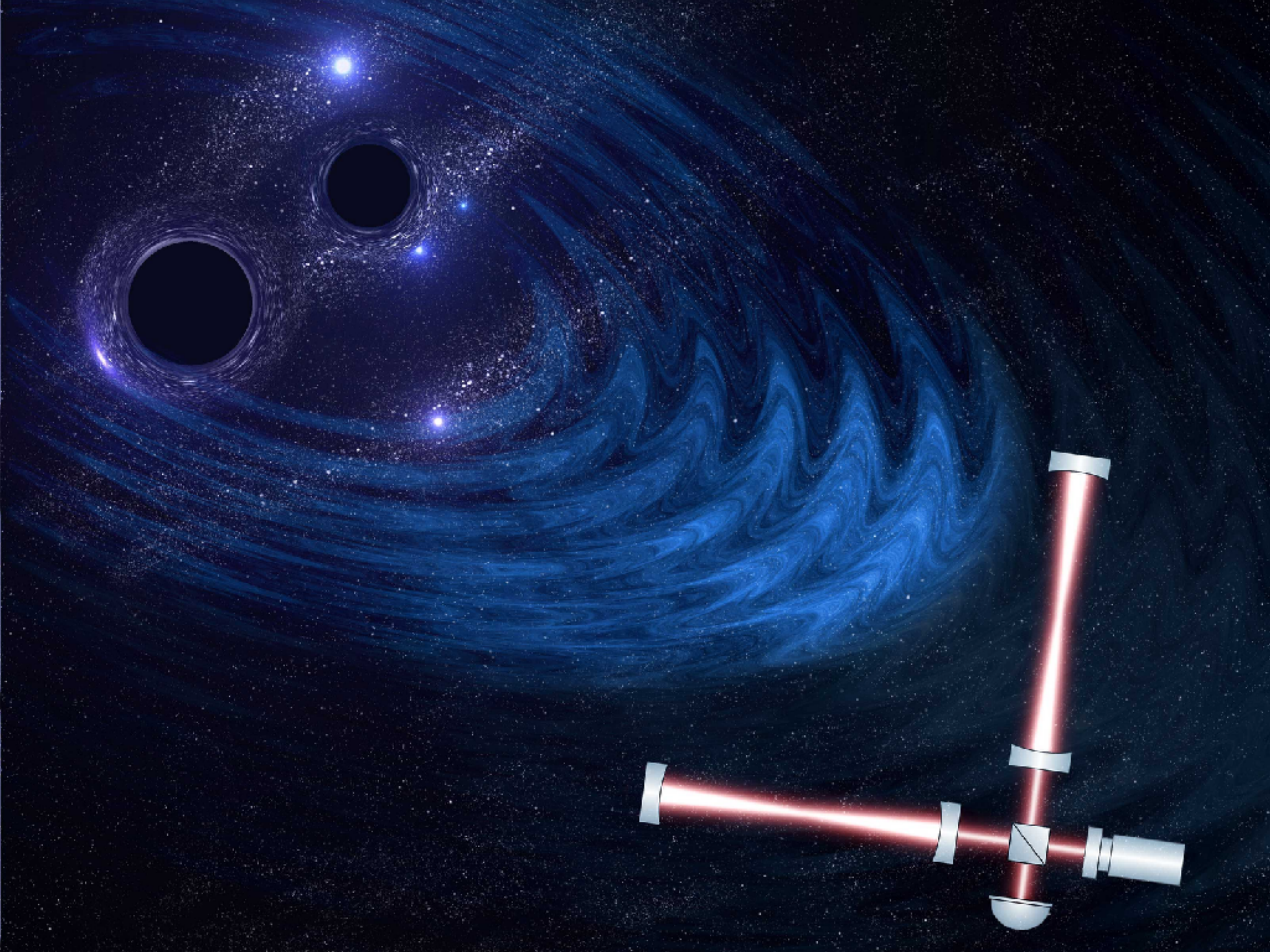
Observing Gravitational Waves:





Gravitational waves change
the **distance** between objects.

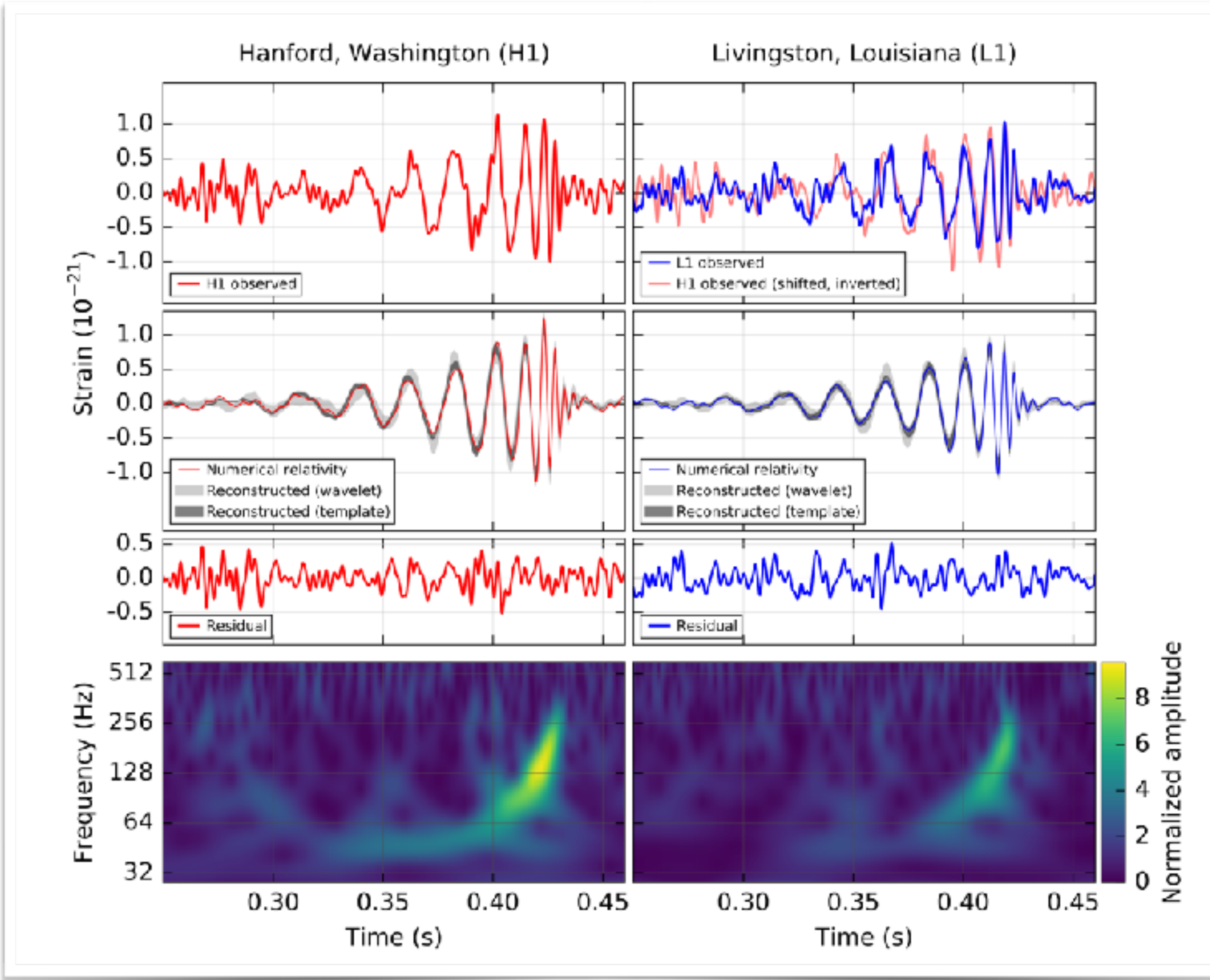
[http://www.einstein-online.info]

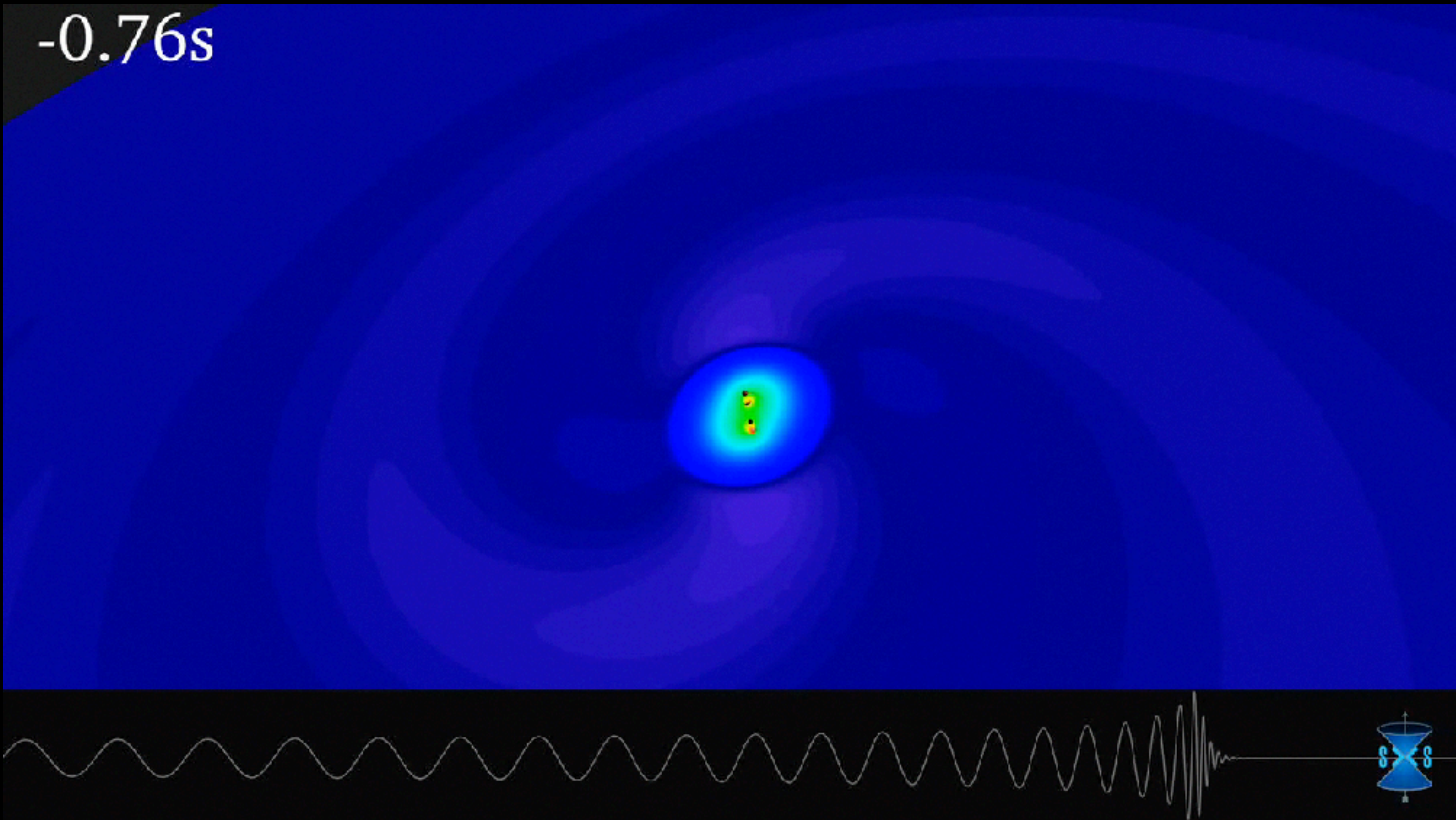


Data

... recorded by LIGO on the
14th of September 2015, at 09:50:45 UTC

GW150914

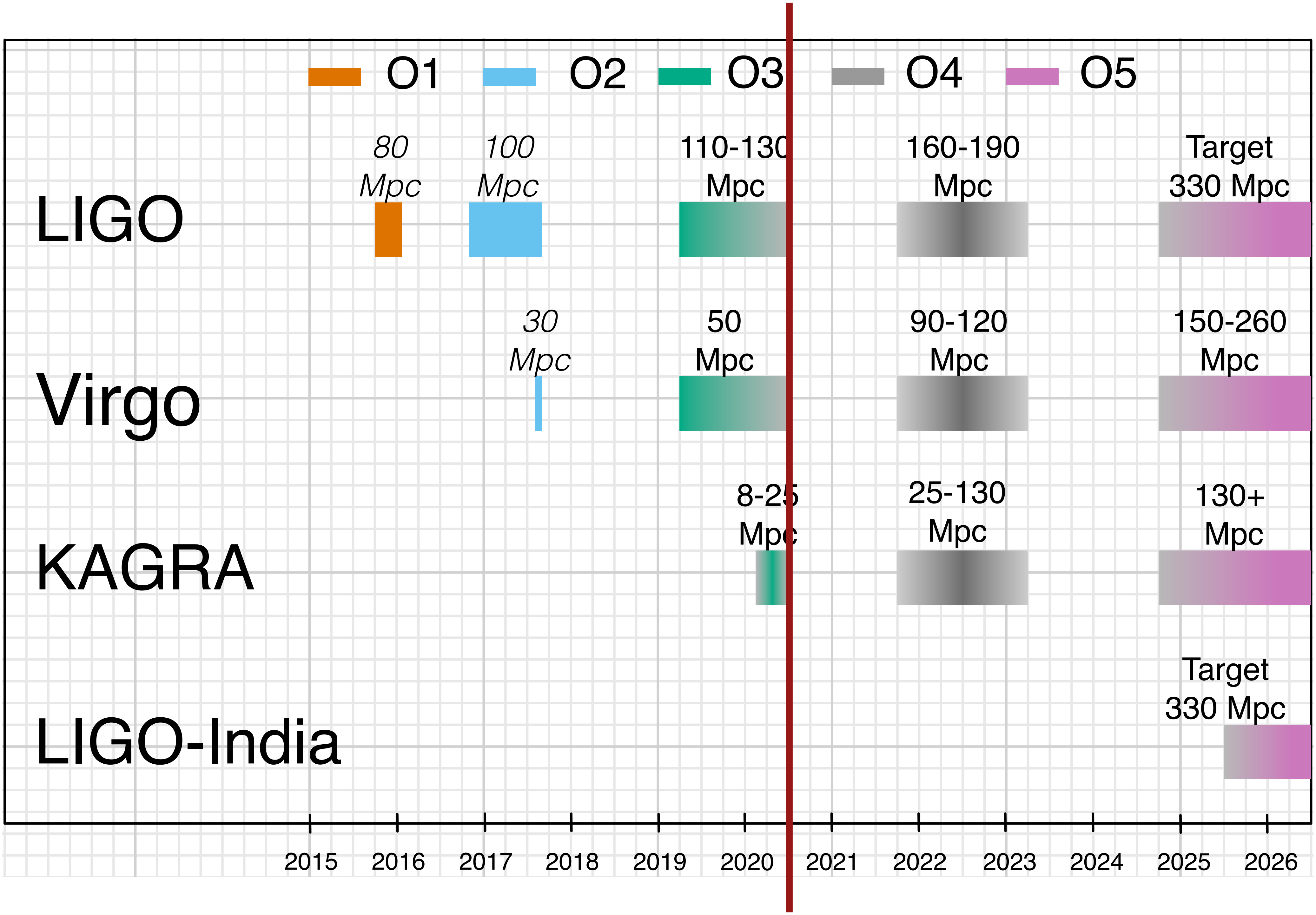




-0.76s

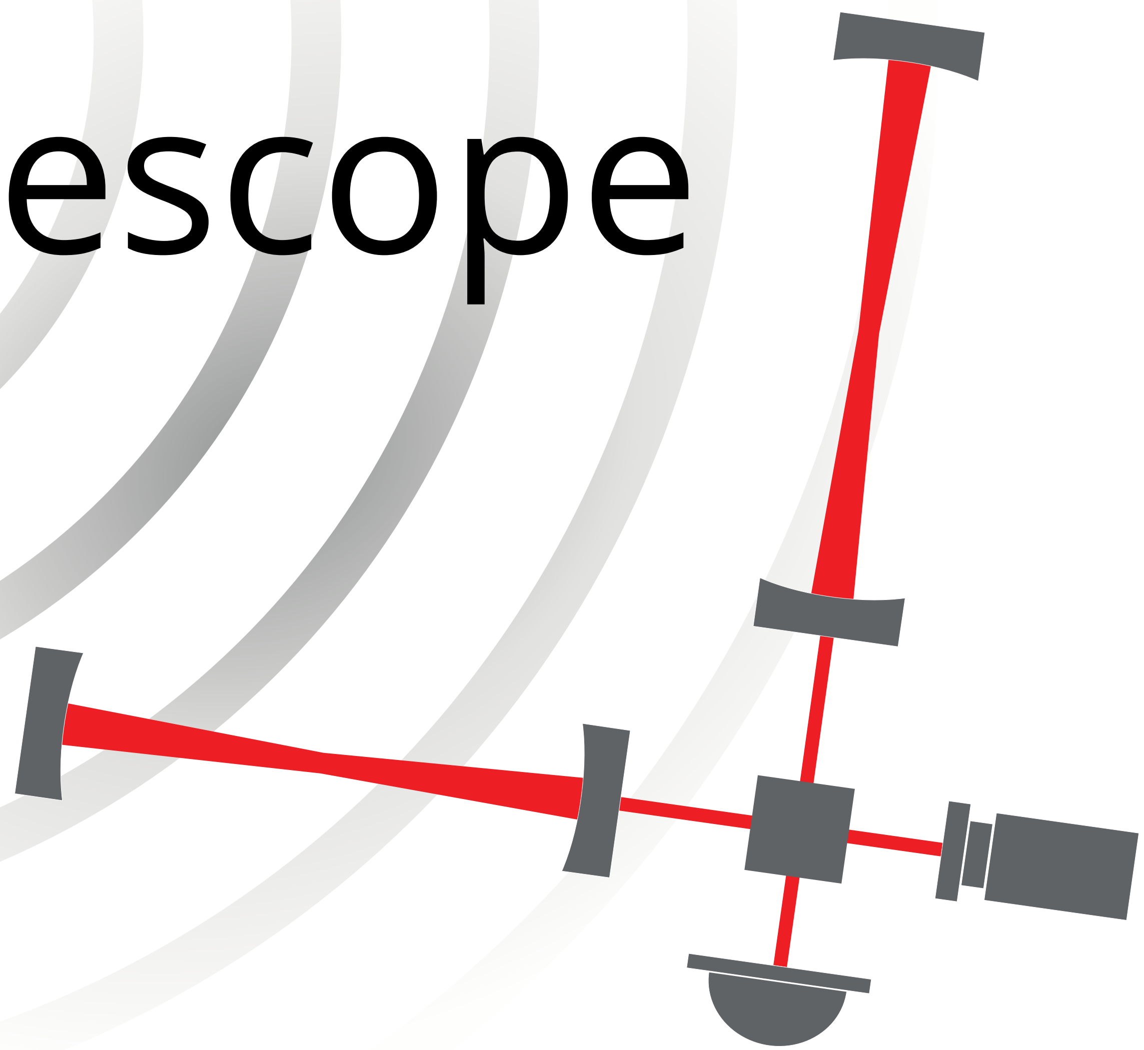
Ground-based network

Planned observations with current detectors



?

The case for the Einstein Telescope

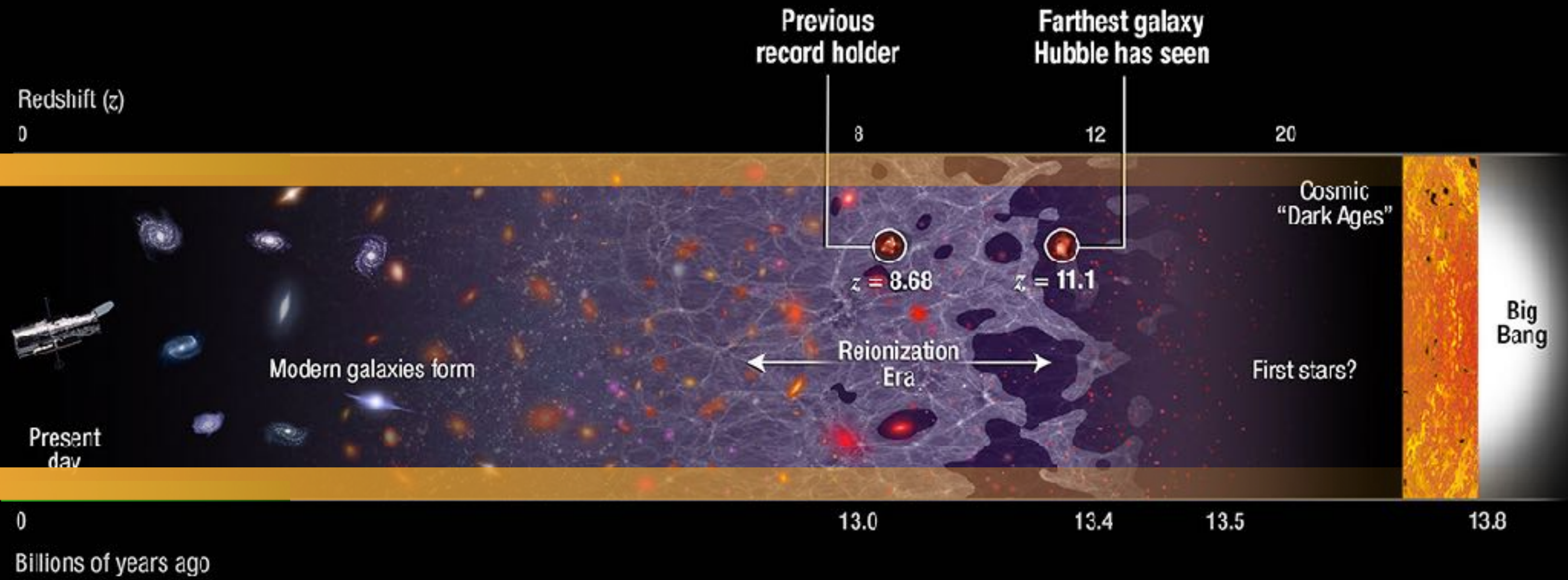



So, Galileo, now that you discovered Jupiter’s moons, do we need this new ‘telescope’ for anything else?

Probing the history of the universe

Current detectors

Einstein Telescope



[Credits: NASA, ESA, P. Oesch and B. Robertson (University of California, Santa Cruz), and A. Feild (STScI)]

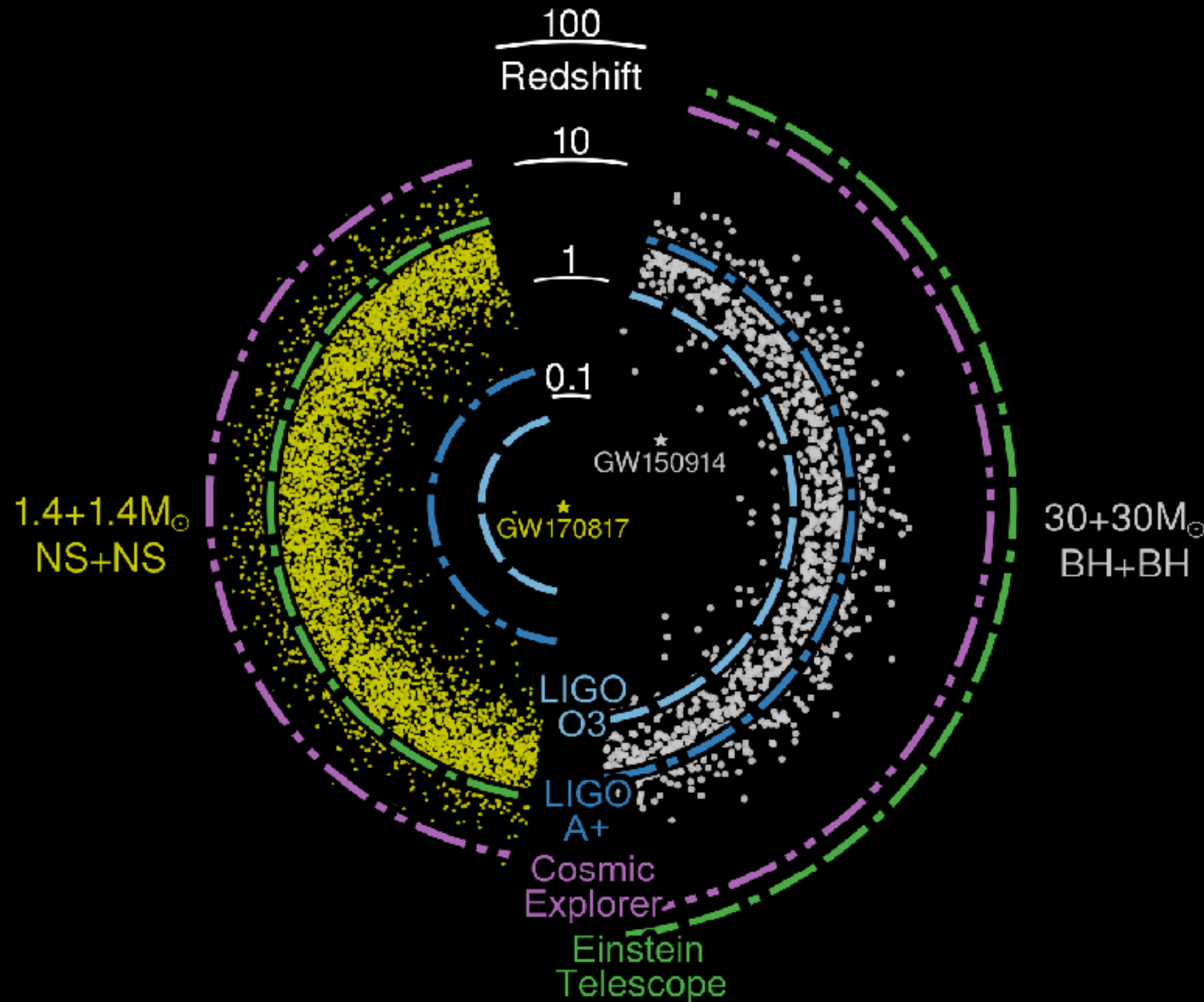
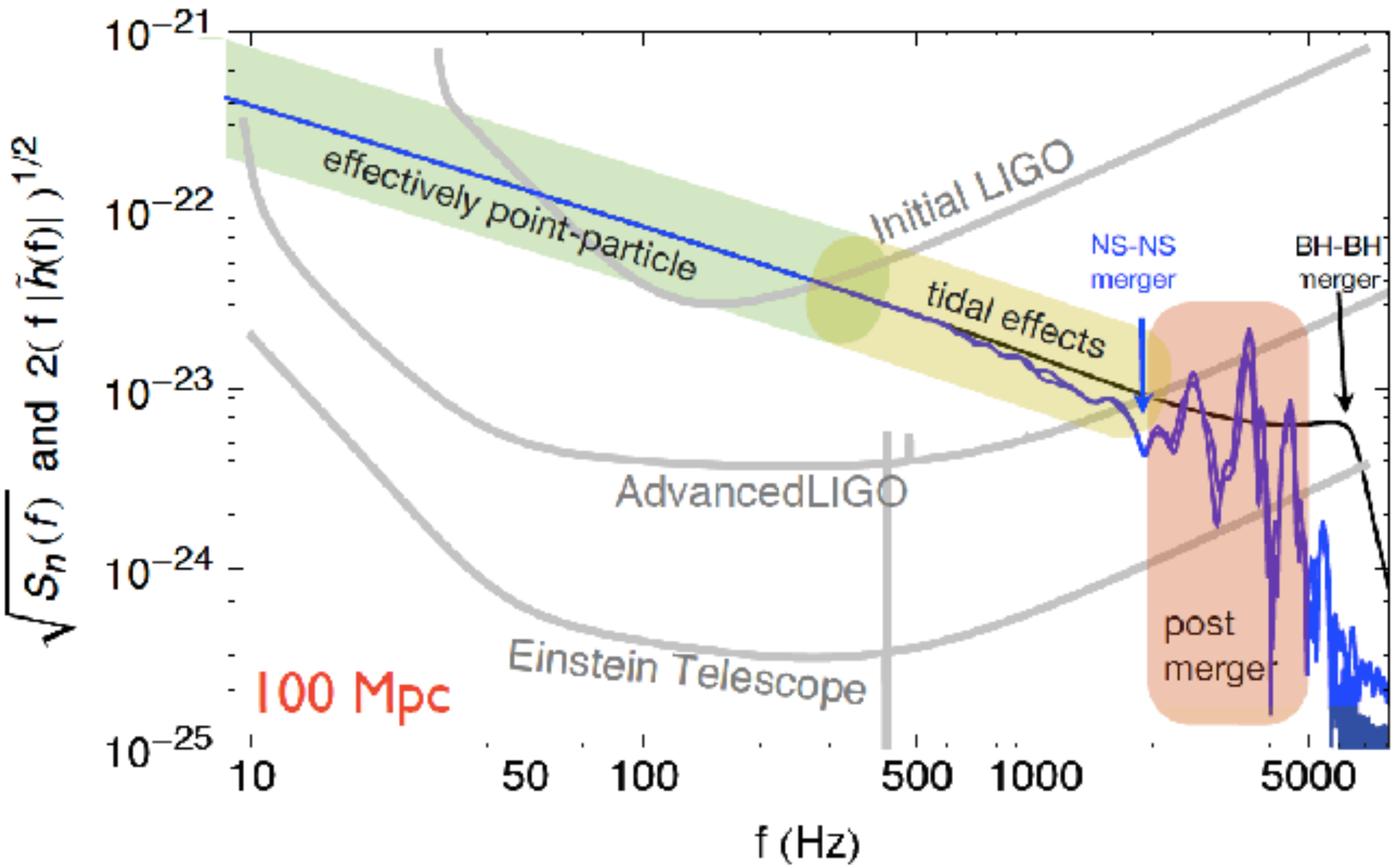


Image by Evan Hall and Salvatore Vitale

Strange Matter in Neutron Stars



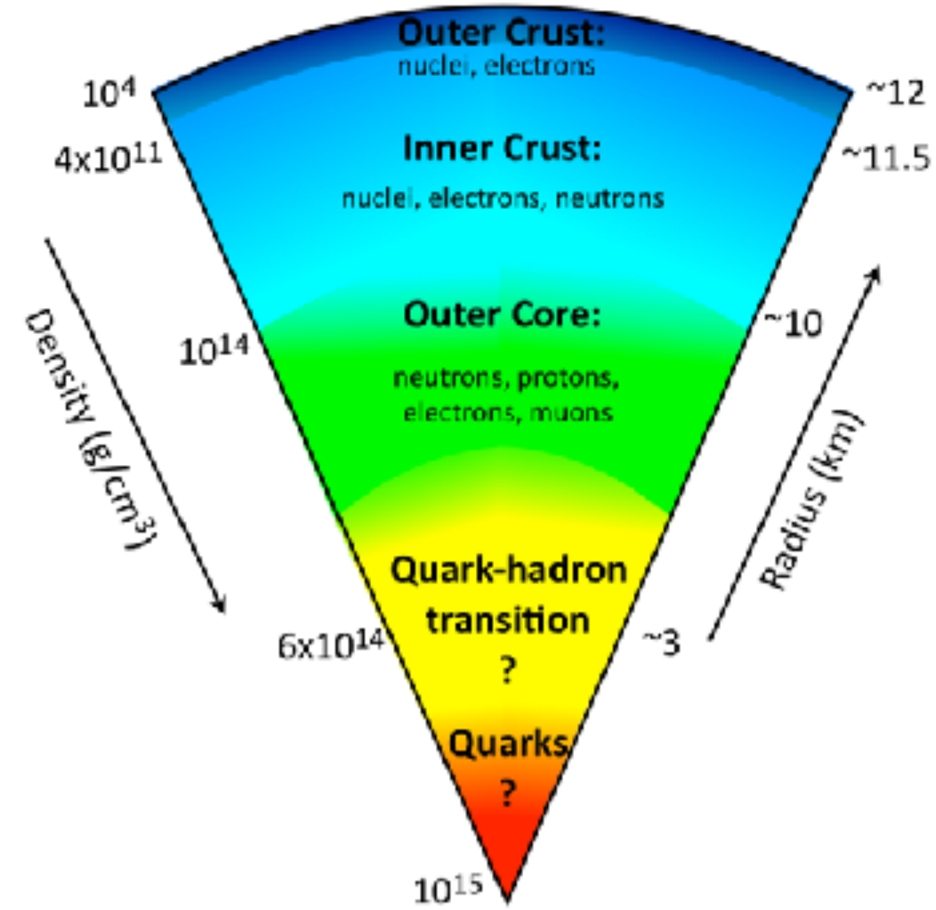
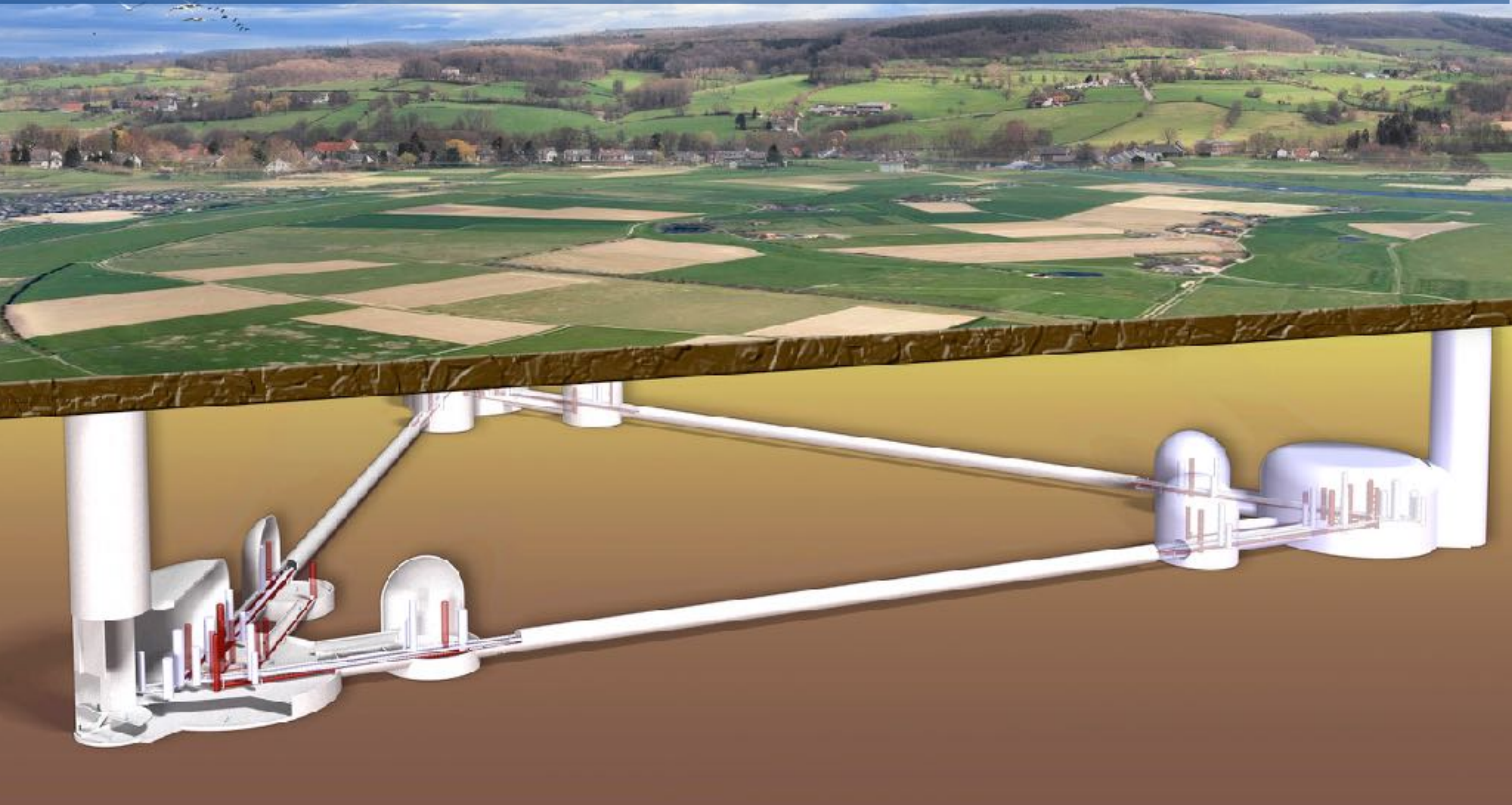
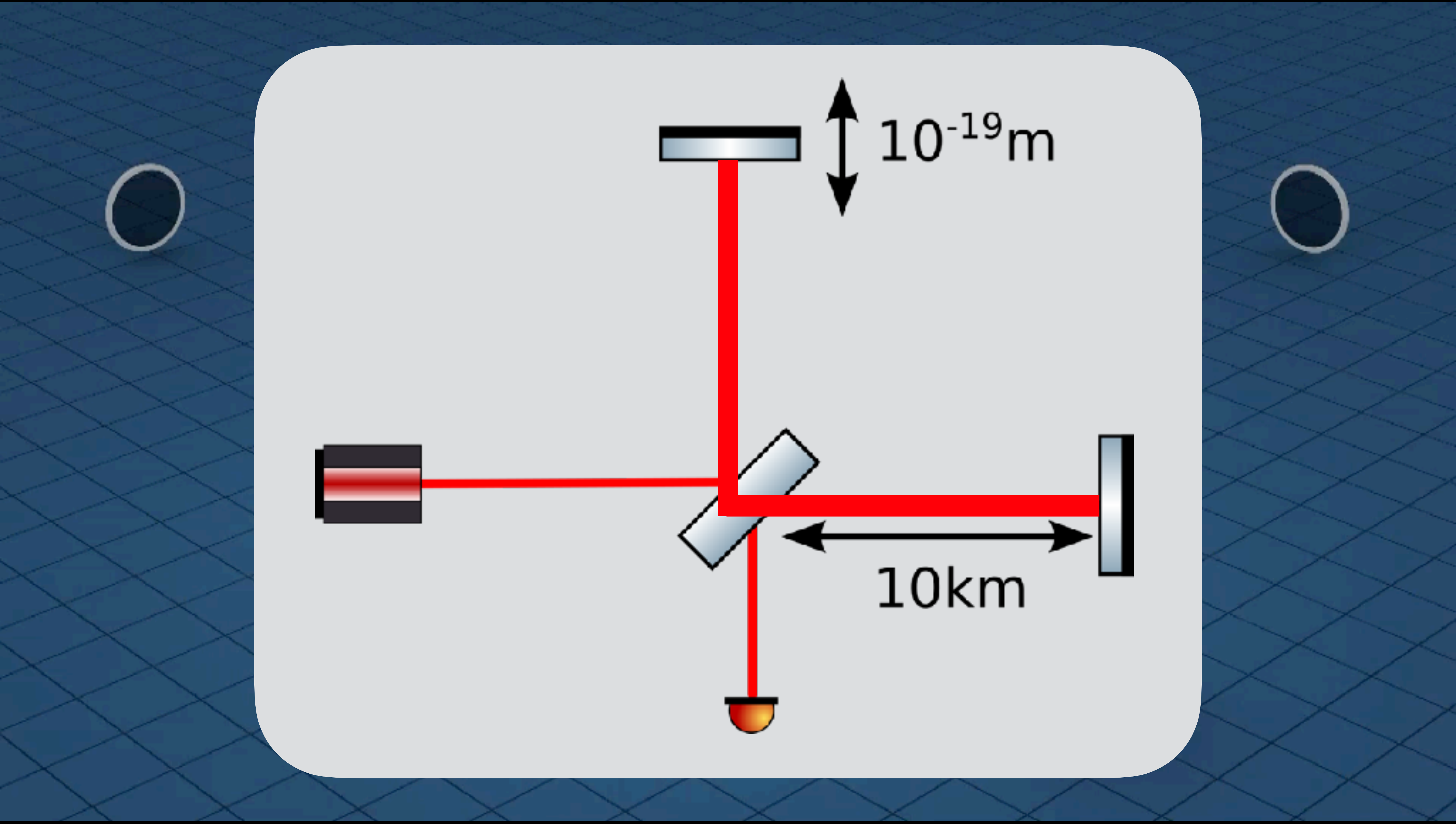


Figure by Jocelyn Read, see also arXiv:1306.4065

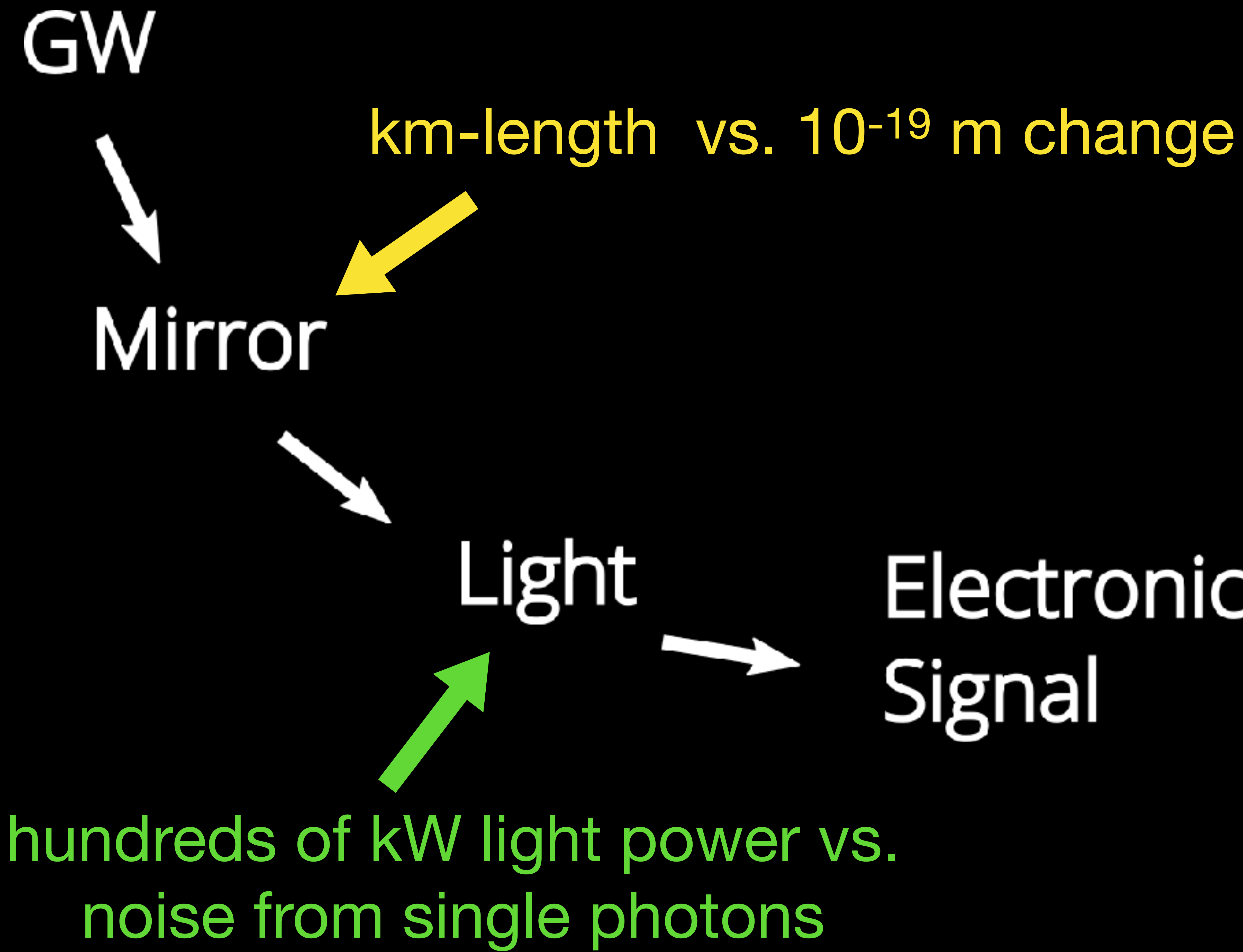
Einstein Telescope

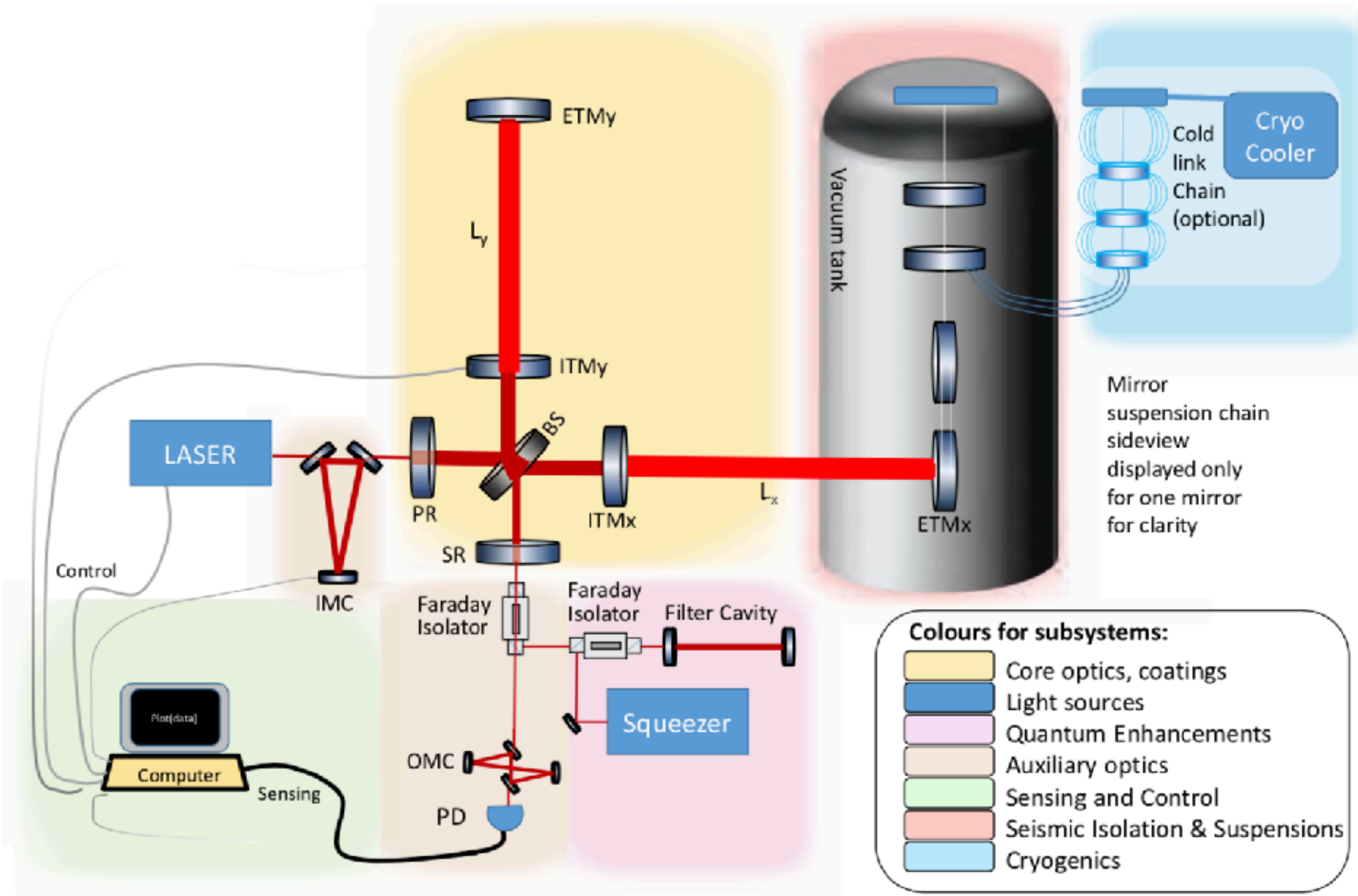
Vision for a new large-scale European gravitational wave observatory





Credit: LIGO/T. Pyle


GW
km-length vs. 10^{-19} m change
Mirror
Light
Electronic Signal
hundreds of kW light power vs.
noise from single photons



https://gwic.ligo.org/3Gsubcomm/documents/GWIC_3G_R_D_Subcommittee_report_July_2019.pdf

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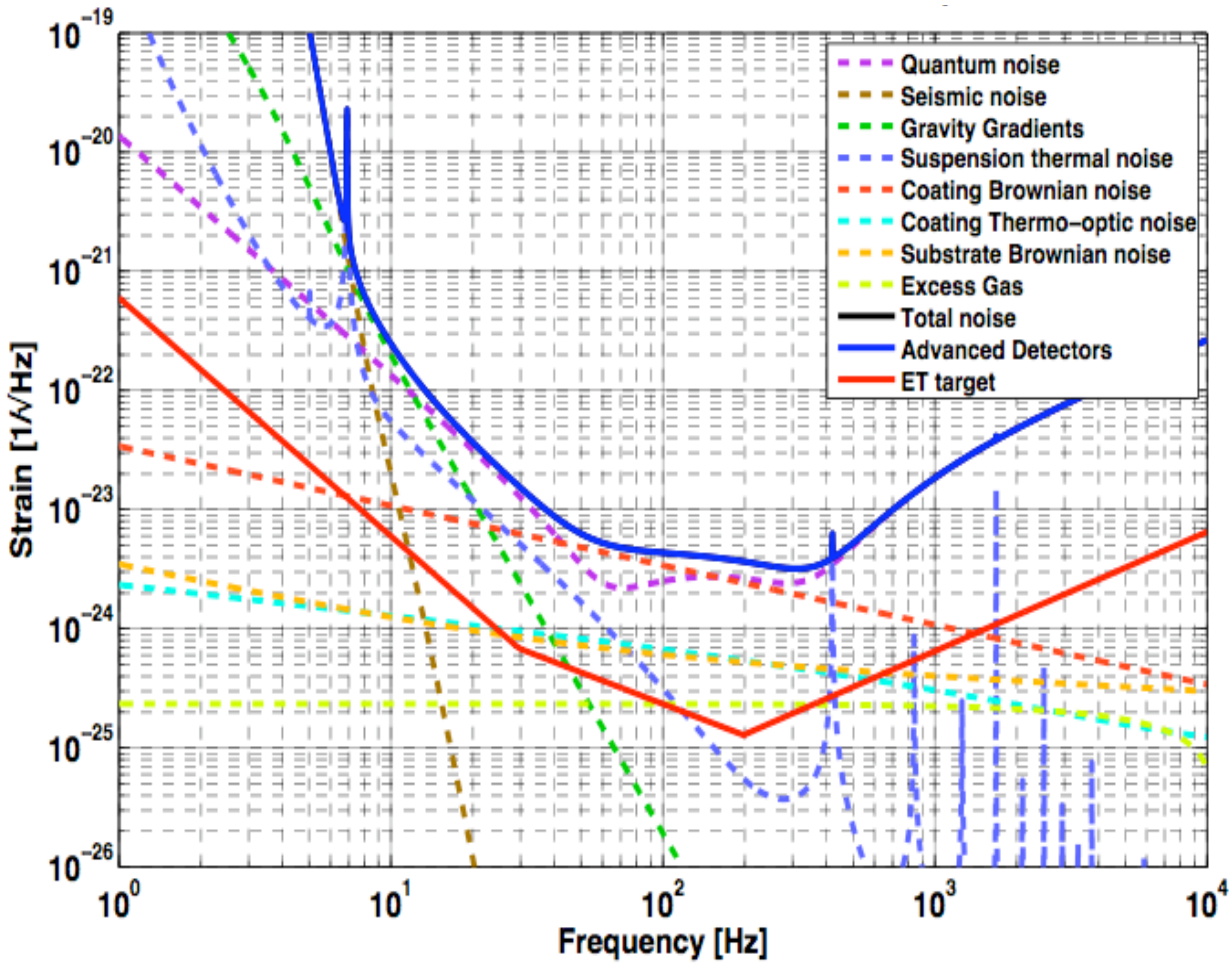
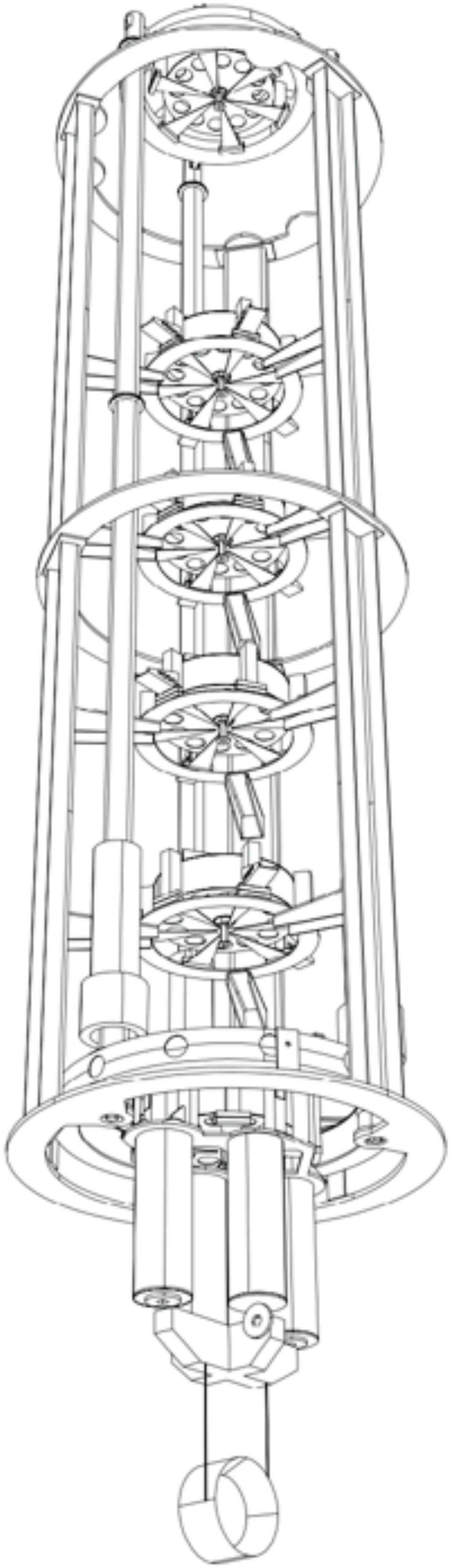
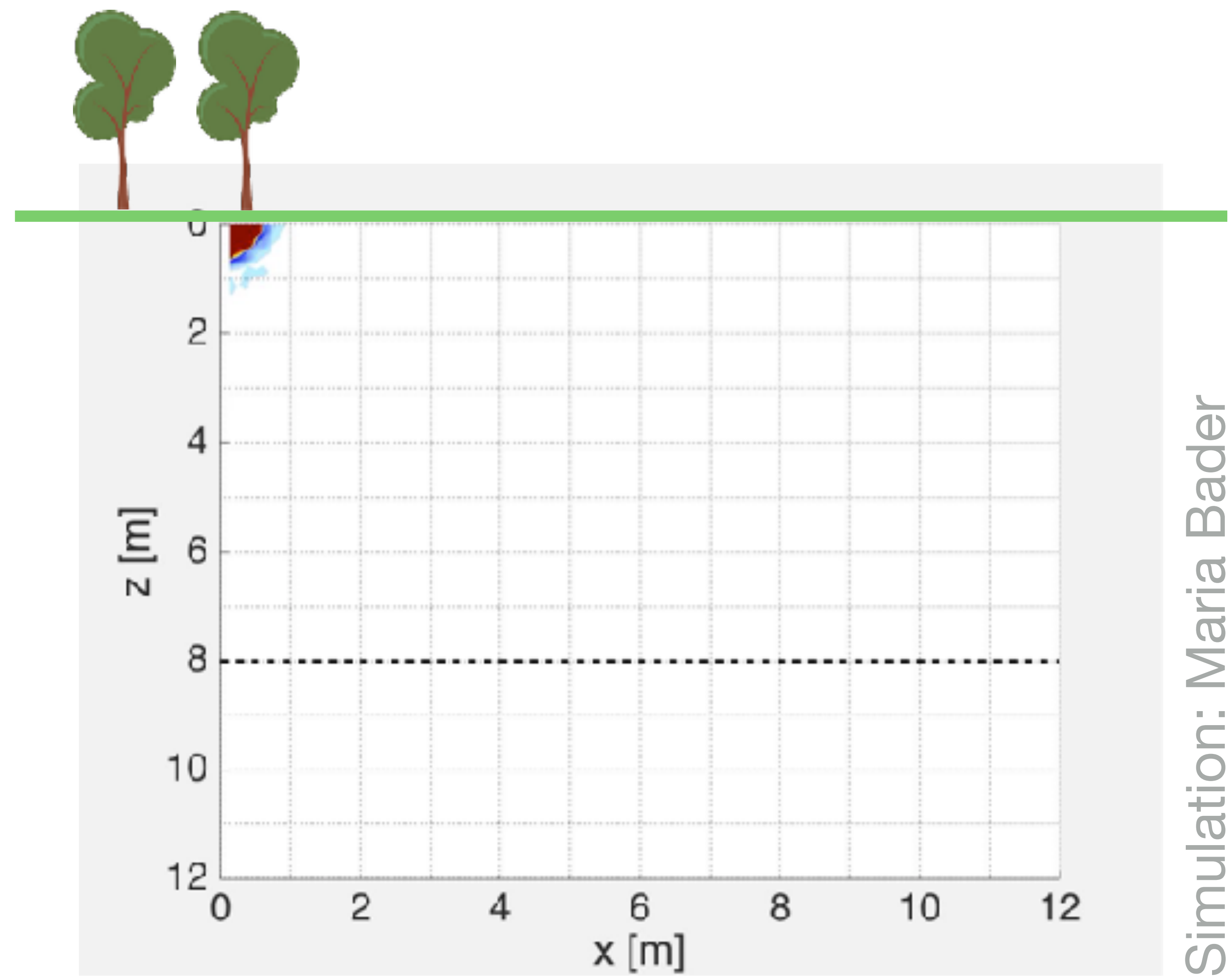
Design tool: noise budget



Reducing vibrations





Simulation: Maria Bader

ET is planned for a depth of >200m

Higher-power and ultra-stable lasers

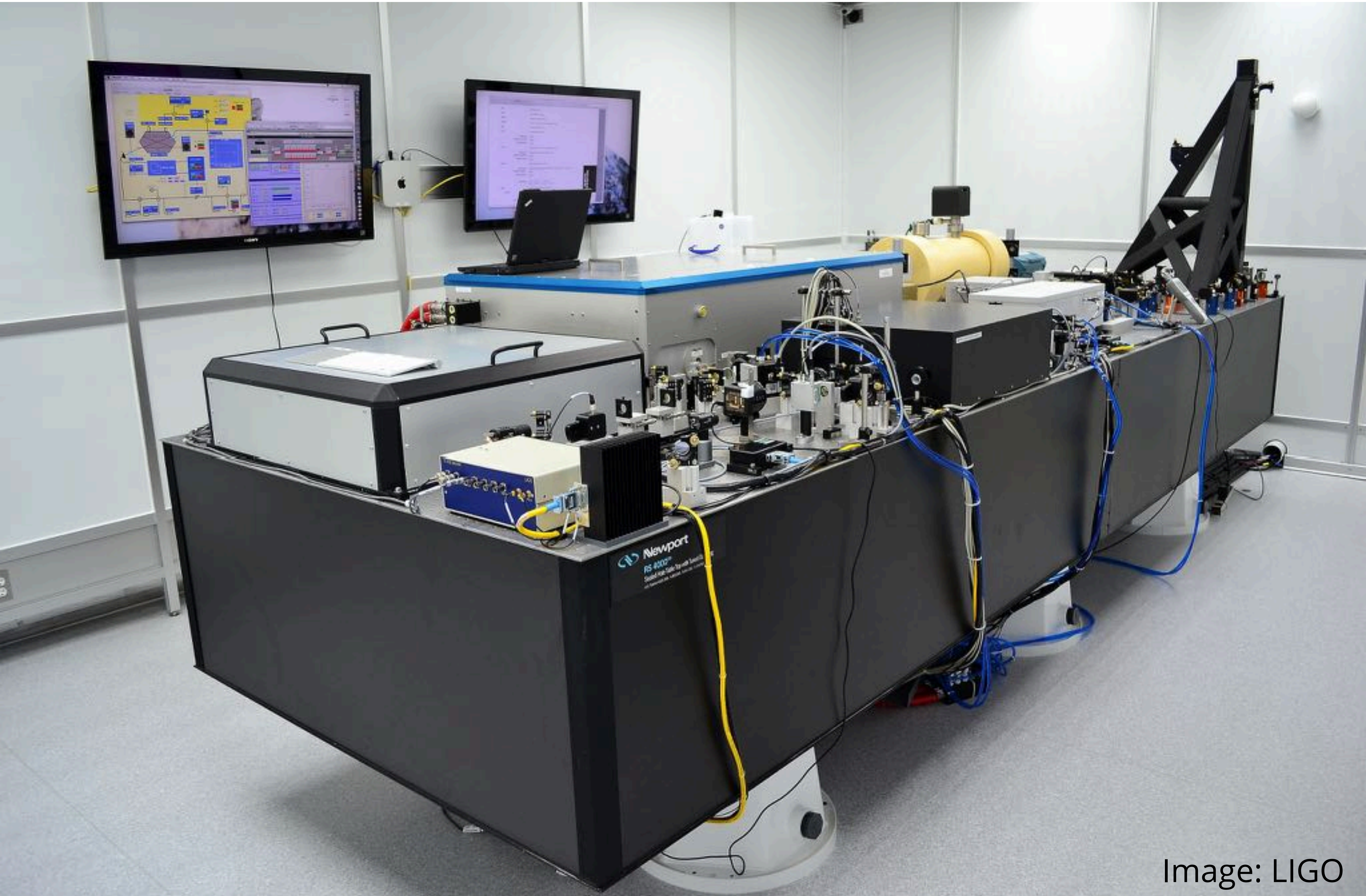


Image: LIGO

Advanced Sensing and Control

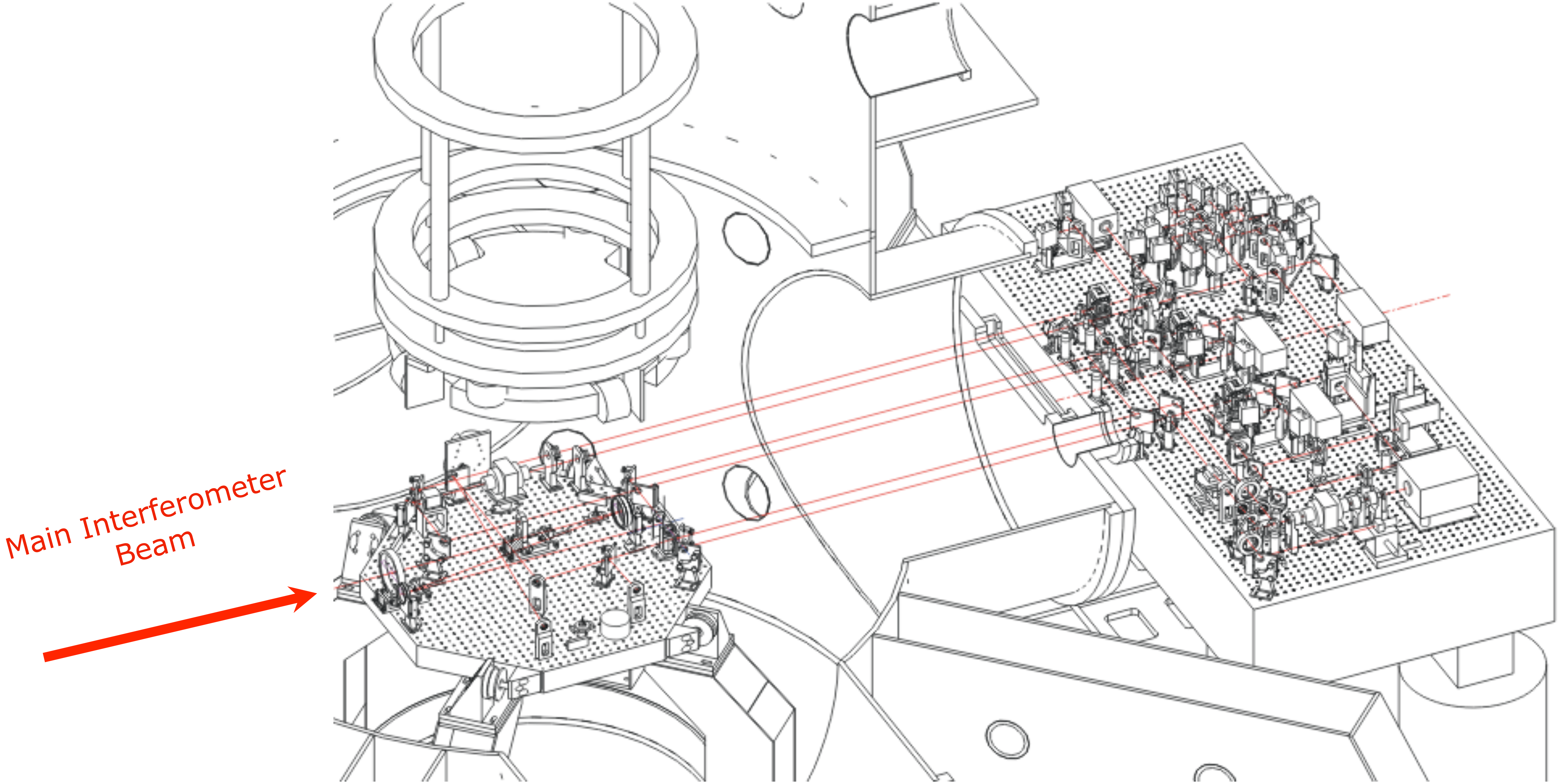


Image: Virgo

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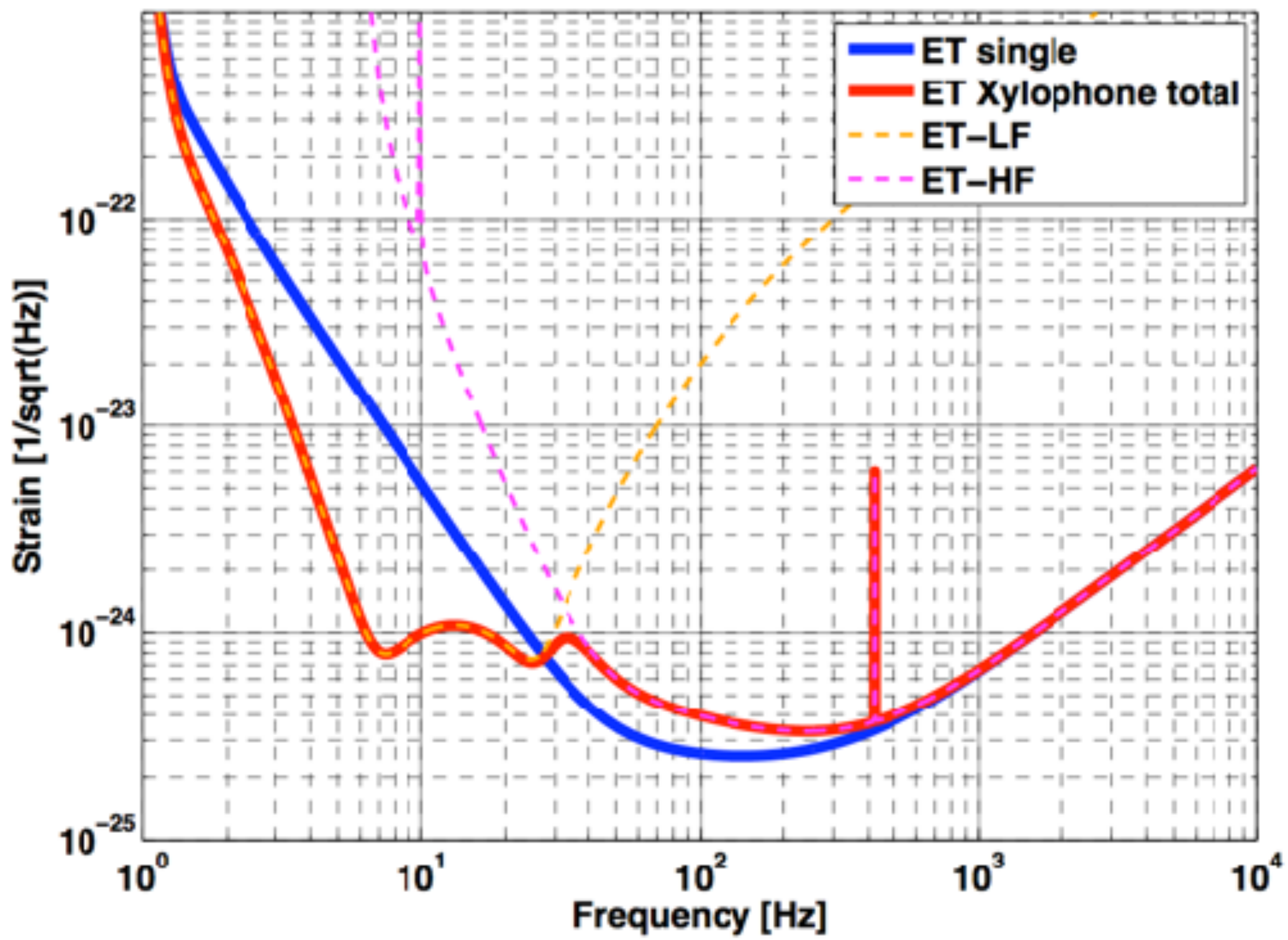
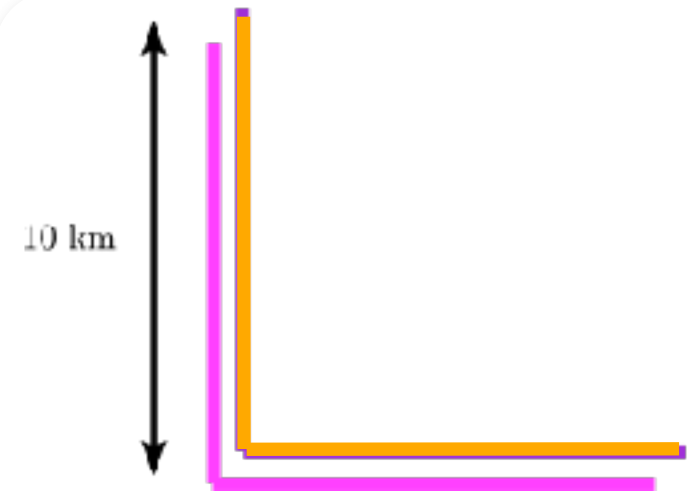
Xylophone design: enabling low-frequencies





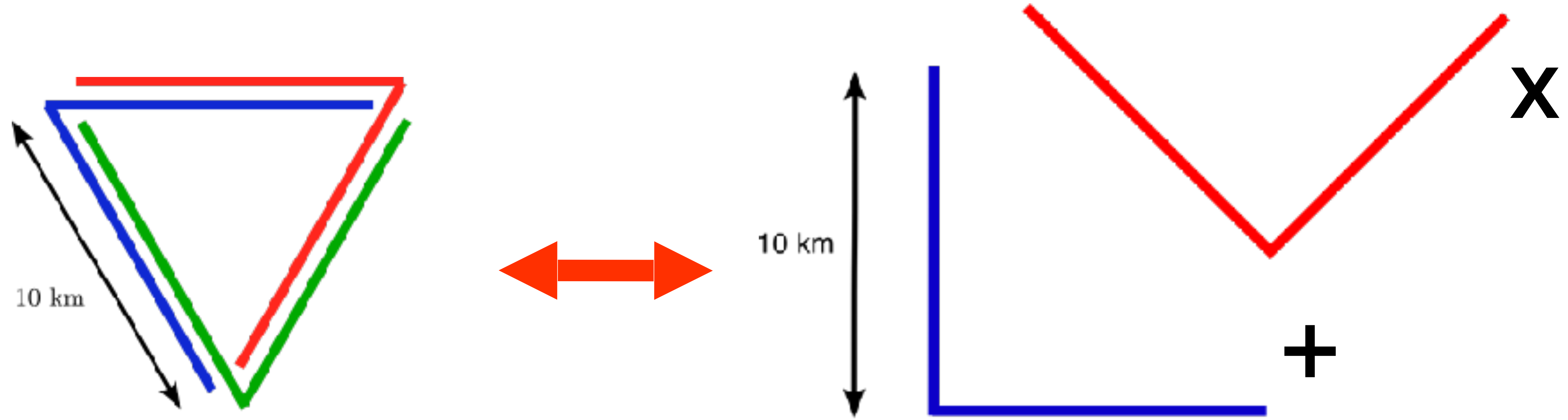
- Low laser power, cryogenic, long suspensions
- High laser power, room temperature, `normal' suspensions

Triangle configuration

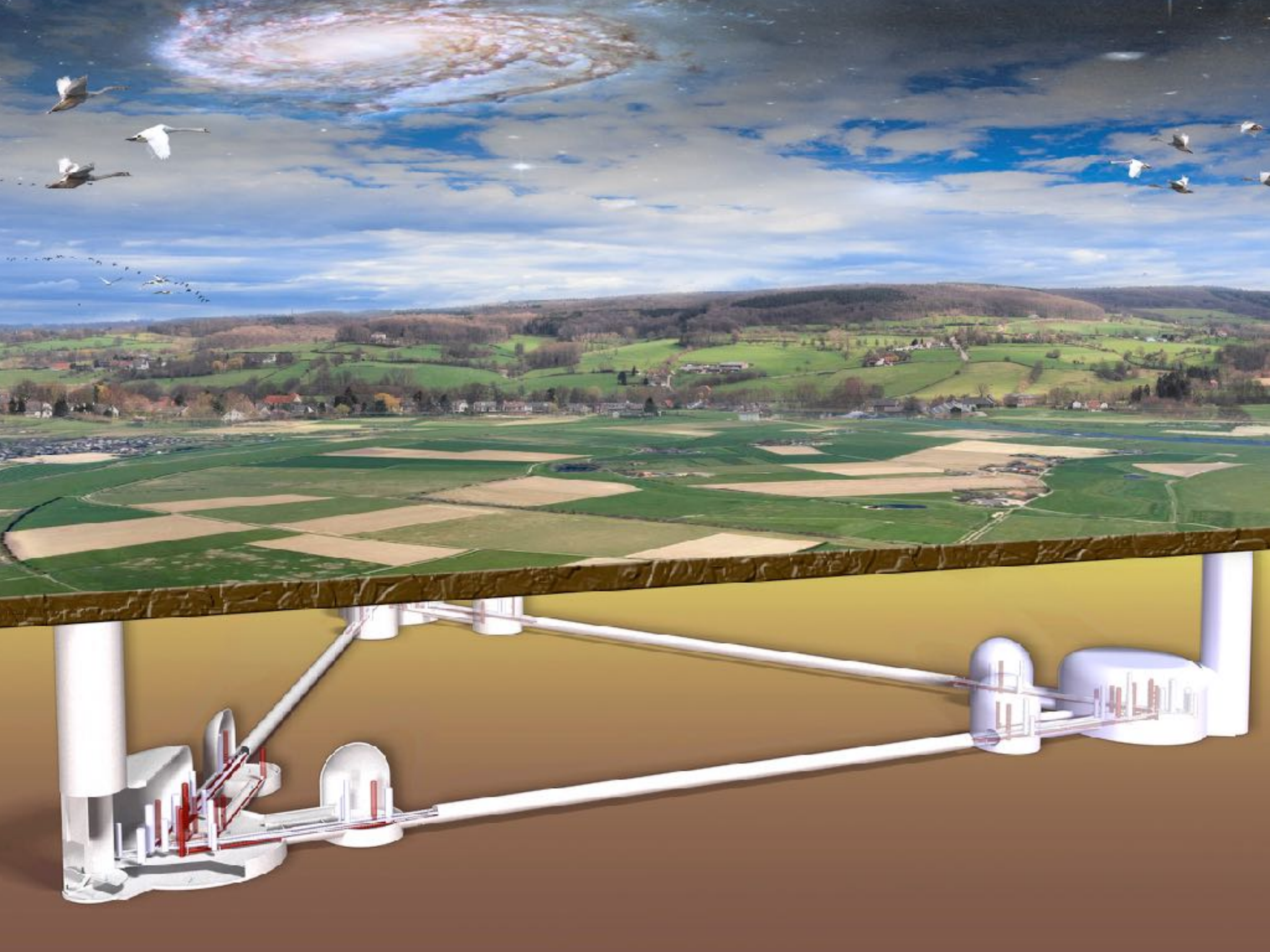
The Einstein Telescope hosts three independent detectors in a **triangle configuration**

Provides:

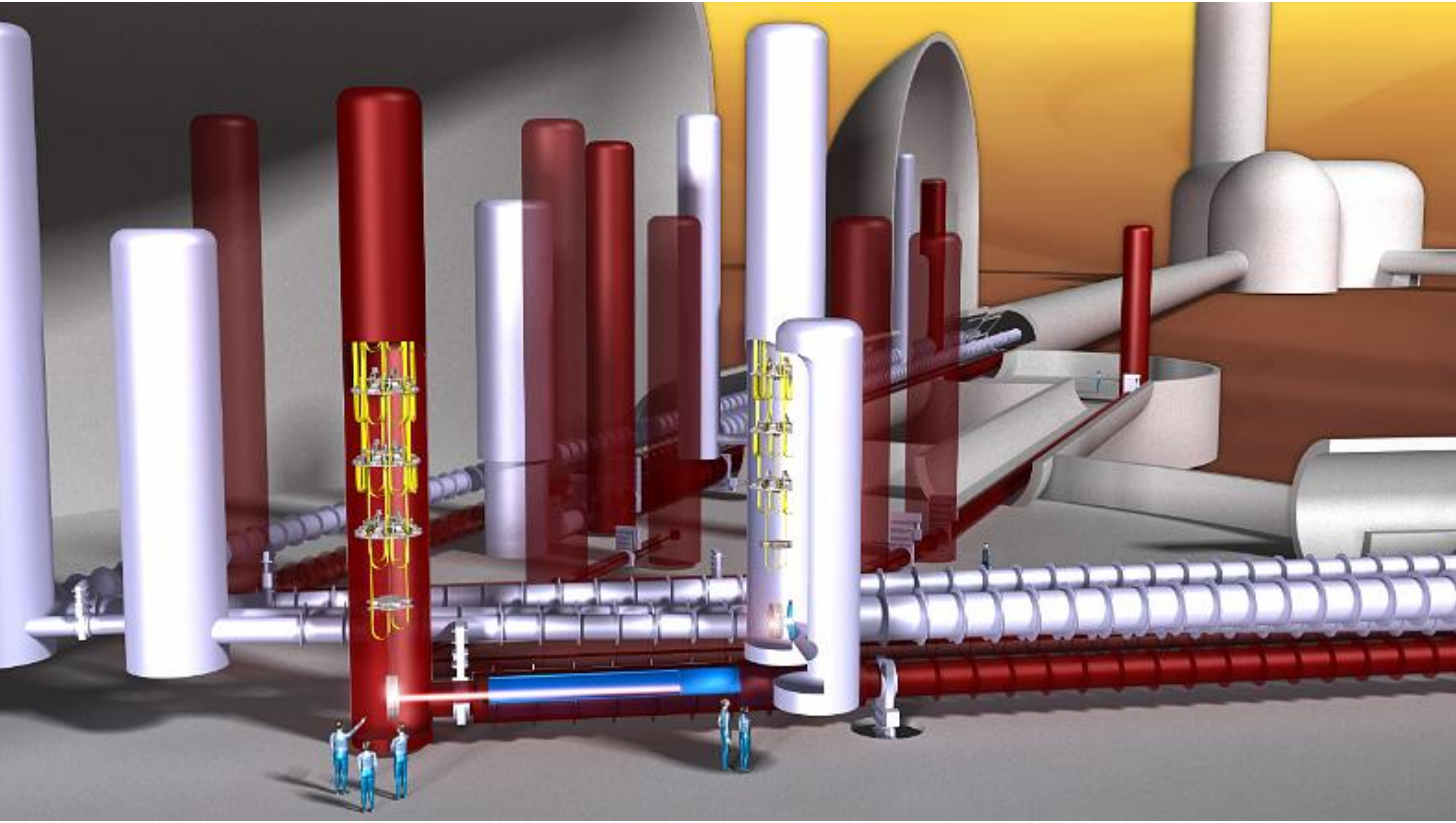
- full signal capture in both polarisations
- redundancy for 24/7 operation



6 laser interferometers, each 10km long!



Large underground facility



Einstein Telescope (ET)

The Einstein Telescope is the vision for a European **GW Observatory,** a large underground facility with a **50+ years lifespan**, expected to host a number of **different experiment/technologies.** Timeline:

- 2010 ET conceptual design completed
- **2020 Forming the ET collaboration, design update**
- 2021 ESFRI roadmap
- 2023 Site Selection
- 2025 Full Technical Design
- 2026 Infrastructure realisation start (excavation, ...)
- 2032+: installation / commissioning / operation

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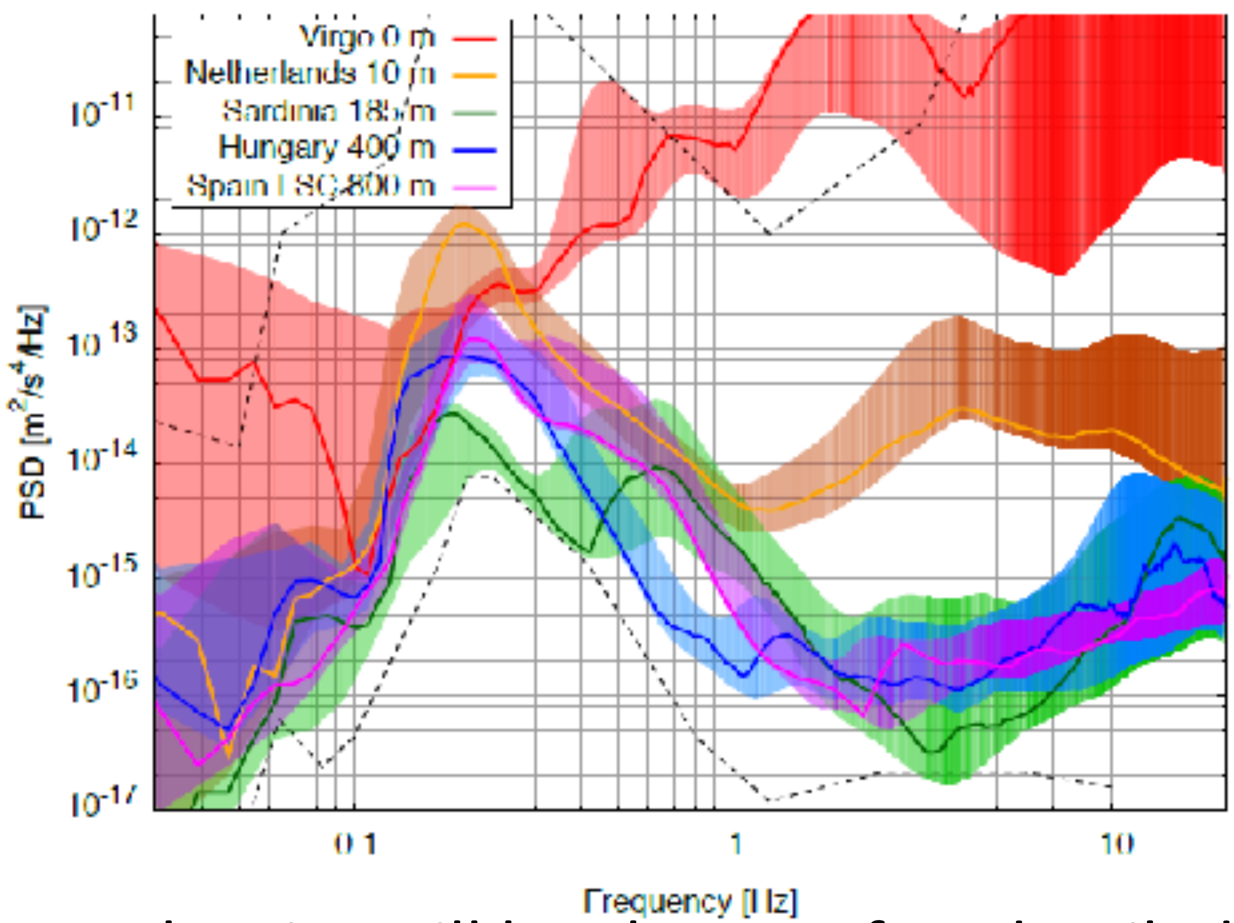
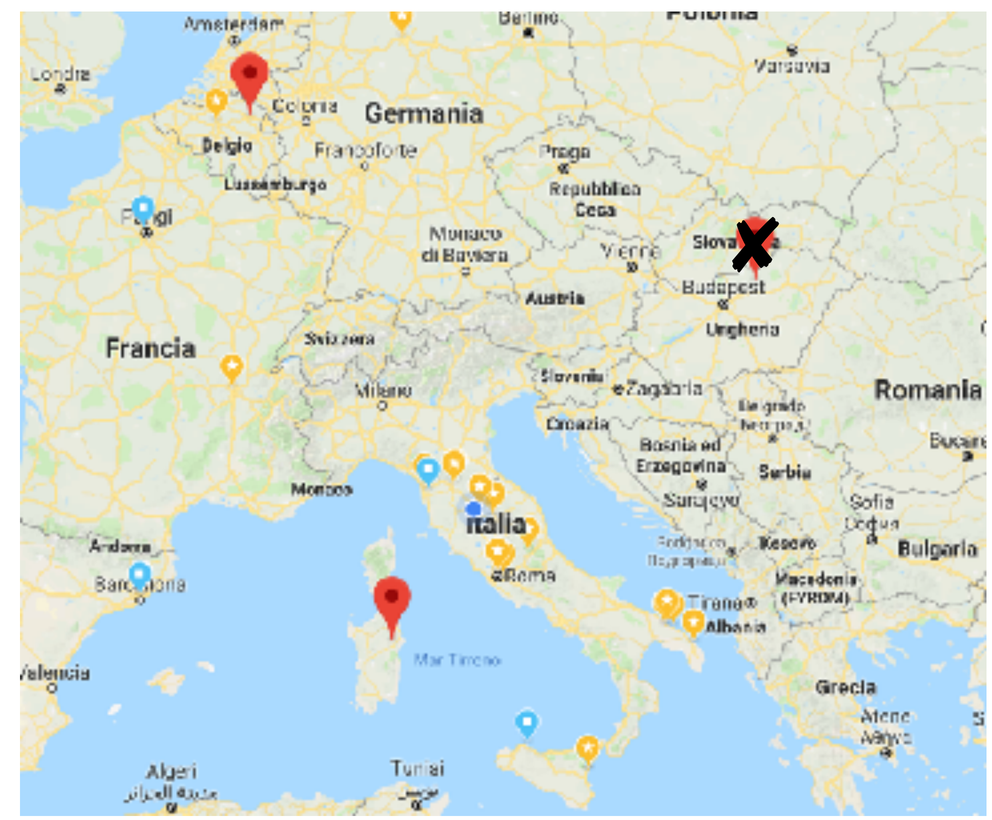
ET Site Selection

ET has two site candidates with community support and political support: a) Limburg, a cross-border region in the Netherlands, Belgium, Germany, and b) Sardinia Italy

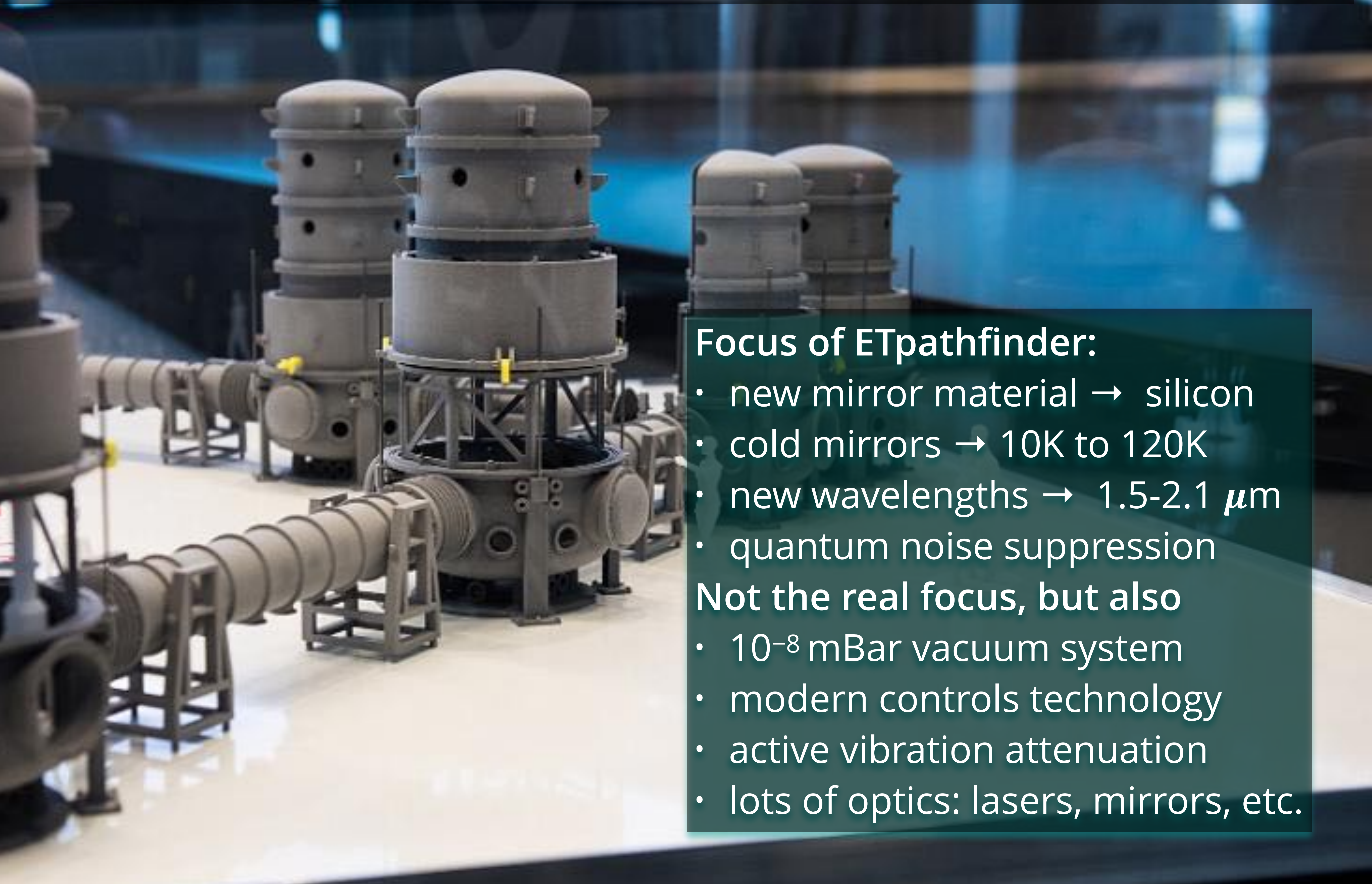




[Michele Punturo]

The site will be chosen after detailed studies on seismic activity. But many other aspects will drive the decision, including industry engagement and socio-economic returns.

ETpathfinder R&D laboratory



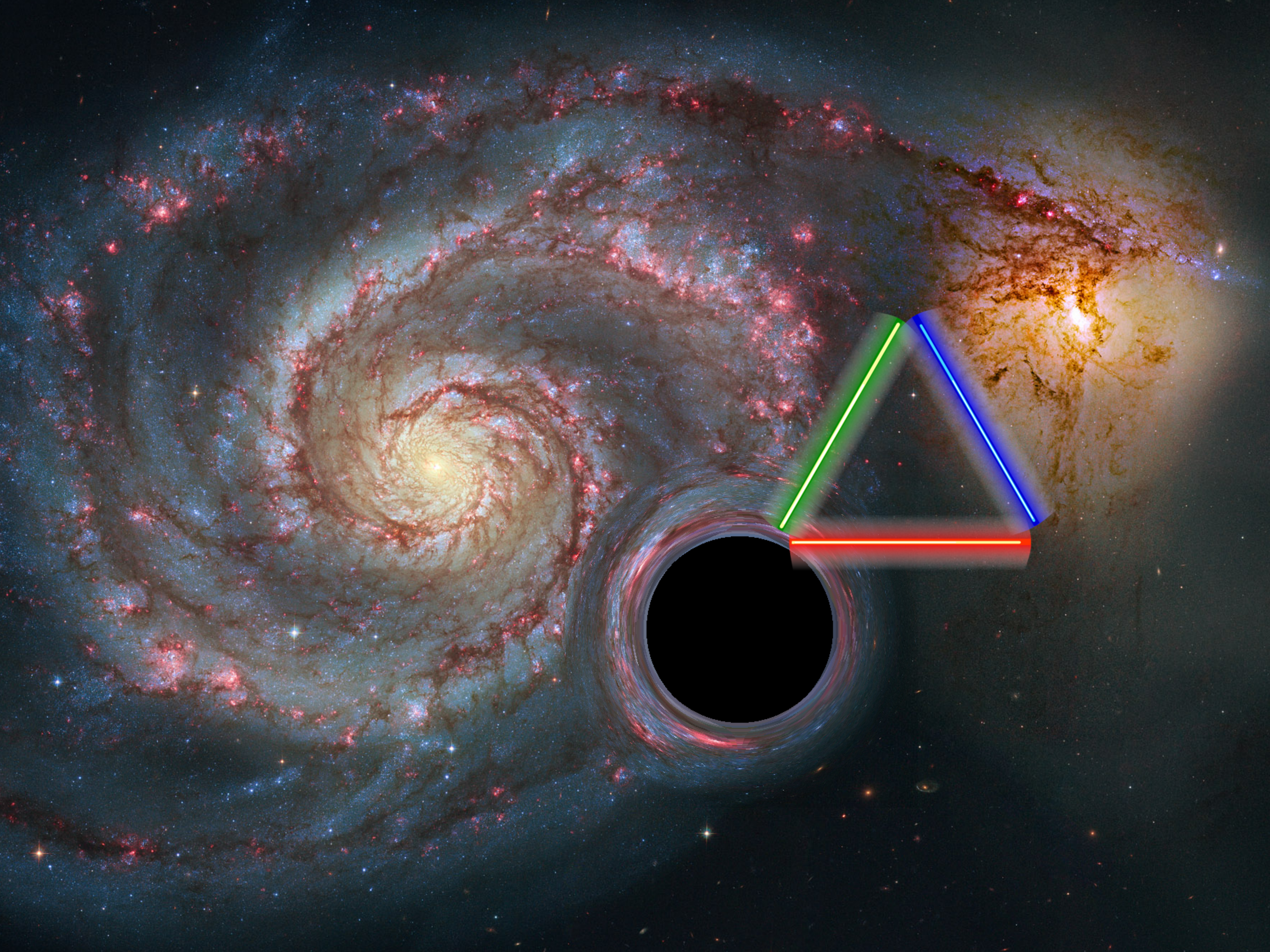
Focus of ETpathfinder:

- new mirror material → silicon
- cold mirrors → 10K to 120K
- new wavelengths → 1.5-2.1 μm
- quantum noise suppression

Not the real focus, but also

- 10^{-8} mBar vacuum system
- modern controls technology
- active vibration attenuation
- lots of optics: lasers, mirrors, etc.

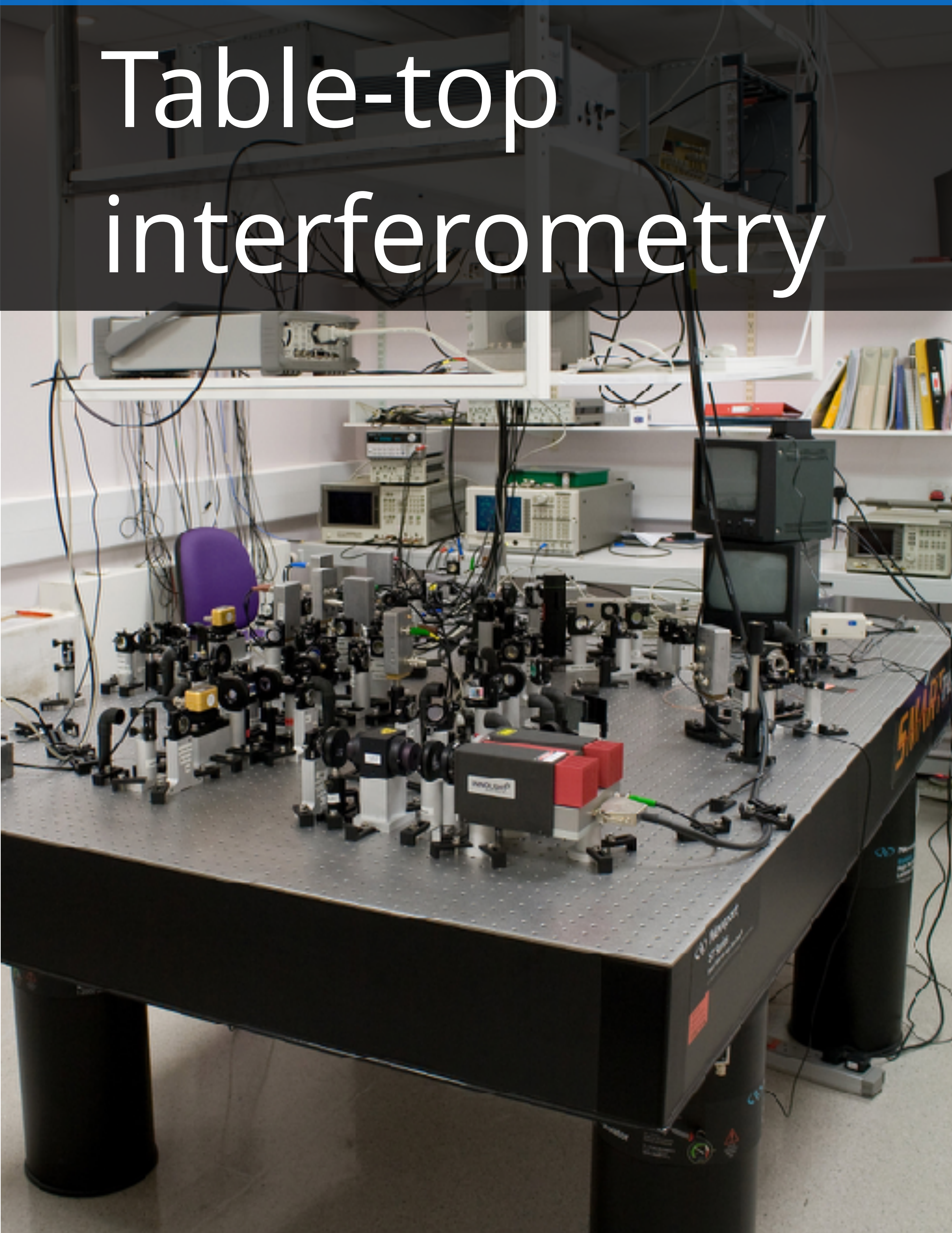
More details on the technology in the next talk.



Extra Slides

Interferometer R+D

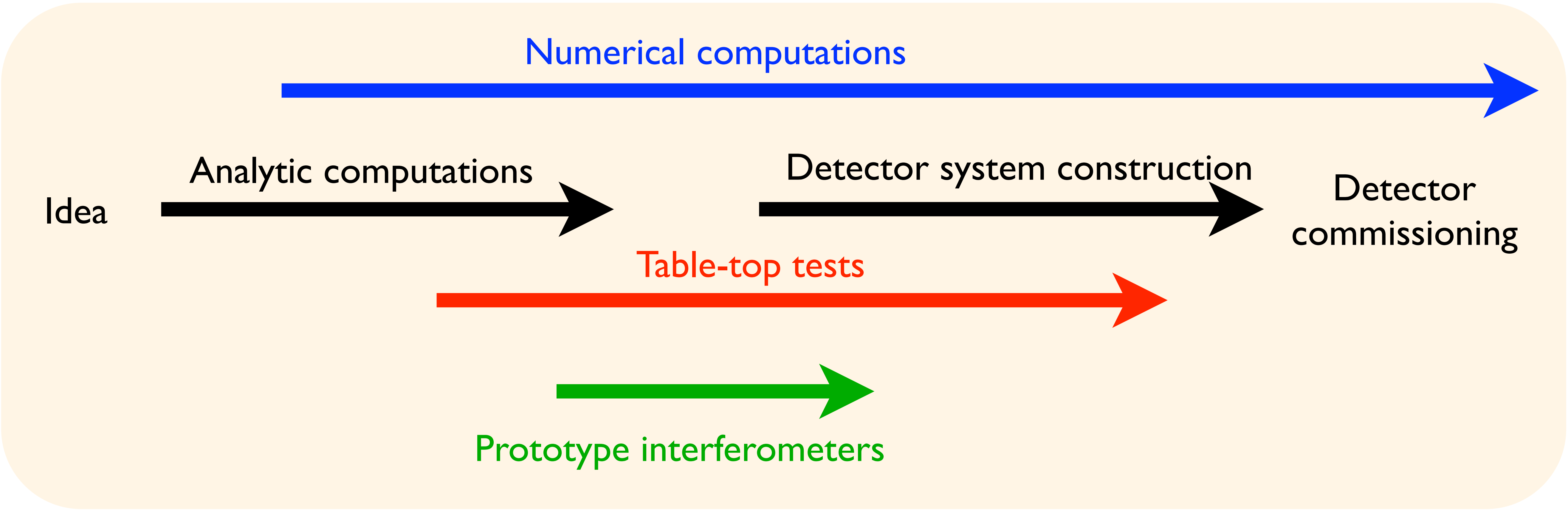
Table-top interferometry



Numerical modelling


```
assert(Nhom > 0)
assert(Nf > 0)

s_rhs_idx = 0
s_f_idx = 0

for i, n in enumerate(self.nodes):
    # Optical nodes have HOM information, mech/e
    if n.type is NodeType.OPTICAL:
        #(index, RHS index, frequency index, num freqs, nu
        self.__node_info[n] = (i, s_rhs_idx, s_f_idx, Nf,
        # Add in the diagonal elements of the matrix
        for freq in range(Nf):
            self.M().add_diagonal_elements(Nhom, self.find

        s_rhs_idx += Nf * Nhom
        s_f_idx   += Nf

    elif n.type is NodeType.MECHANICAL or n.type is NodeTyp
        #(index, RHS index, frequency index, num freqs, nu
        self.__node_info[n] = (i, s_rhs_idx, s_f_idx, 1, 1
        # Should mechanical motions have multiple frequenc
        self.M().add_diagonal_elements(1, self.findex(n, 0
        s_rhs_idx += 1
        s_f_idx   += 1
    else:
        raise Exception("Not handled")

_done = {}

# Store all the edge owners we'll need to loop over and ca
self.__edge_owners = []
# use set for unique edges
for el in set(self.__nx.get_edge_attributes(self.model.netw
    self.__edge_owners.append(el())
```

From Idea to Implementation



10 to 30 years is a good time scale to go from idea to an implementation/application of a new concept or technology