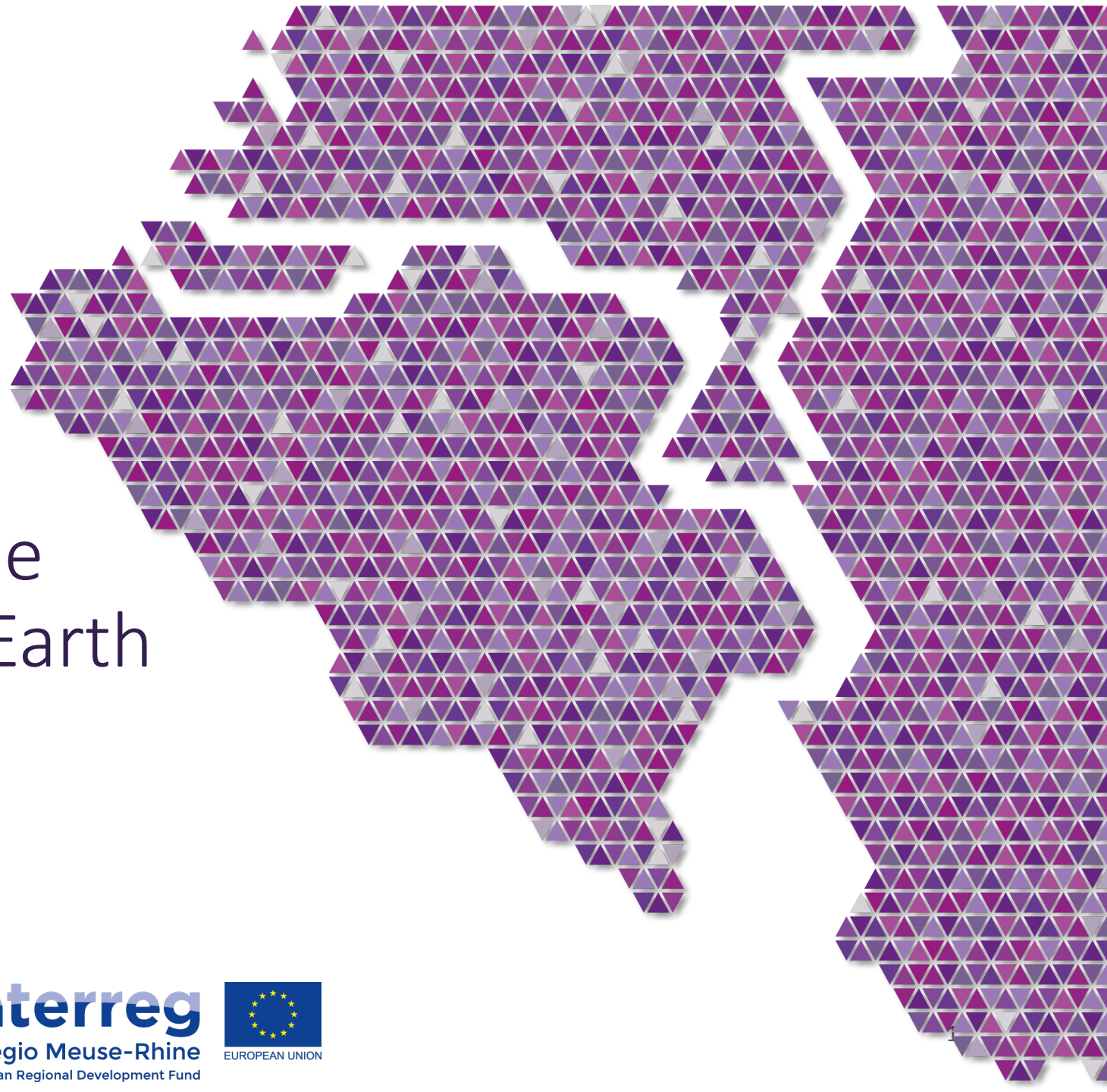
E-TEST Einstein Telescope EMR Site & Technology



ET CRISTAL, building the Einstein Telescope on Earth and Lunar detectors

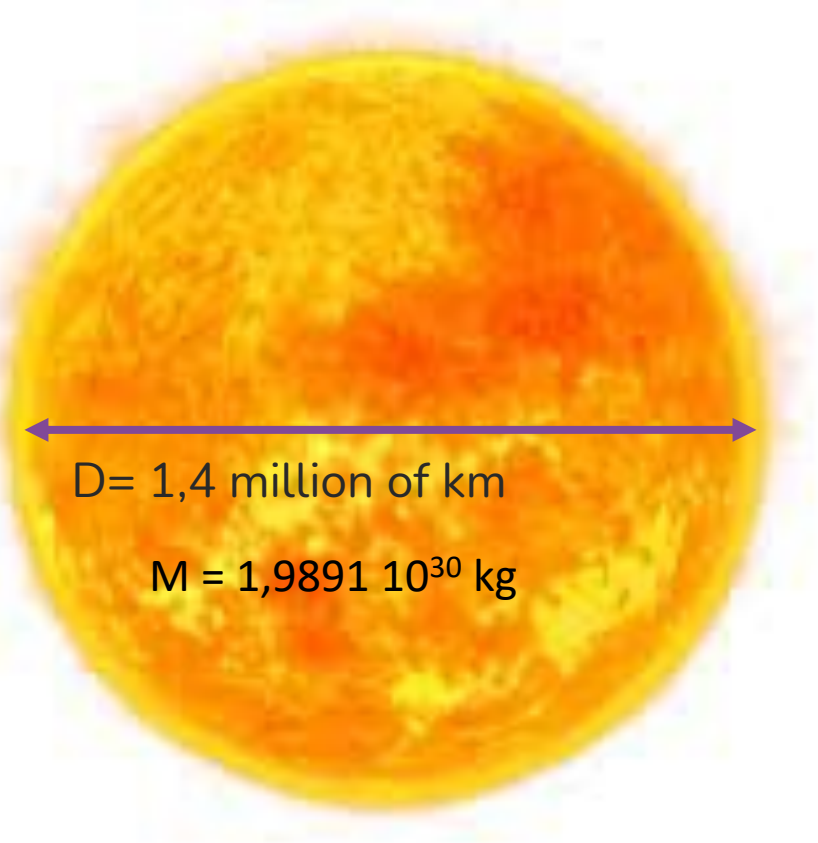
Christophe Collette

https://www.pml.uliege.be

19.11.26

Interreg Euregio Meuse-Rhine European Regional Development Fund

EUROPEAN UNION





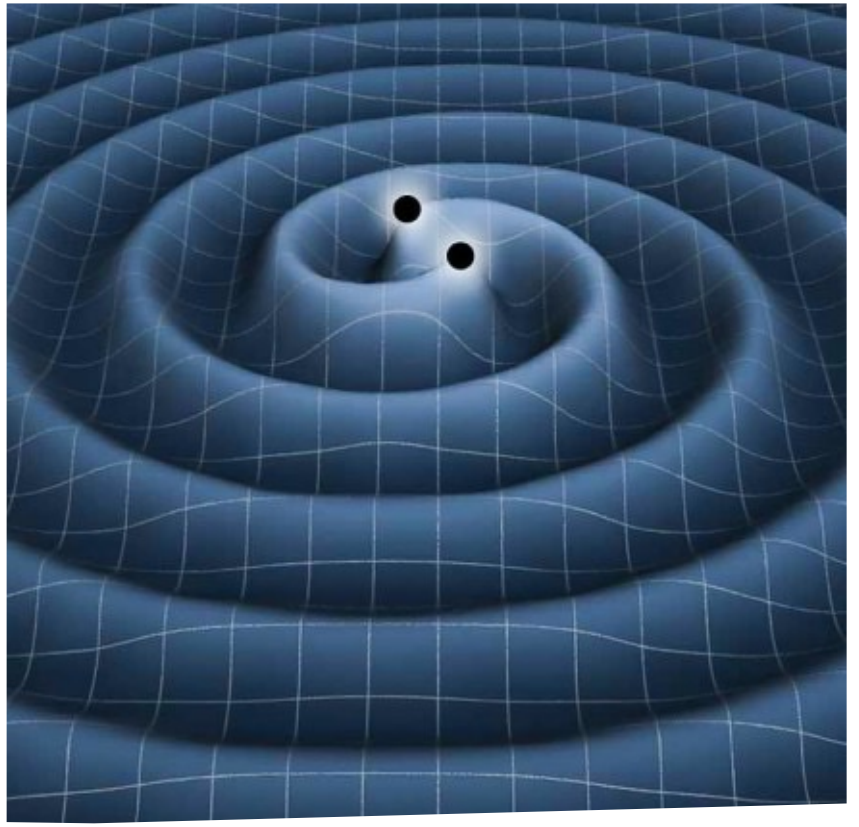
D= 3 km

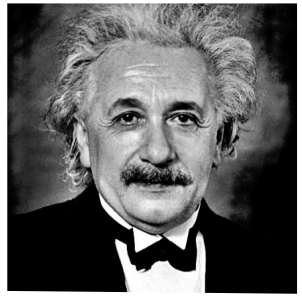
Density:
20 billions of tons per cm³ !

4×10^{19} black holes in the universe

1-2% of stars becomes black holes

10 % of stellar mass



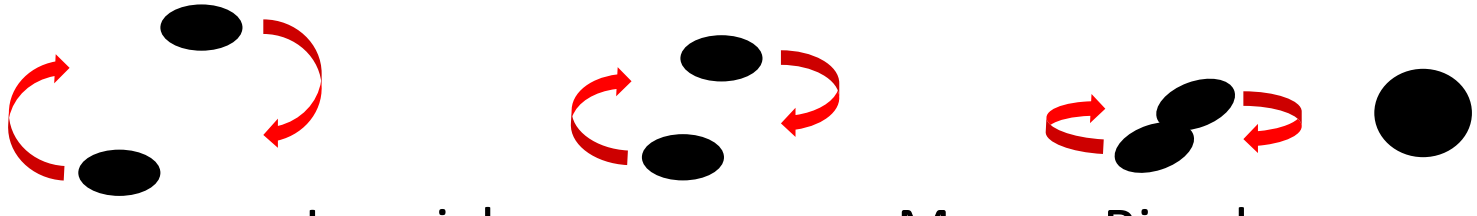


1916



Black holes merger

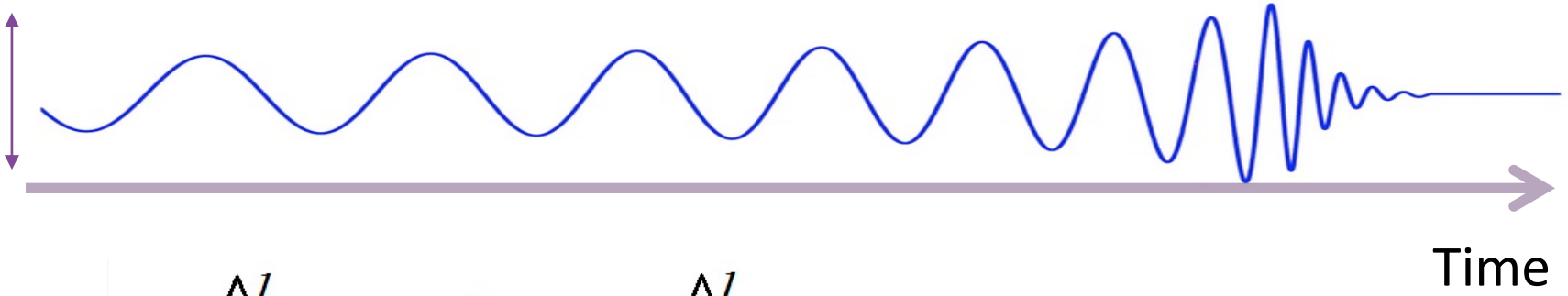
Two black holes:

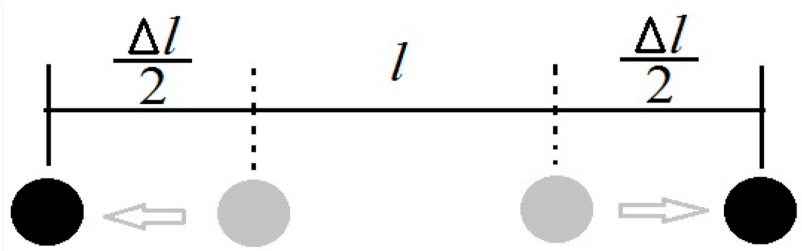


Inspiral Merger Ringdown

Amplitude:

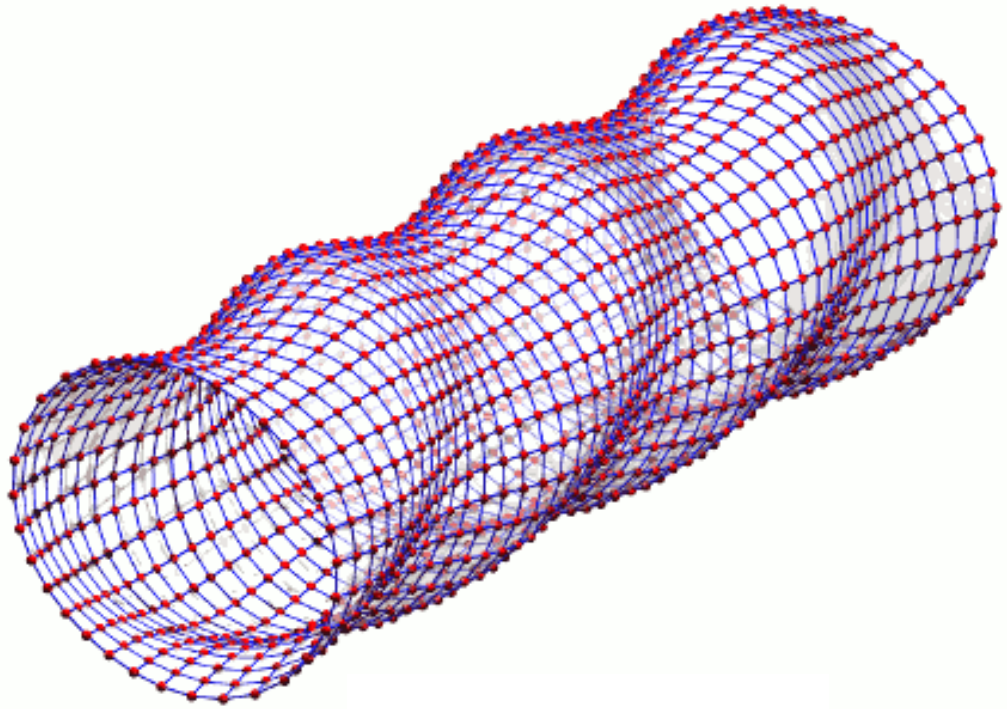
$$h \approx \frac{\Delta L}{L} = 10^{-21}$$

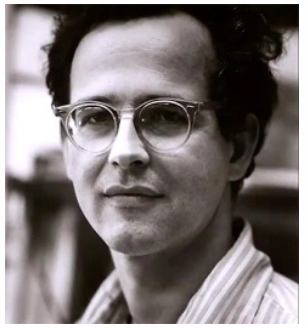




The merger of black holes creates deformation of space/time, corresponding to displacements of **10^{-18} m between objects located 1km apart.**

1972: « Laser Interferometer detector » (Rainer Weiss)



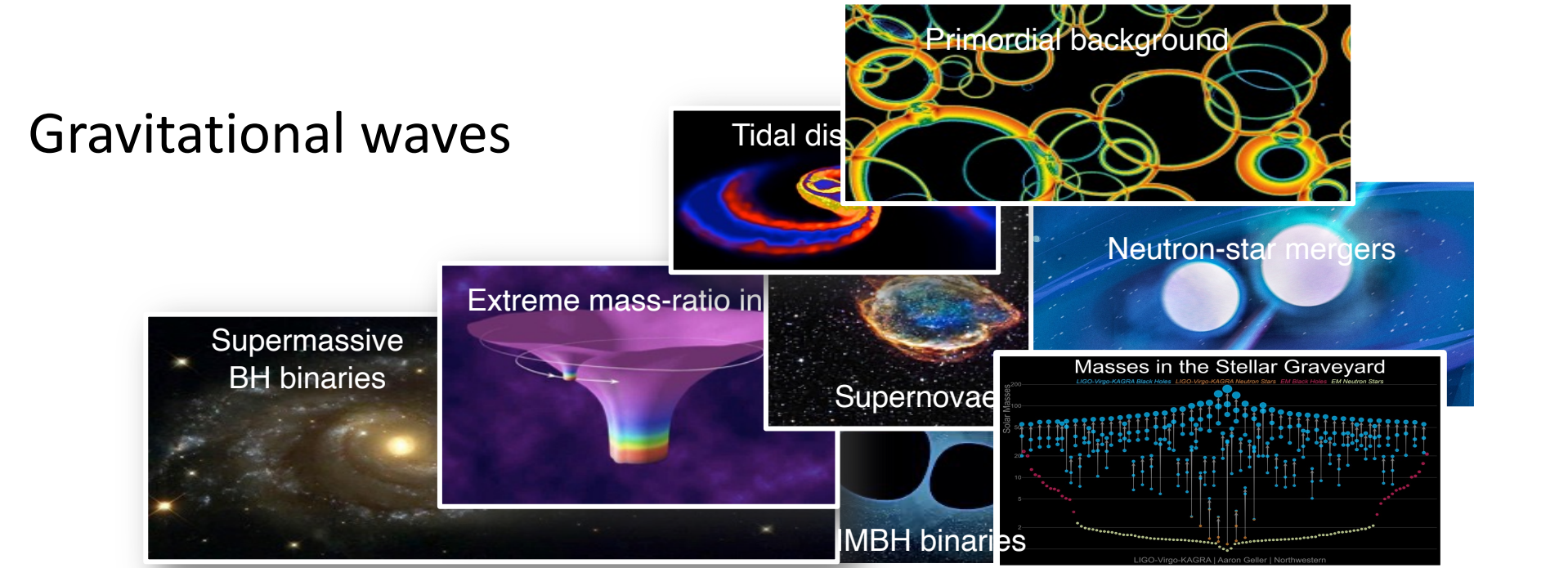


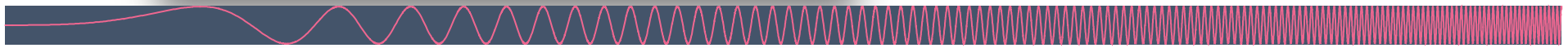




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Gravitational waves



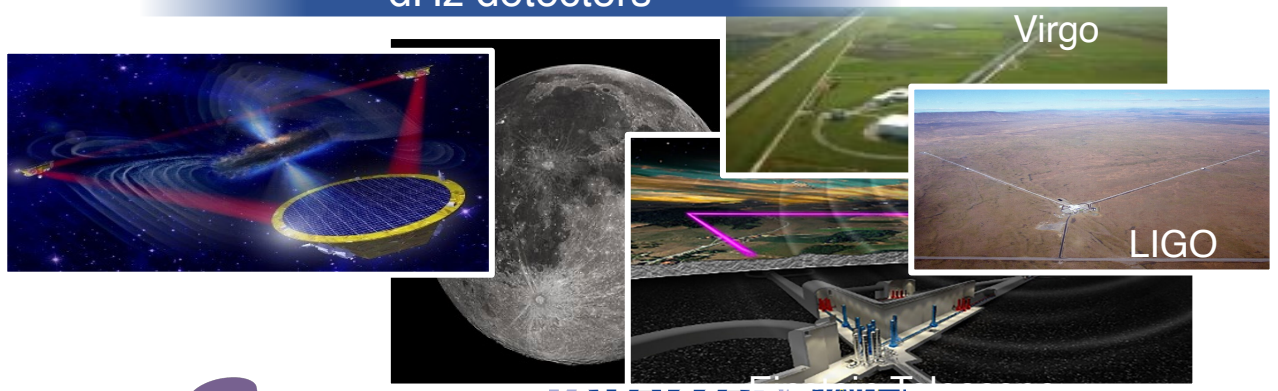


10^{-4} Hz 10^{0} Hz 10^{3} Hz

Space detectors Terrestrial

dHz detectors

Detectors



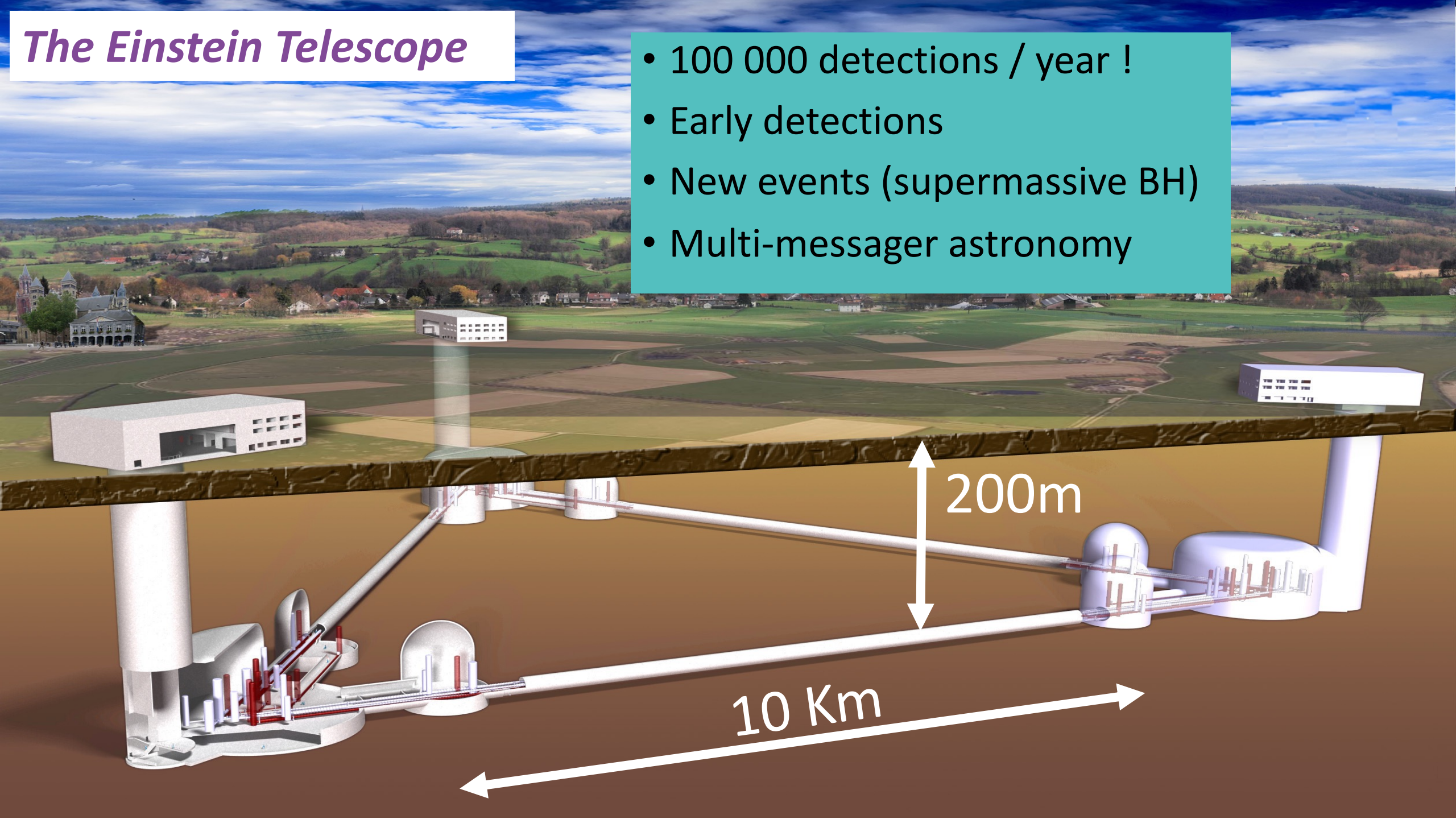
E-TEST Einstein Telescope EMR Site & Technology

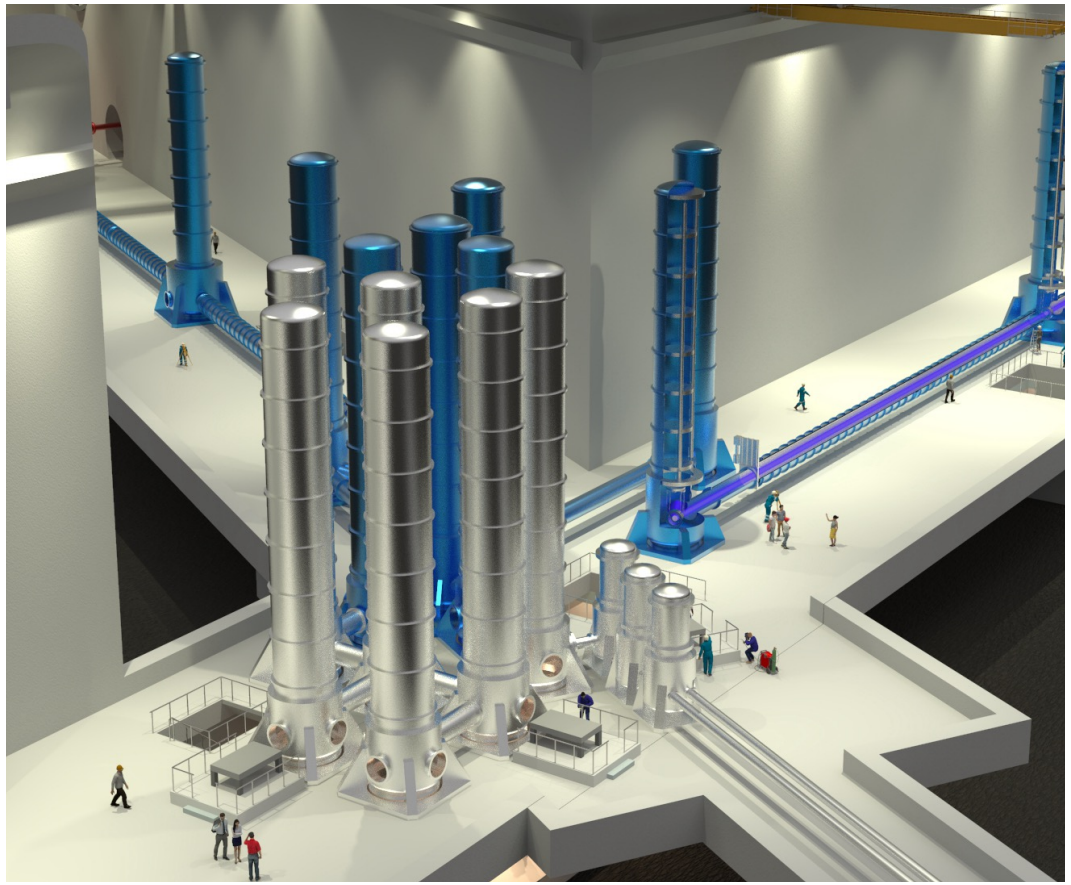
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The Einstein Telescope

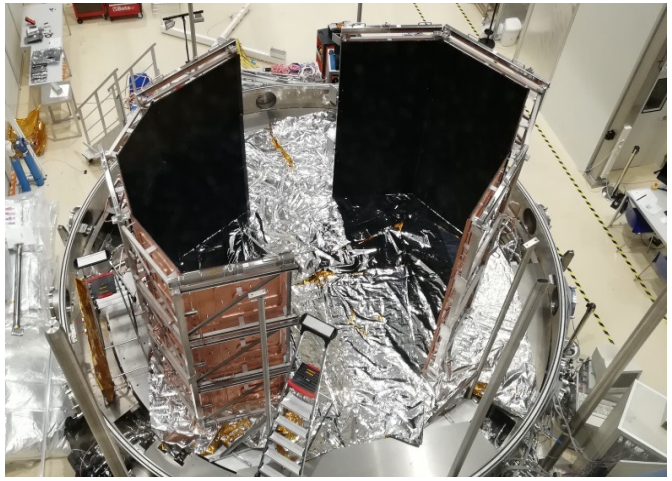
- 100 000 detections / year !
- Early detections
- New events (supermassive BH)
- Multi-messager astronomy





ET CRISTAL Objectives

- Large mirror (100 Kg)
- Cryogenic temperature (20 K)
- Radiative cooling
- Isolated at low frequency (0.01-10 Hz)
- Compact suspension (4.5 meters)





Partners

Precision Mechatronics Laboratory

CSL Centre Spatial de Liège

RWTH Aachen University

KU Leuven

Nikhef

UCLouvain

micas KU Leuven

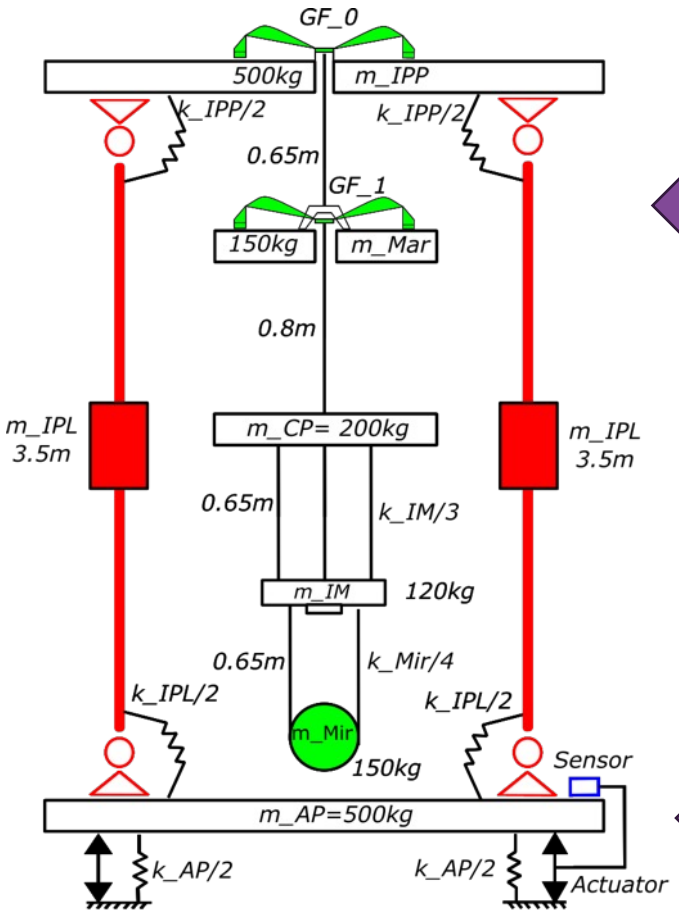
Fraunhofer ILT

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Interreg Euregio Meuse-Rhine European Regional Development Fund

European Union

Low-Frequency seismic isolation



Passive

\+

Active

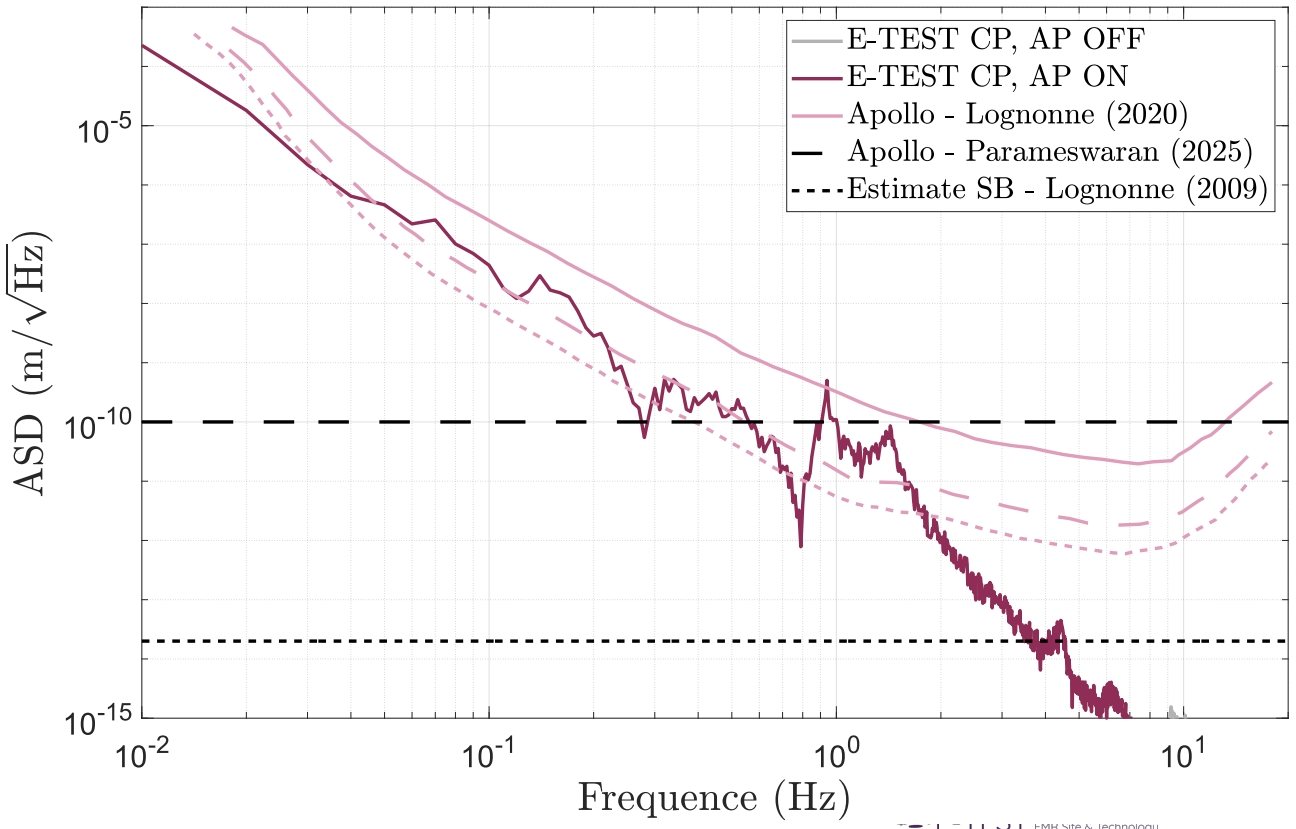


LGWA & E-TEST requirements compatibility

E-TEST is a prototype suspension, combining passive and active isolation techniques, of a 100 kg silicon mirror cooled down radiatively to 25 K in a suspended cryostat

Monitor residual motion at the last isolation stage, in the cryostat

Cryogenic compatible inertial sensors with a sensitivity of 2×10^{-14} **m/√Hz from 3 Hz** at **20K**

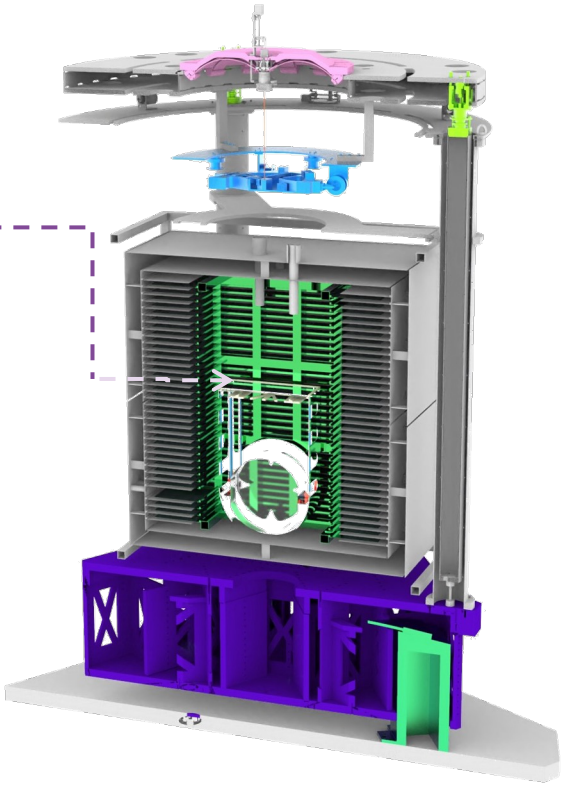


E-TEST

Target residual motion at E-TEST mirror level

Moon vibration estimate

LGWA LUNAR GRAVITATIONAL WAVE ANTENNA



Compatibility

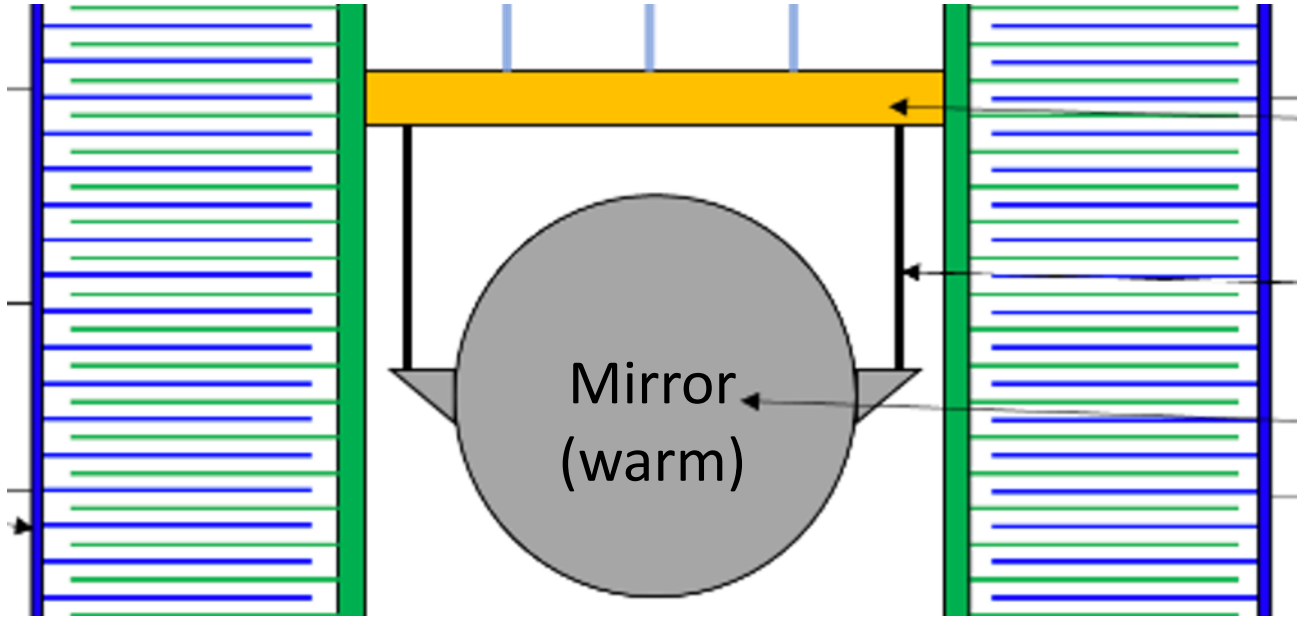
- High-resolution cryogenic sensors
- Vibration level

9

Radiative cooling strategy

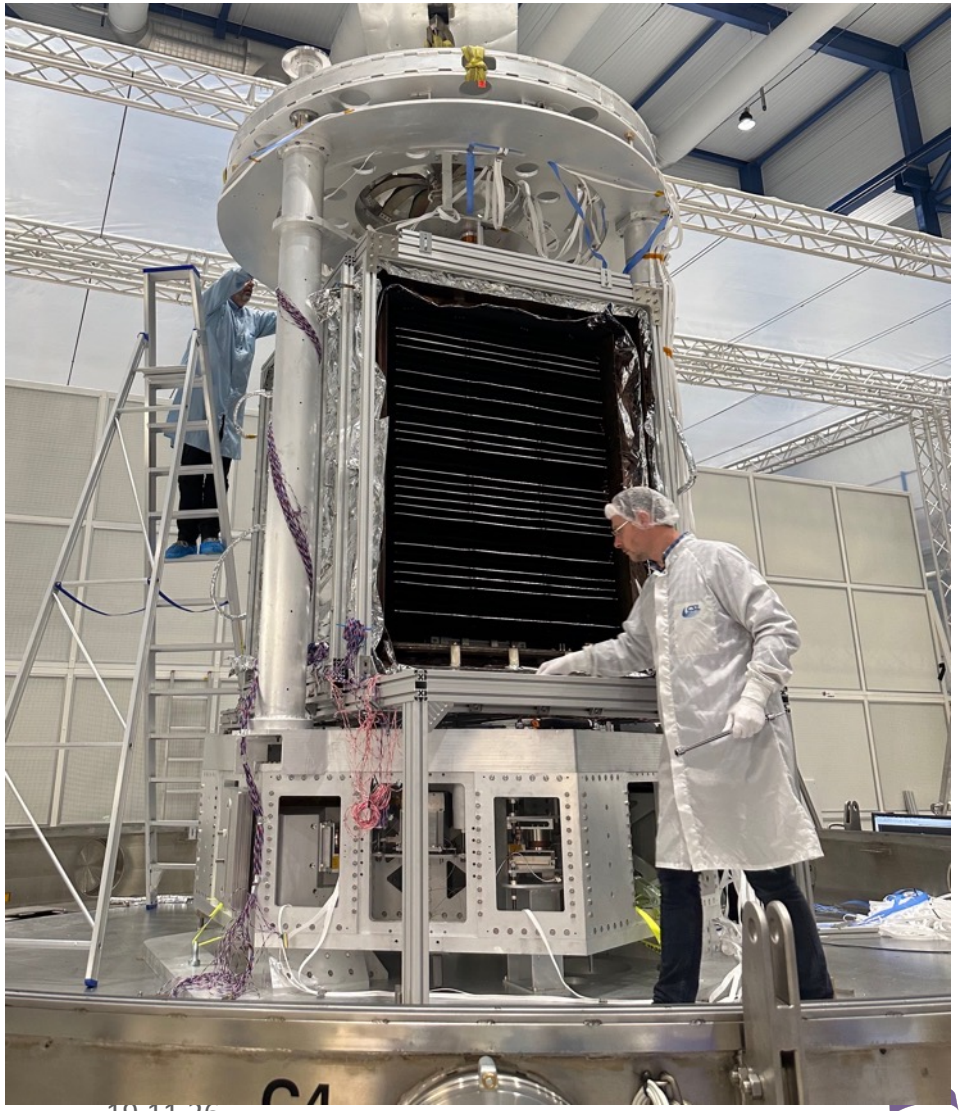


- Interlacing fins to increase the radiative heat exchange area (80m² for E-TEST, ~500m² for ET).
- Themo-mech. topology optimisation of fin geometry with radiation
- Emissivity enhancement at low temperature (coating)
- Cryogenic heat pipes

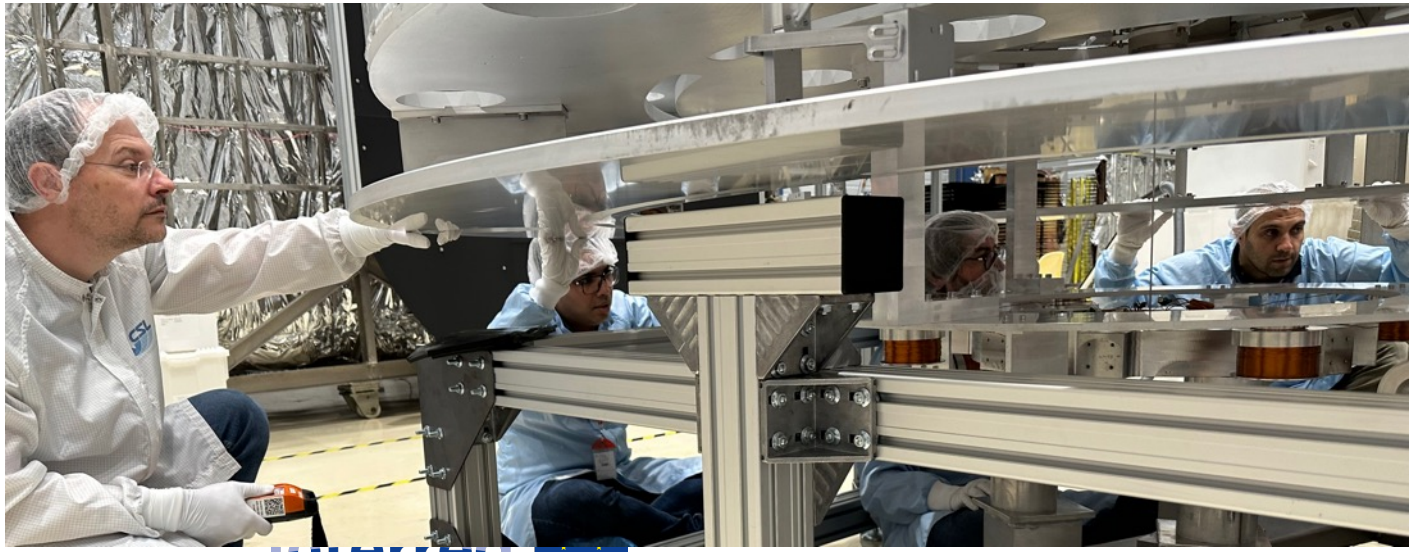


Contact: Lionel Jacques (CSL)
ljacques@uliege.be

First run at CSL 12/2023





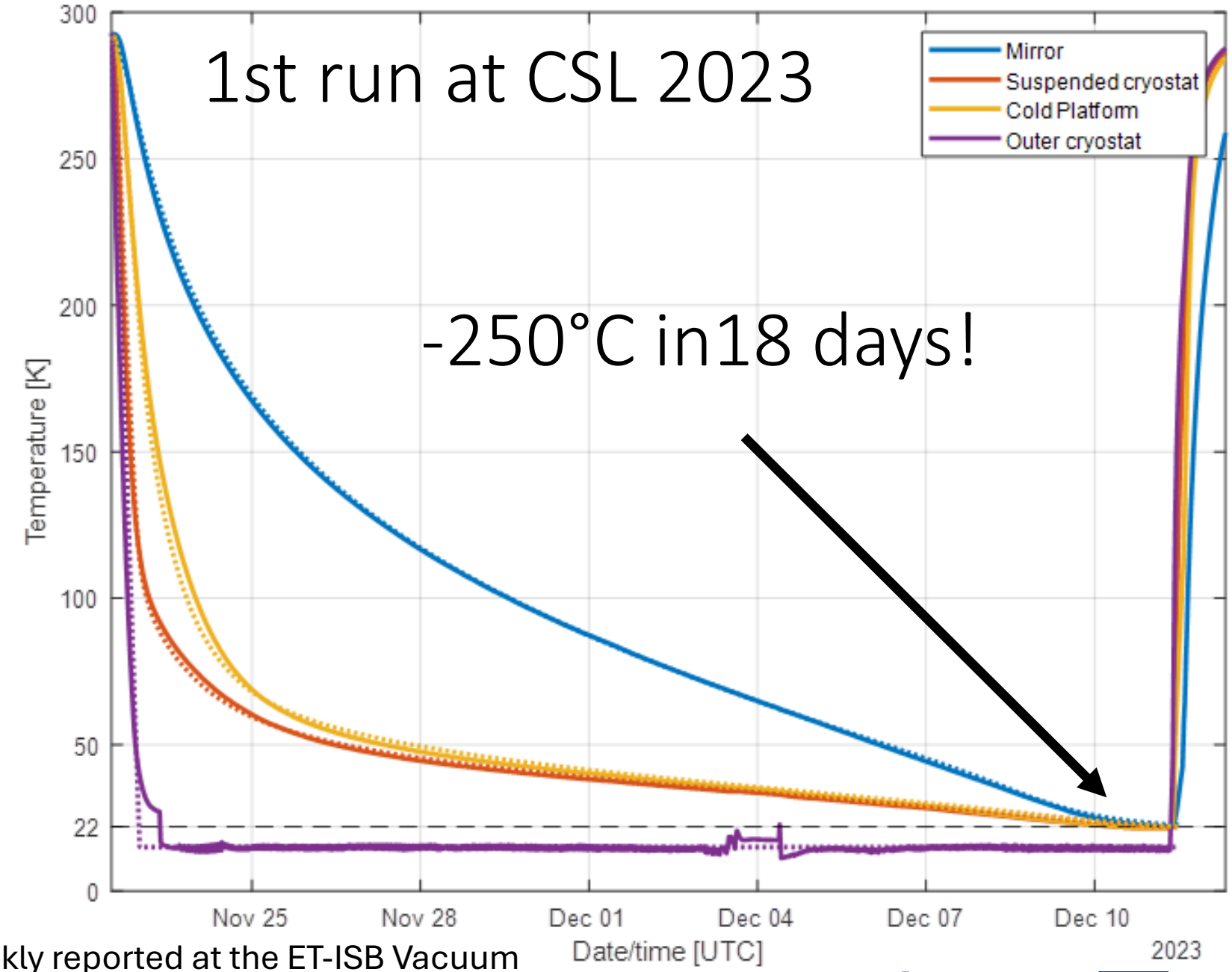


1st run at CSL 2023

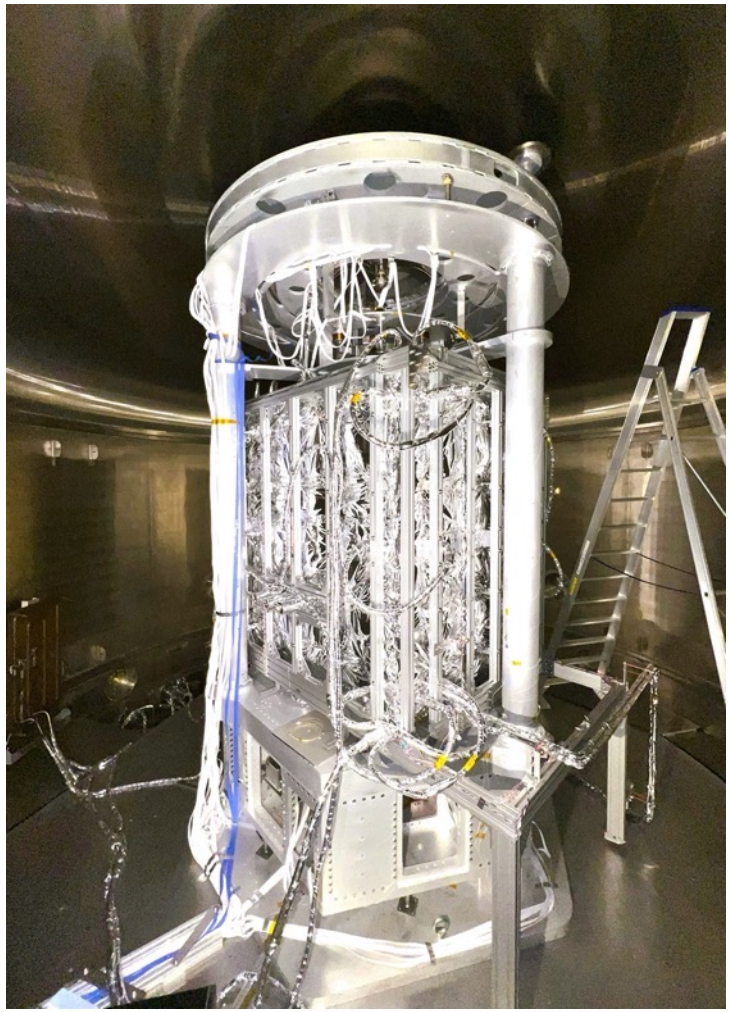
Contact :Cédric Lenaerts (CLS)
cedric.lenaerts@uliege.be

Lionel Jacques (CSL)
ljacques@uliege.be

CENTRE SPATIAL DE LIÈGE



-250°C in18 days!



L. Jacques et. Al. , Cryogenics, Volume 147, 15 April 2025, 104057

Weekly reported at the ET-ISB Vacuum and Cryogenics

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Contact: Morgane Zeoli
Morgane_zeoli@uliege.be

Horizontal cryogenic inertial sensor

Monolithically suspended Ti6Al4V proof-mass (0.68 kg)

Shielding-magnets voice-coil actuator

Frame

Watt's linkage leg

10 cm

Interferometric read-out

Collimator (p-pol)

PBS

WPQ

BS

M_1

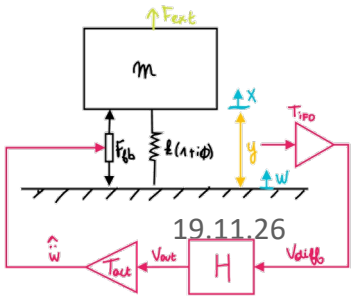
M_2

PD_1

PD_2

Cryo-H

Closed-loop homodyne interferometric readout



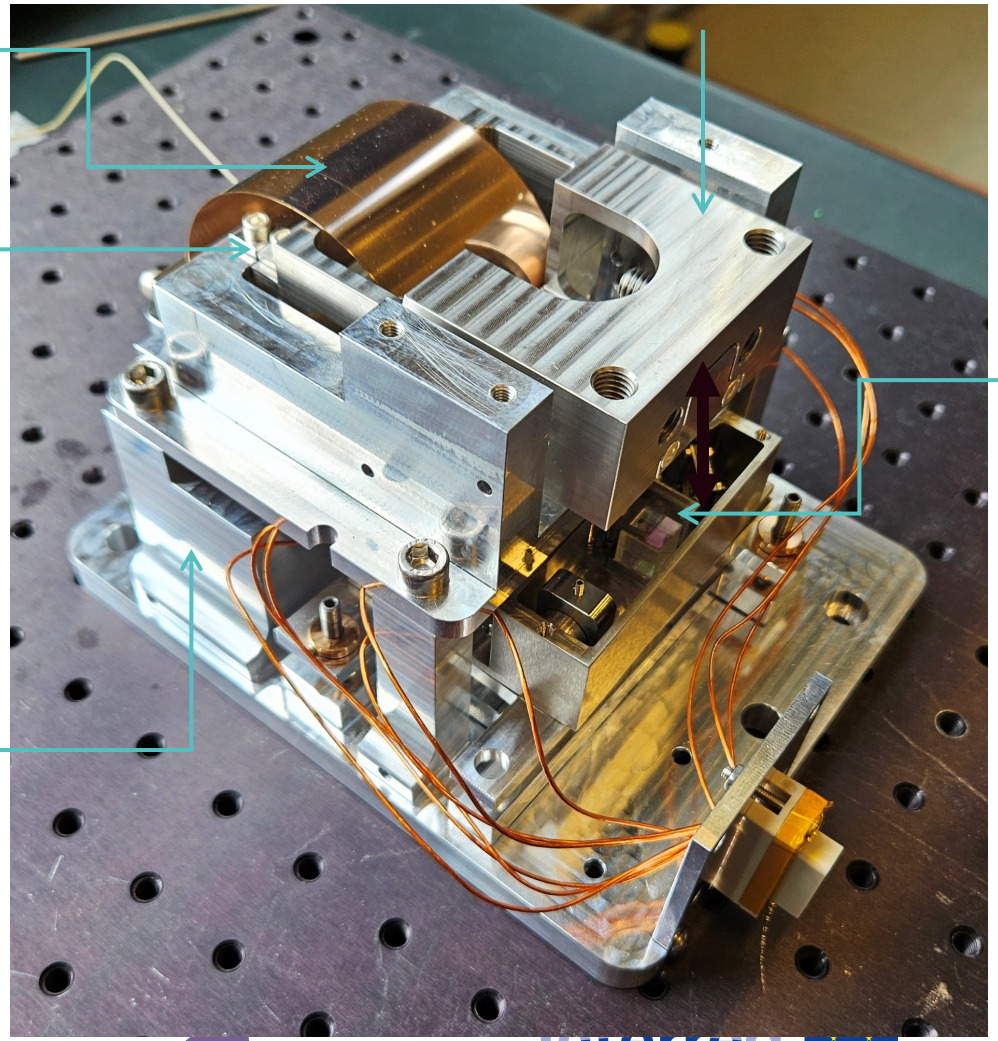
Contact: Morgane Zeoli
Morgane_zeoli@uliege.be

Vertical cryogenic inertial sensor

Inertial mass (AISI)

Leaf-spring suspension (BeCu)

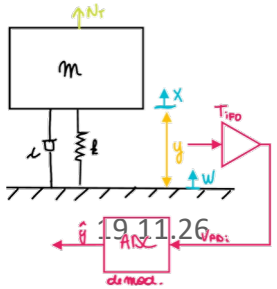
Double-clamped blade hinge (BeCu)

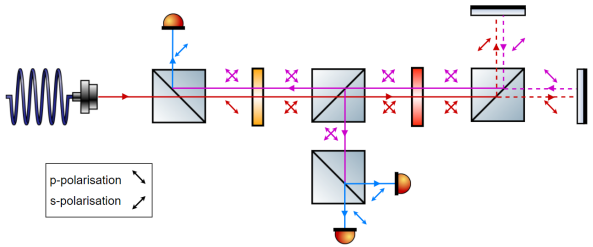


Frame (Al)

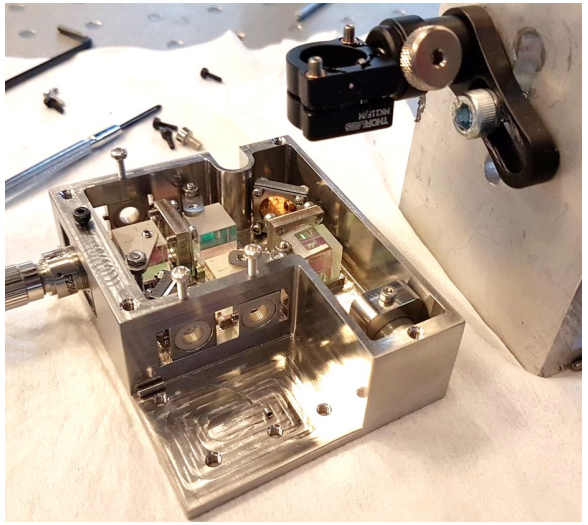
Cryo-V

Open-loop homodyne quadrature interferometric readout



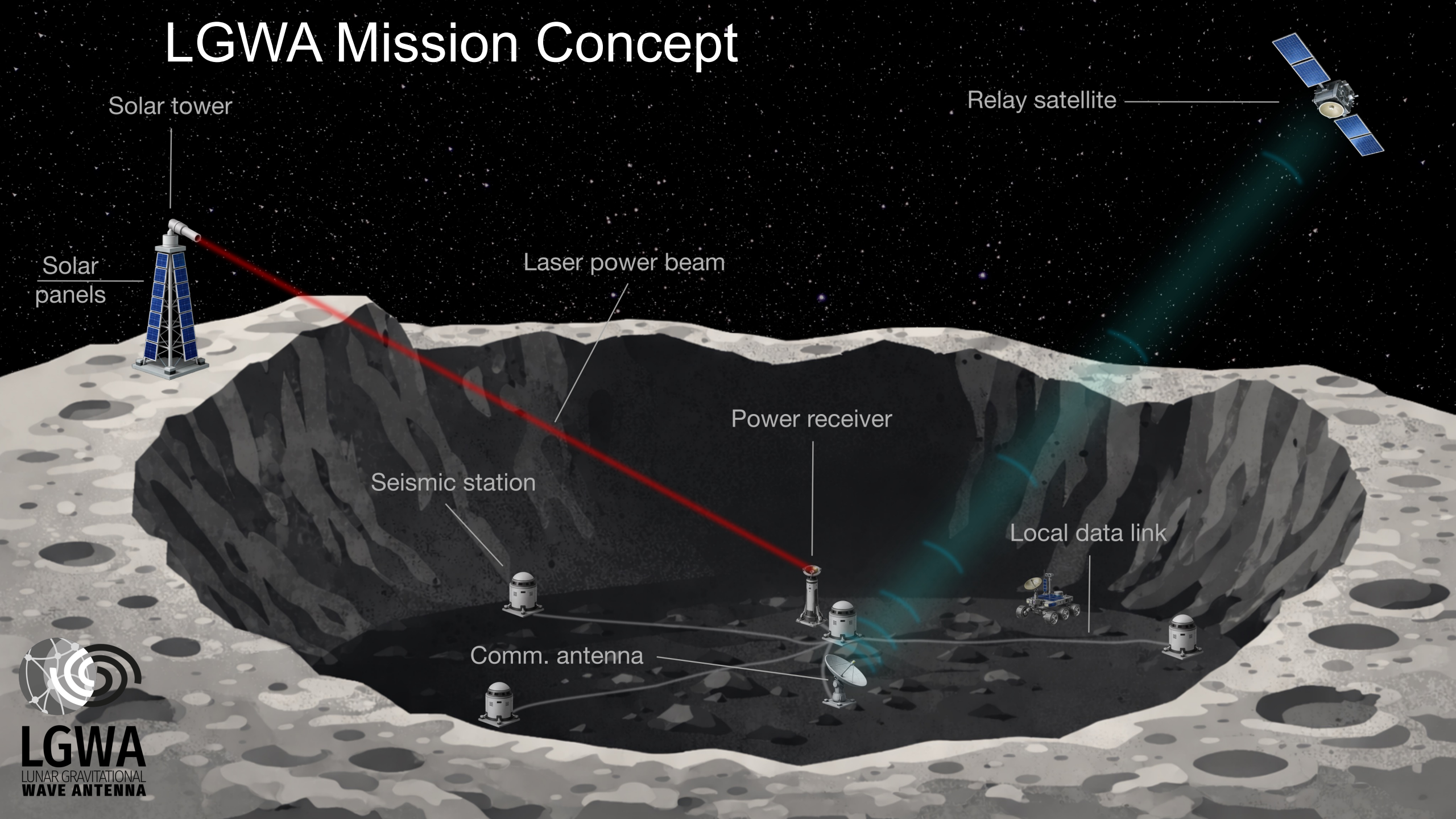


Homodyne quadrature IFO for parallel R&D and comparison with homodyne architecture



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LGWA Mission Concept

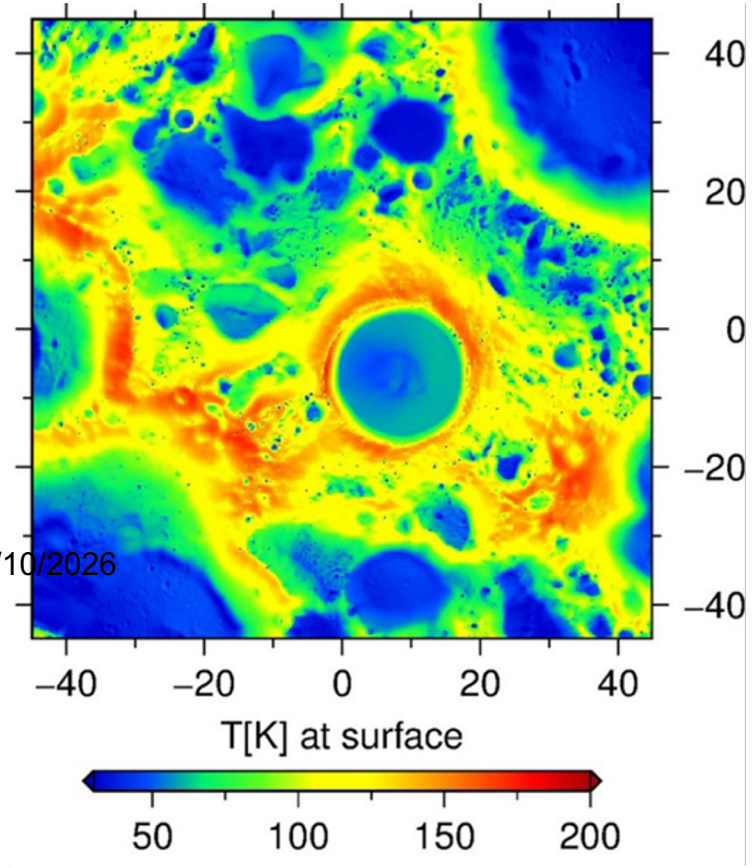


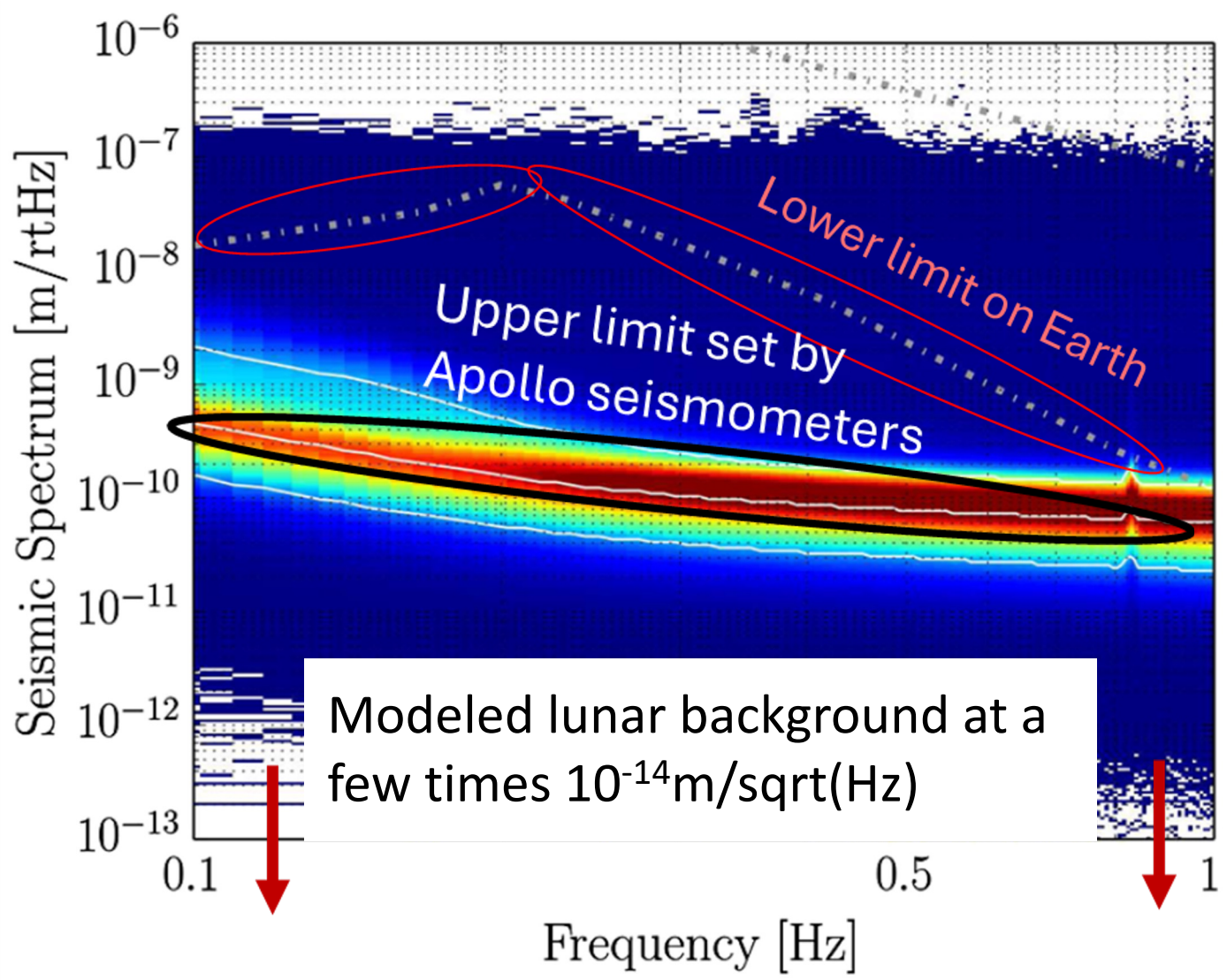
LGWA
LUNAR GRAVITATIONAL WAVE ANTENNA

Why the Moon?

The Moon's PSRs might be the seismically quietest sites in the solar system in the dHz band

Cold and relatively stable temperatures inside a PSR





Low-vibration cryogenic testbench

15-20 K

- 10 nm RMS in [0.01-10] Hz
- pm/√Hz level from 3 Hz



CS210-GMX-20B cryocooler

Cryocooler support

Rubber bellow

gHe-filled heat exchanger

Vacuum chamber

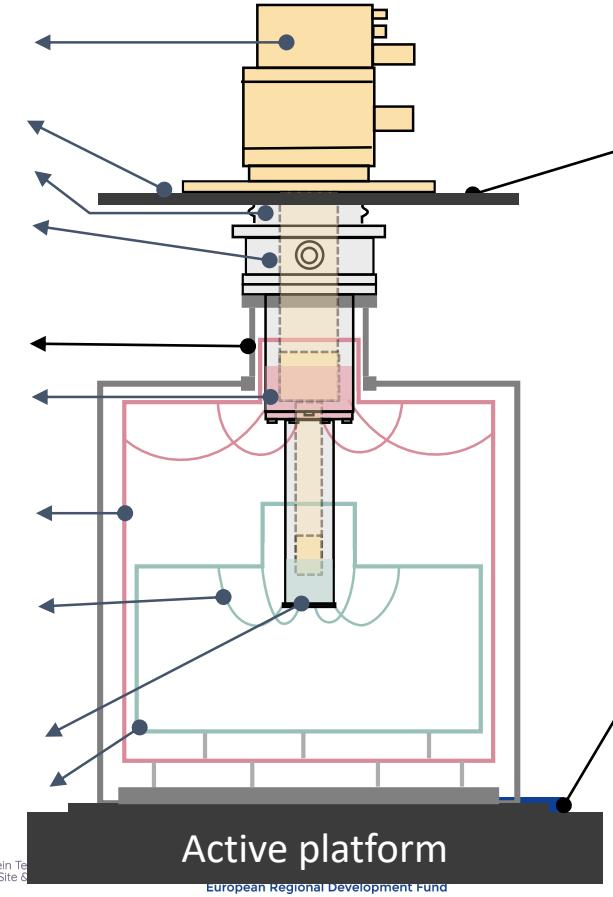
Cryocooler 45K stage

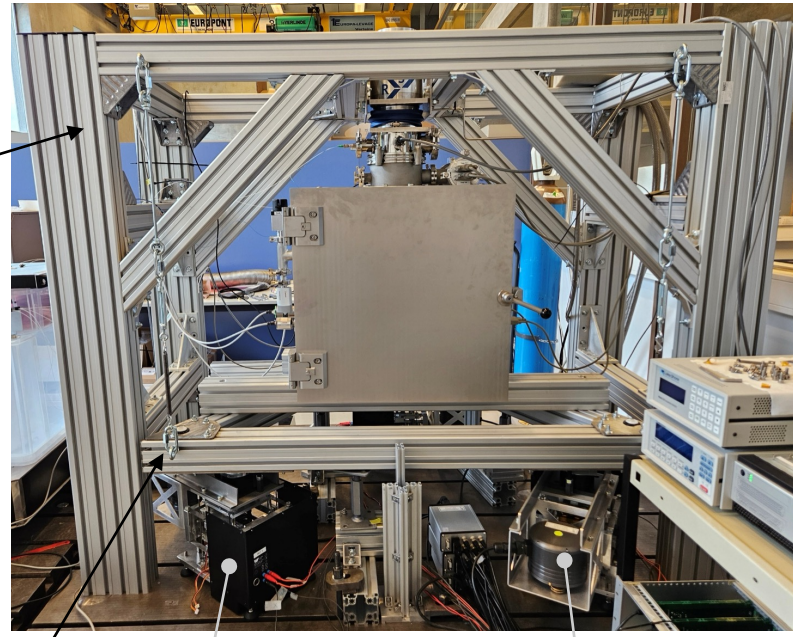
Intermediate thermal shield

Soft OFC thermal braids

Cryocooler 4K stage

Cold thermal shield



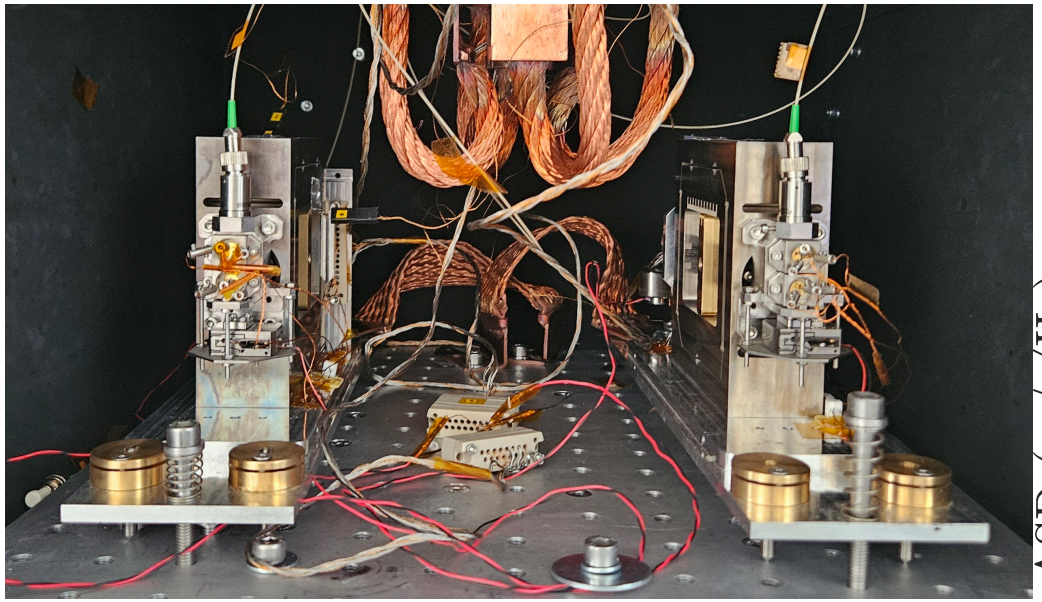


Suspension and actuator

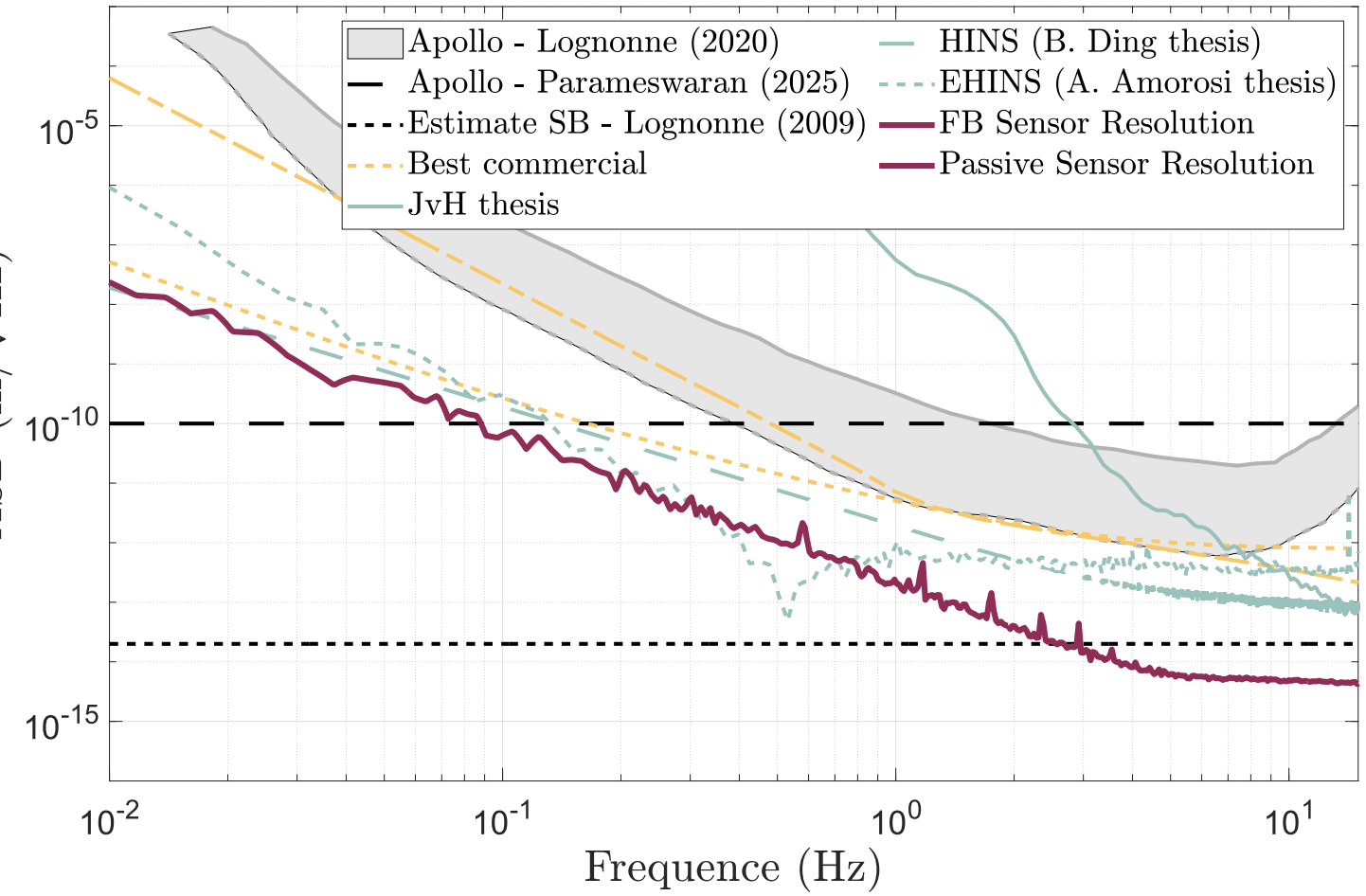
Geophones (custom Theta from GaiaCode)

17

Projections for LGWA Soundcheck

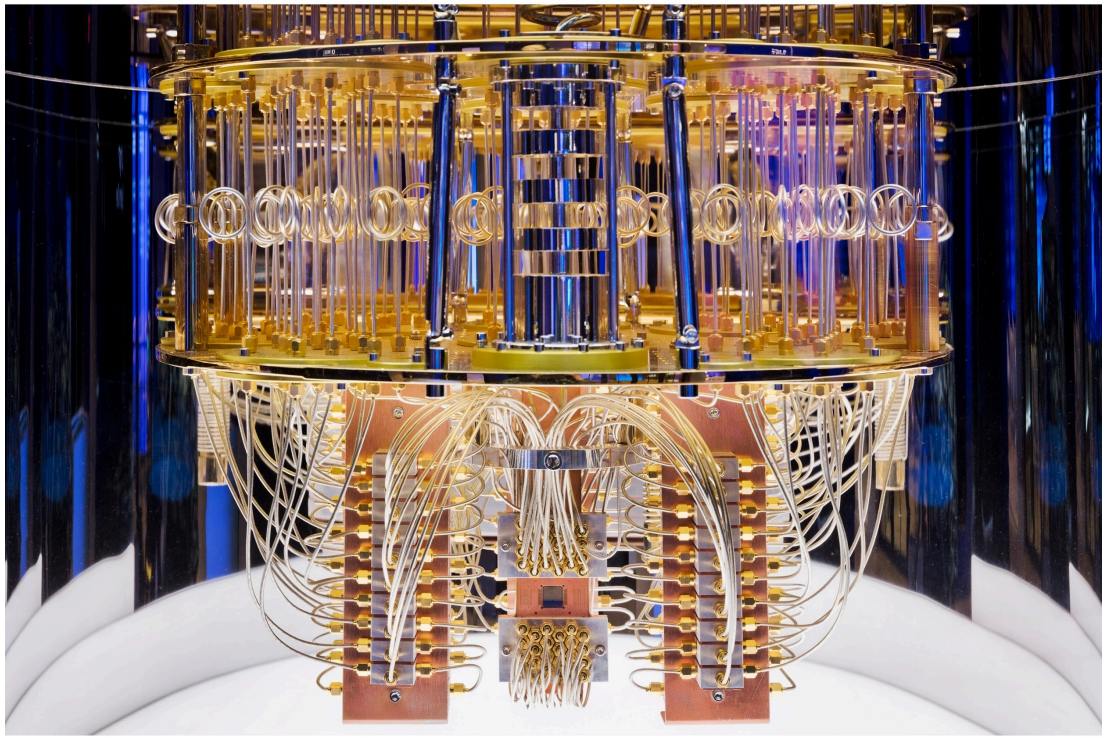


Resolution 10-100 times better than upper limit !!



Applications:

Cryo electron microscopy, astronomy, metrology, atomic force microscopy,…



Quantum computing



1989: Internet, Tim Berners-Lee, CERN !!!