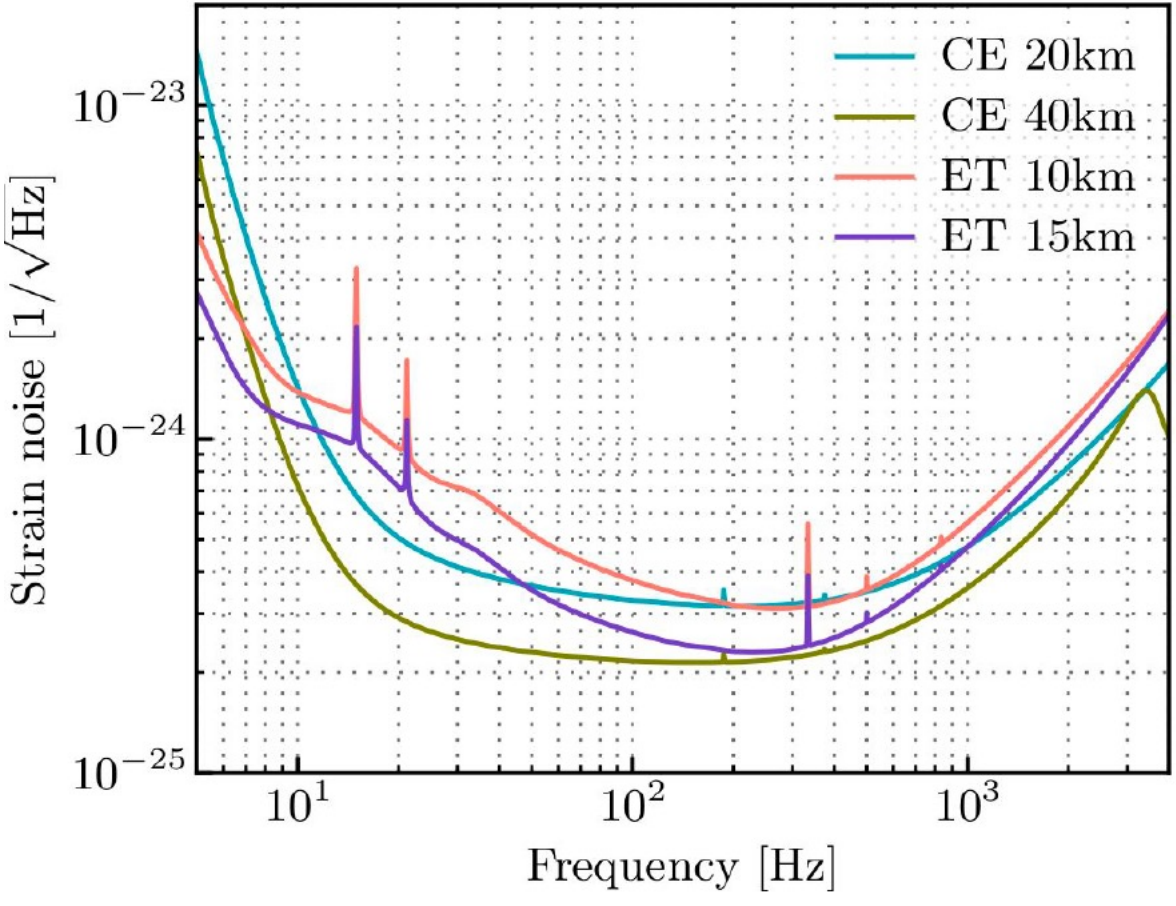
# Building the right ET infrastructure

- Low Frequency
- Duty cycle
- CE plans

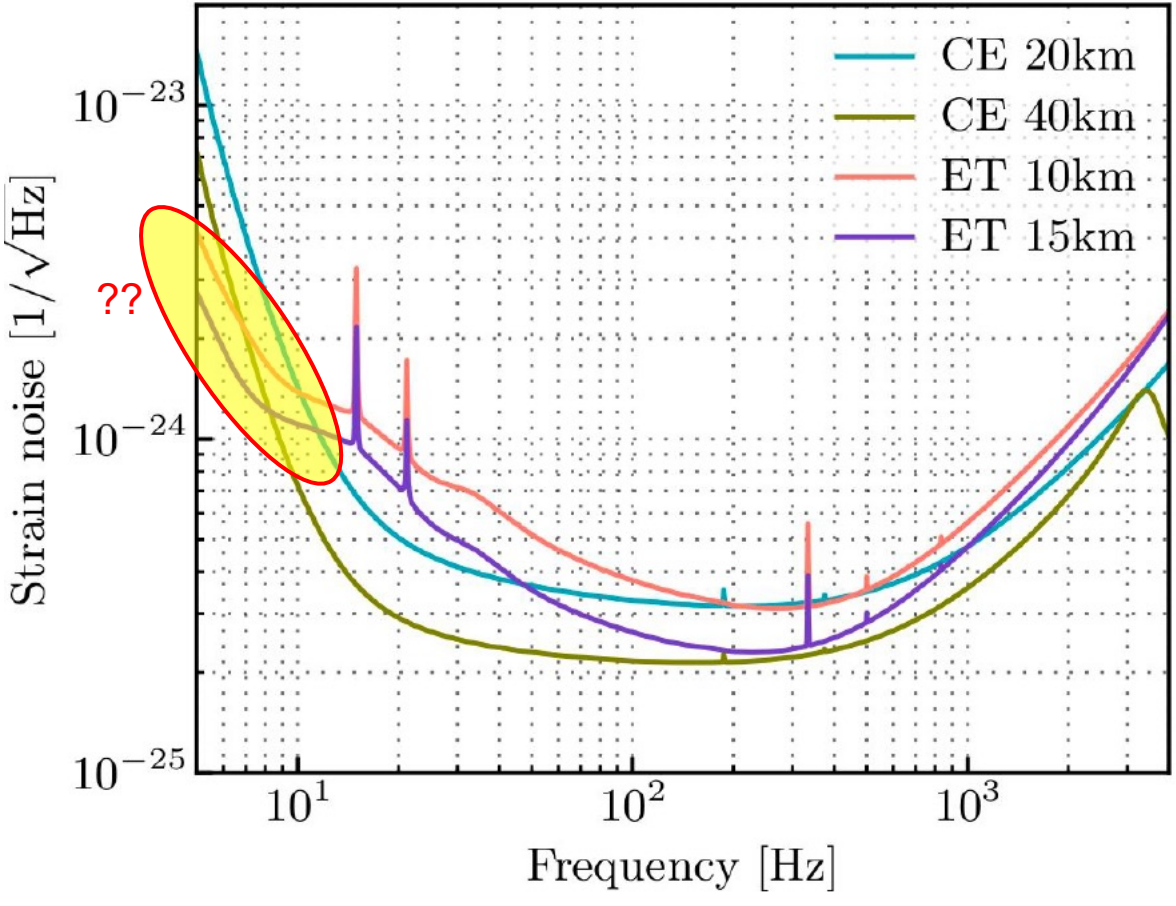
Benoit Mours; October10, 2024

ET France; Caen

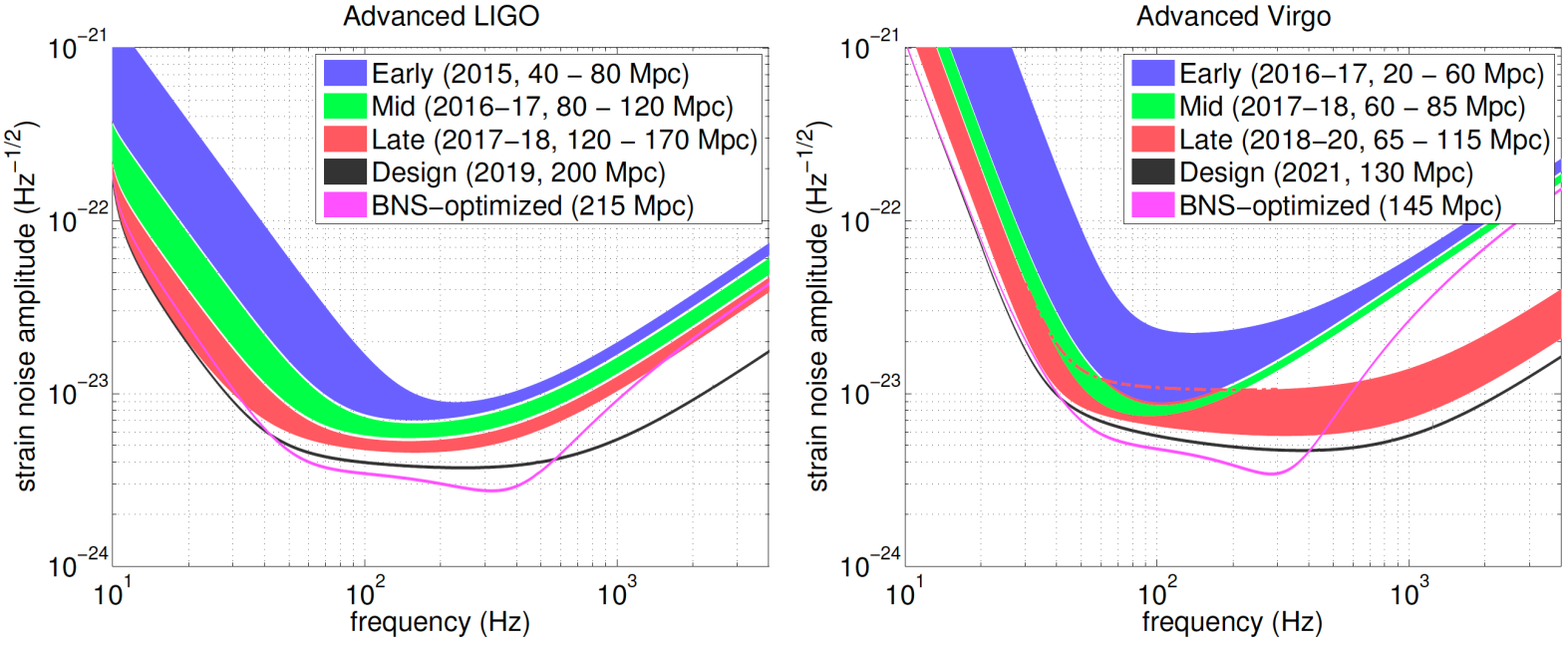
# The ET sensitivity



# The ET sensitivity: could we believe the low frequency ?



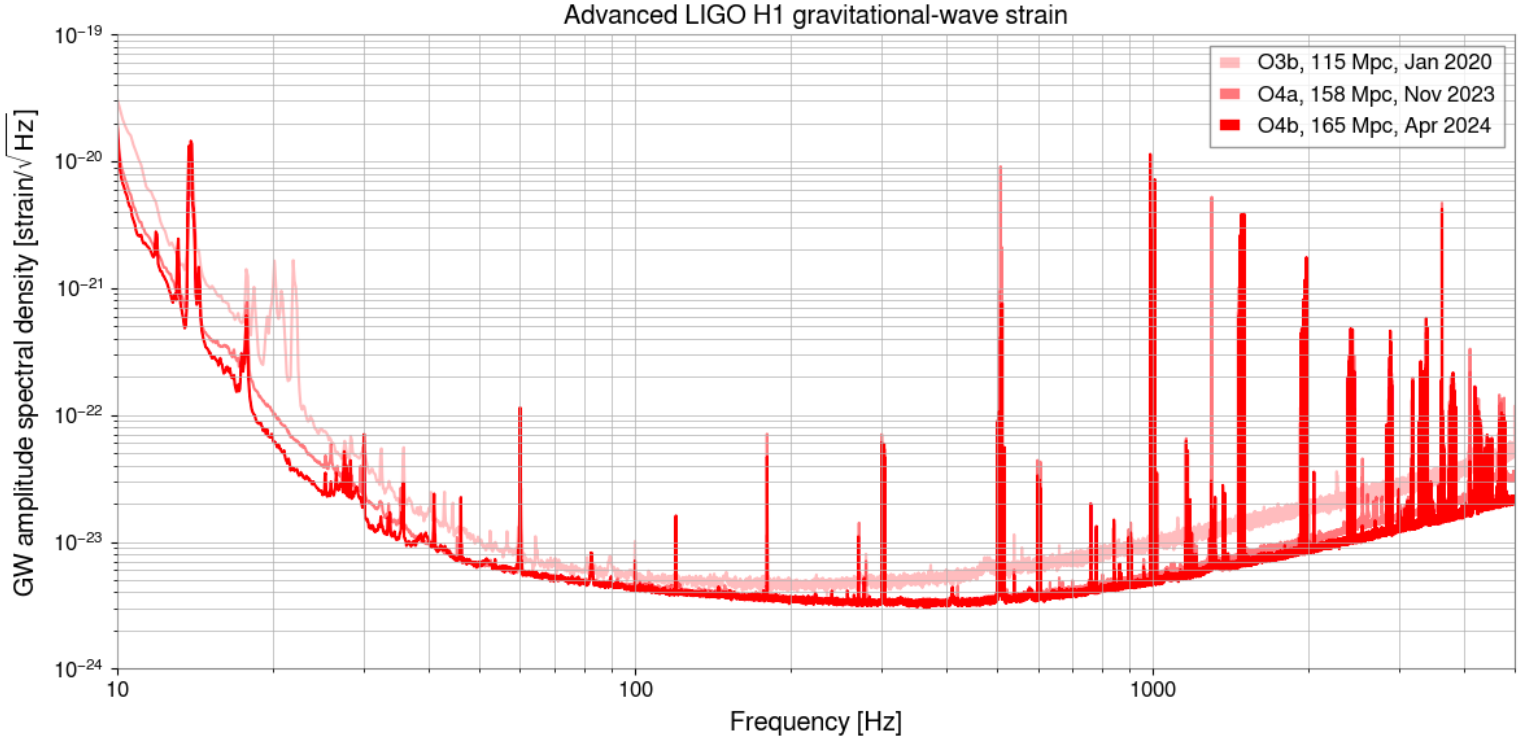
# Learning from real life: the 2014 plan




See: Prospects for Localization of Gravitational Wave Transients by the Advanced LIGO and Advanced Virgo Observatories, April 24, 2014

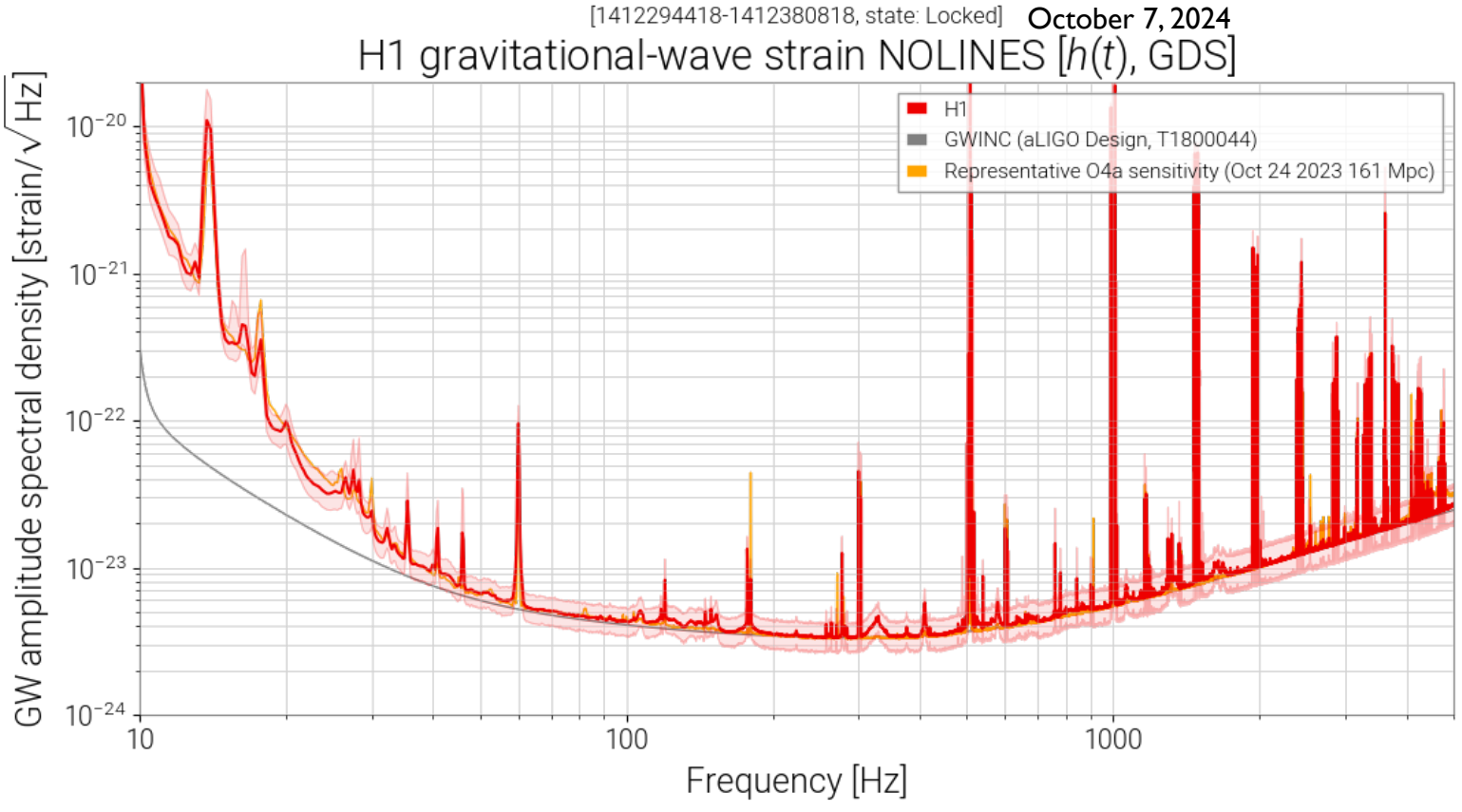
https://dcc.ligo.org/LIGO-P1200087-v19/public

# …10 years later




- L1 BNS range close to design (200 Mpc): impressive success !

# But what about low frequency?



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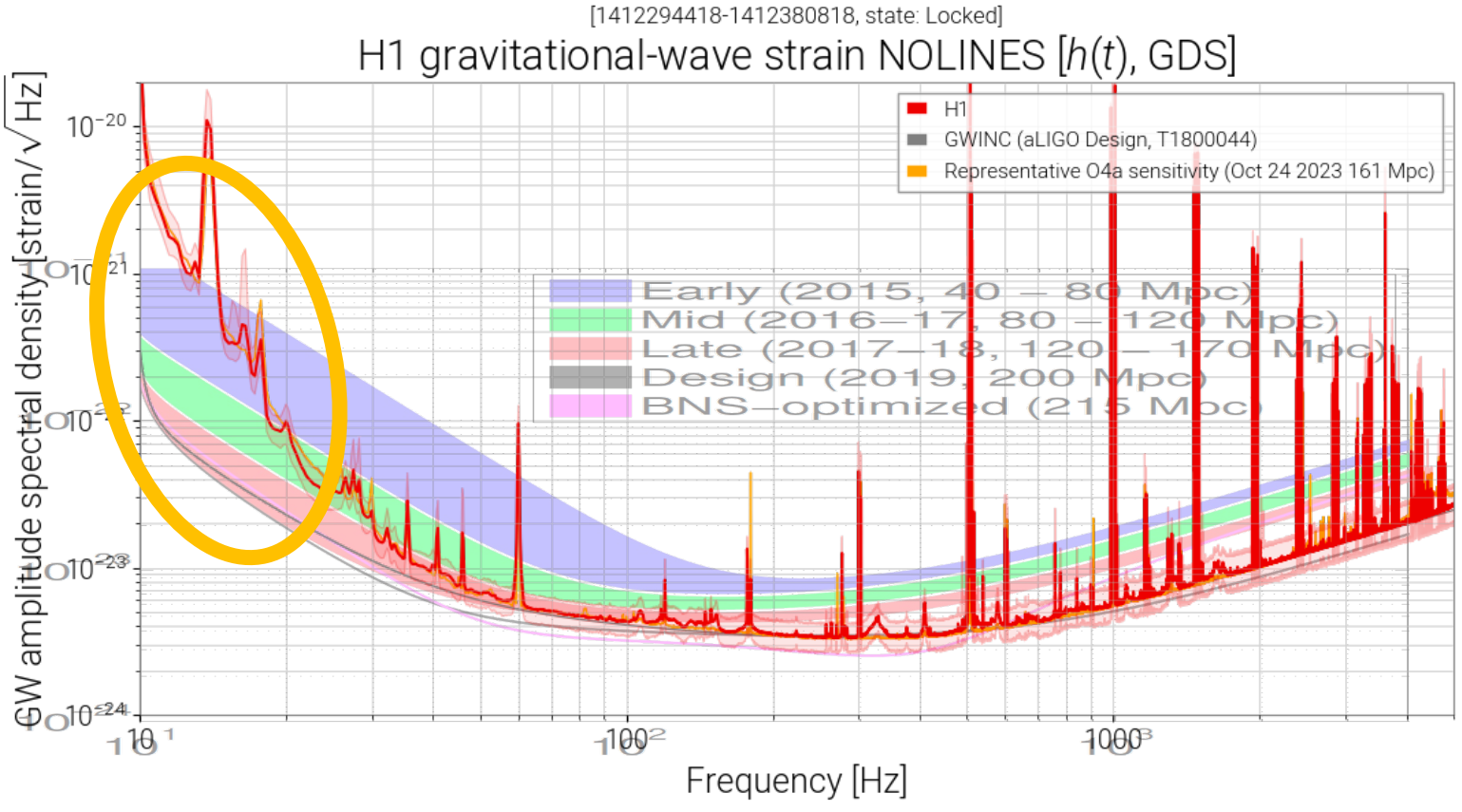
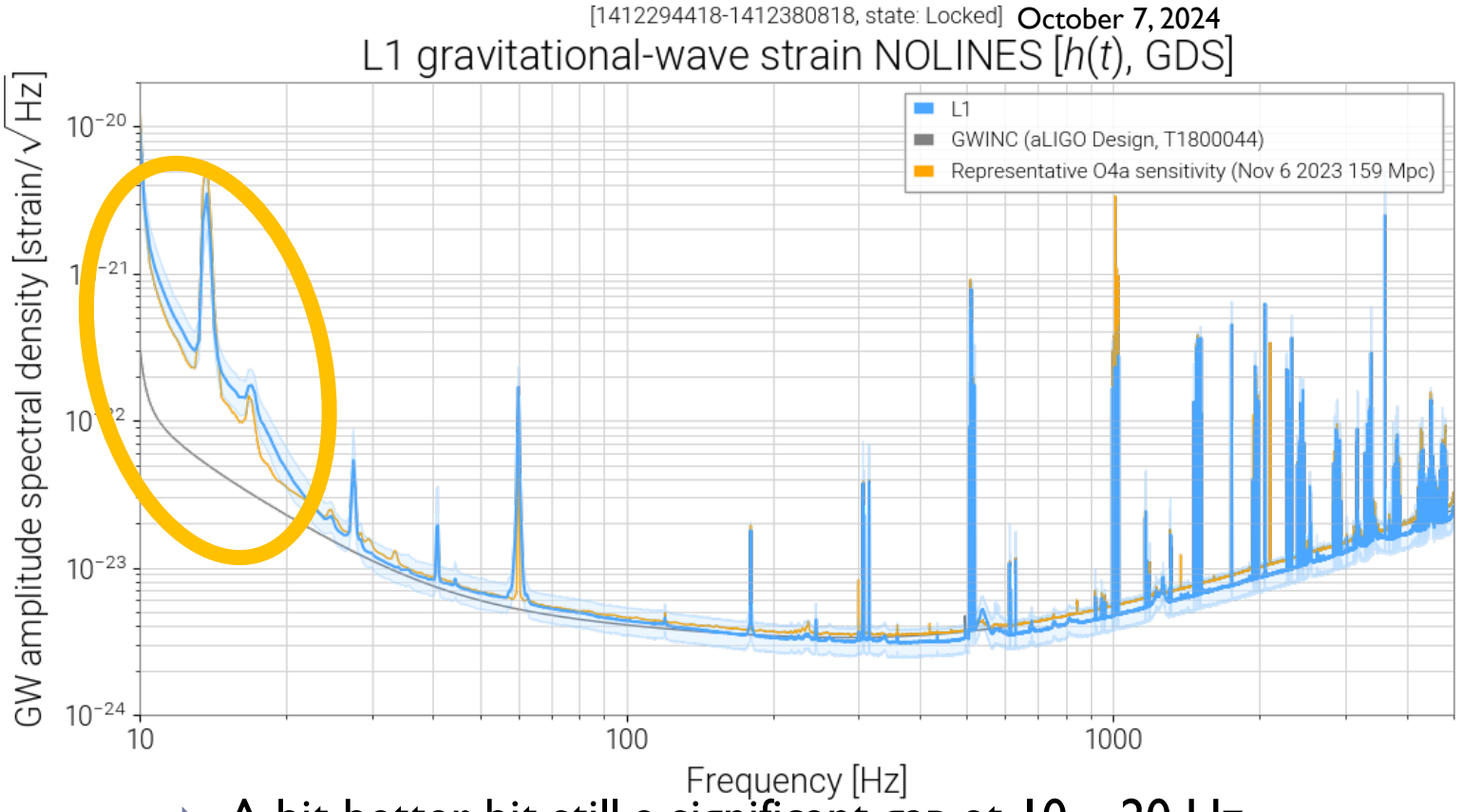


# L1?

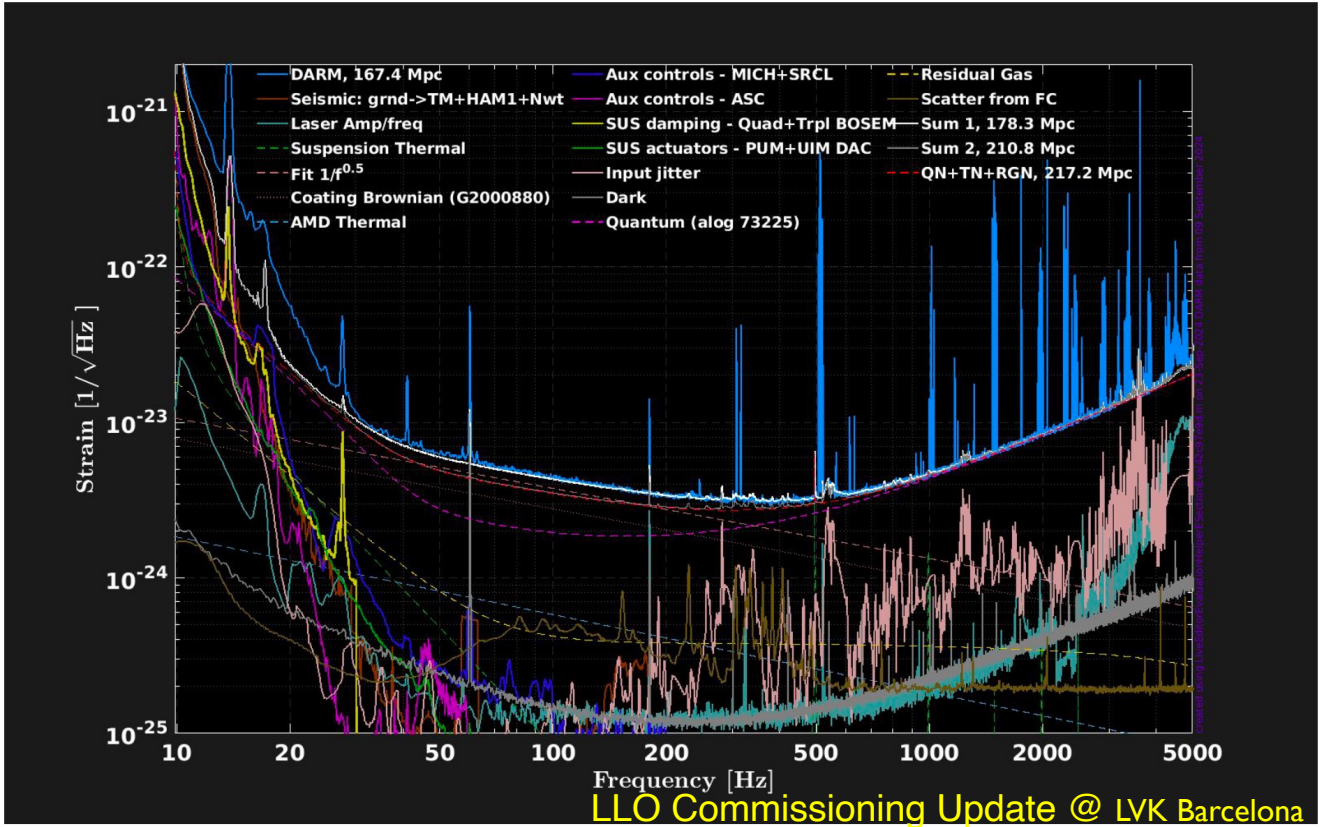



- A bit better bit still a significant gap at 10 – 20 Hz

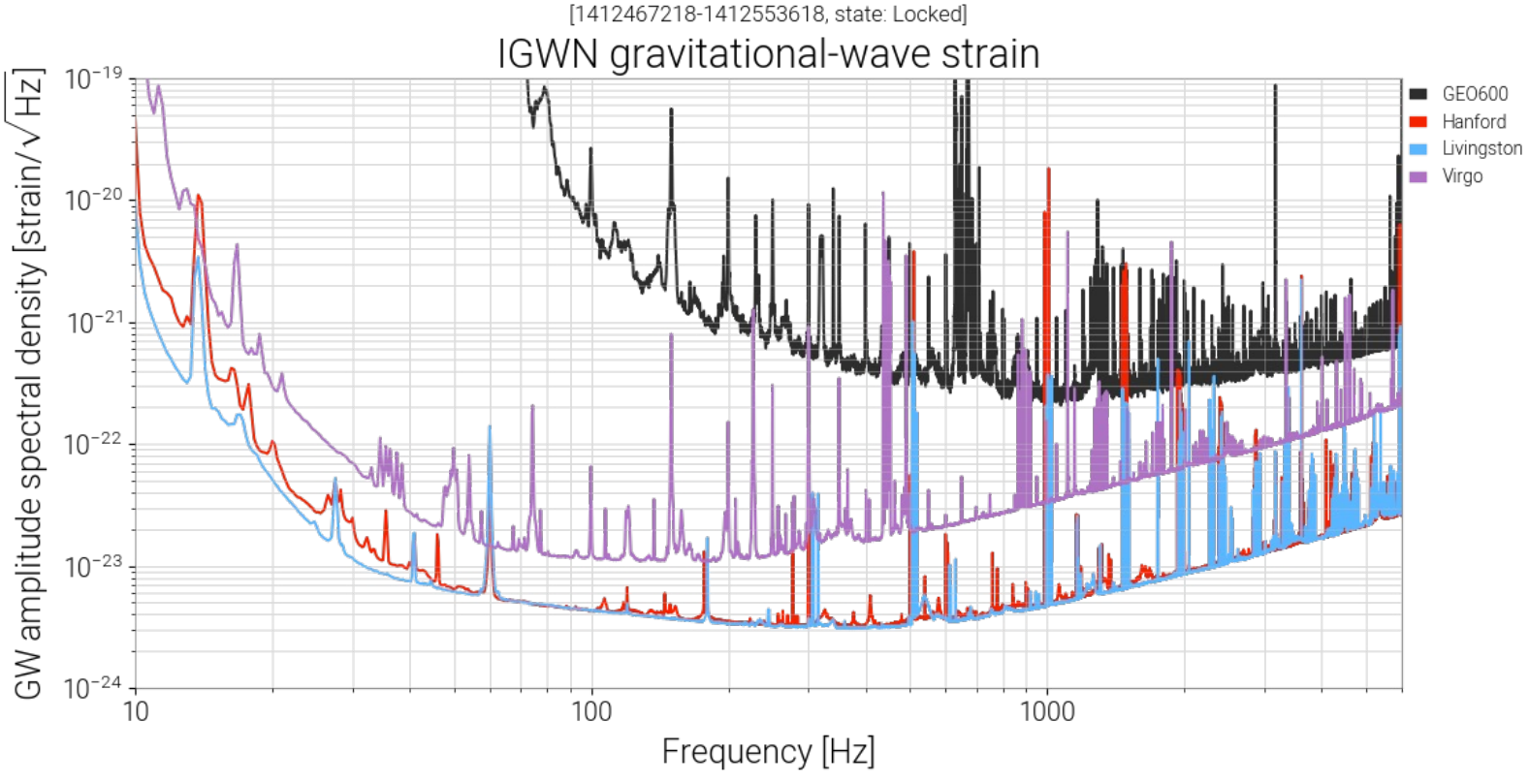
# There are a lot of noises at Low Frequency

LIGO

## Noise Budget



# Is Virgo doing better at low frequency?



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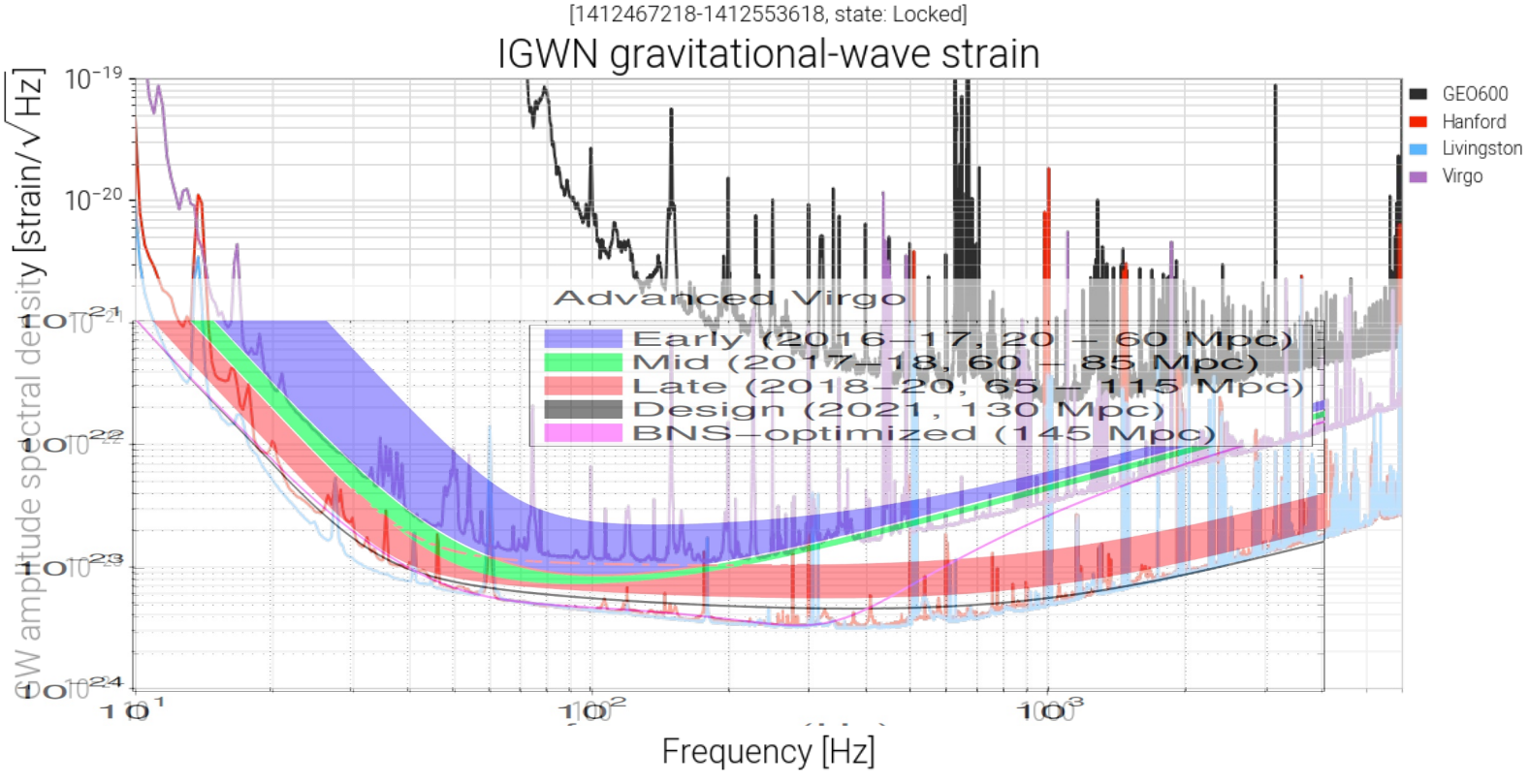


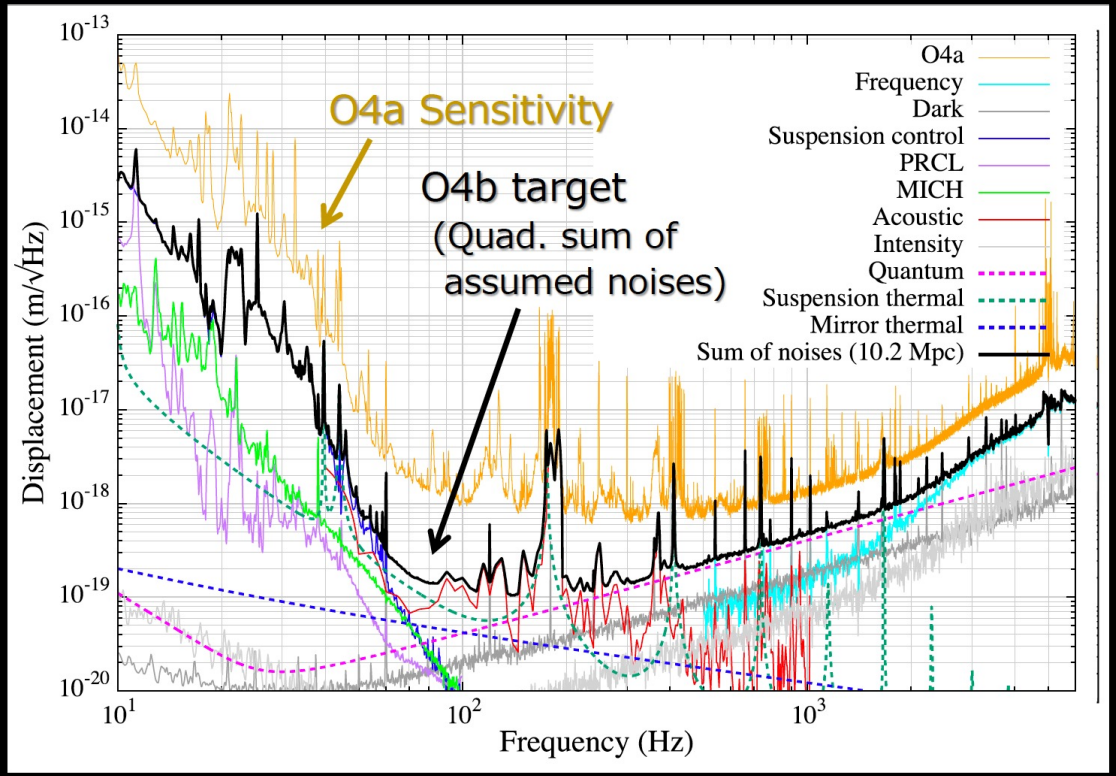
Lesson learned # 1

You never reach design sensitivity at low frequency

# What about KAGRA (Cryogenic, underground…)?

・BNS range of ~10Mpc with assumptions:

1/20 Acoustic noise, 10W Laser power, Test masses 100K




Masaki Ando
LVK Barcelona

K. Komori, JPS meeting (Sep 2025) [JGWDoc JGW-G2415901-v4]

KAGRA upgrade plans presented at LVK Barcelona

# KAGRA Summary

- Joining O4b with > 10 Mpc
- New ITMs for O5 (better symmetry and birefringence)
- Joining O5 with > 25 Mpc
- Make a detailed plan for post-O5 upgrade in 2025
  - Broadband sensitivity enhancement with FDS (Frequency Dep. Squeezing) ?
  - High-Frequency sensitivity enhancement with FIS (Frequency Index. Squeezing)?

# KAGRA Case study: 1

## BB40FDS-HQS

**Broadband upgrade**

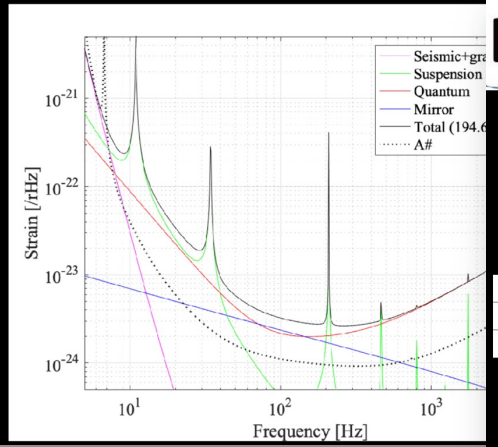
Frequency-Dependent Squeezing

High Q suspensions

| | |
|---|---|
| **Suspension loss** | 2x $10^{-7}$ |
| **Squeezing** | 6dB FDS |
| **Larger mirrors** | 40kg |

Kentaro Komori (RESCEU)
Yoichi Aso (NAOJ)
Yuta Michimura (RESCEU)
Shinji Miyoki (ICRR)

JGW-G2415936




# KAGRA Case study: 2

## HF2KFIS-HQS

**Create a dip in sensitivity around 2kHz**

Frequency-Independent Squeezing

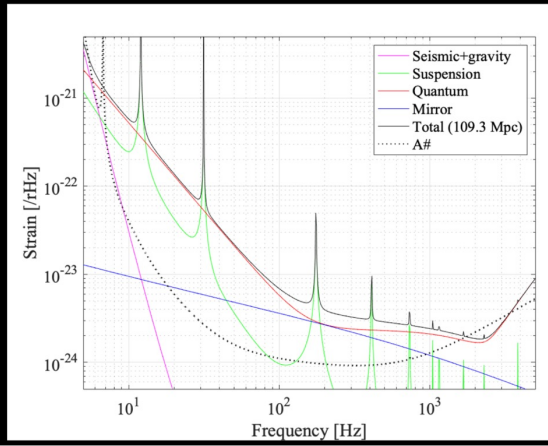
High Q suspensions

| | |
|---|---|
| **Suspension loss** | 2x $10^{-7}$ |
| **Squeezing** | 10dB non-FDS |
| **Higher ITM reflectivity** | 99.6%-> 99.8% |

Kentaro Komori (RESCEU)
Yoichi Aso (NAOJ)
Yuta Michimura (RESCEU)
Shinji Miyoki (ICRR)

Also K. Somiya

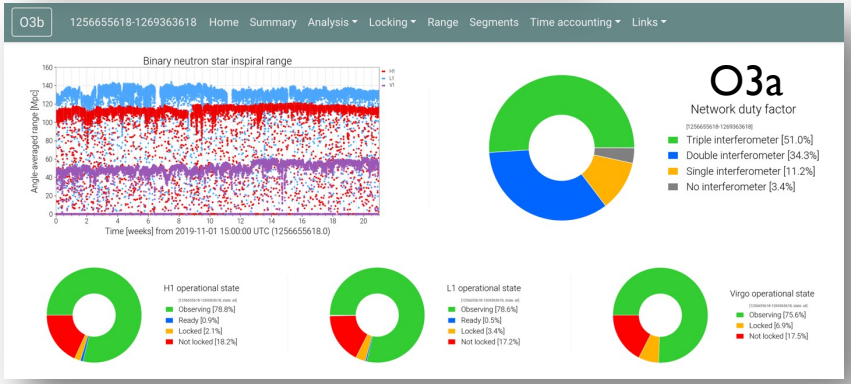
JGW-G2113082

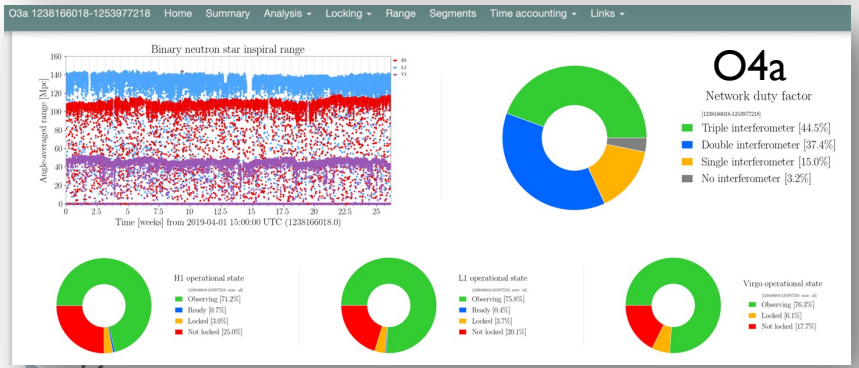


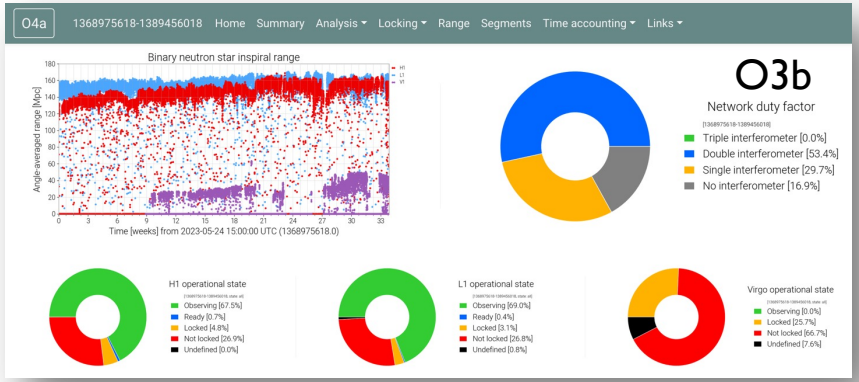
# Lesson learned # 2
# Cryogeny does not help but make it more difficult

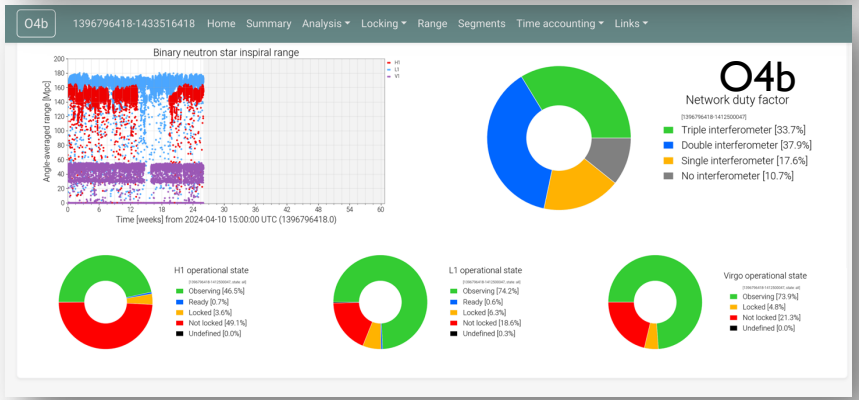
# Duty cycles

O2

# Duty cycles

| Run | H1 | L1 | V | HL | HLV |
|---|---|---|---|---|---|
| O2 | 62 | 61 | - | | - |
| O3a | 71 | 76 | 76 | | 44.5 |
| O3b | 79 | 79 | 76 | | 51.0 |
| O4a | 67 | 69 | - | 53.4 | - |
| O4b | 47 | 74 | 74 | | 33.7 |
| Average | 65 % | 72 % | ? | | 43 % |

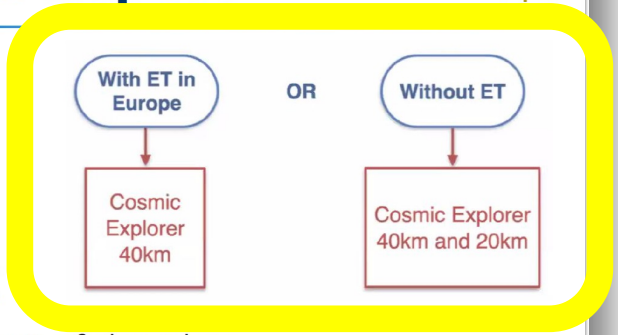
- Average 3 detectors duty cycle is 43% → for 6 ITFs expect 18 %
- Remarks:
  - The start of a run is often delayed:, delays not included here
  - Including O4 with Virgo down: 32% triple time → 10% for 6 ITFs
  - If ITFs are collocated it is difficult to fix one ITF while collecting science data

Lesson learned # 3

Combined ITFs have a much lower duty cycle than single ITF

# NSF Blue Ribbon Panel Report

- International review team; chaired by V. Kalogera
- **Strong recommendation for Cosmic Explorer**
- Strong recommendation for a Network
  - 40km CE plus ET are the basis
  - Complemented with LIGO-India, or 20km CE
- 4km LIGO phase-out requirement a critical element of the plan
- Prominence of LIGO-India highlights the importance of Asia-pacific detector
- If indeed H1/L1 are phased out: A# detecto available
  - Could potentially go to India, and per infrastructure, in the 2030's
- https://www.nsf.gov/mps/phy/nggw.jsp




# CE plans

## Launching the Cosmic Explorer Conceptual Design

Coordinated NSF proposals funded in 2023-24

Total funding: 27 M$

| Scope | Award | Investigators (PI/co-I) | Status |
|---|---|---|---|
| Establishes CE Project Office and Management Team | $3.3M | **M. Evans (PI)**, S. Ballmer, H. Hansen, J. Key, B. Sathyaprakash | Funded |
| Site Evaluation and Indigenous Partnership Program | $4.5M | **J. Smith (PI)**, K. Daniel, S. Ballmer, M. Landry, G. Lovelace, V. Mandic, J. Russell, R. Schofield, C. Scholz, P. Sledge, A. Strunk | Funded |
| Interferometer Optical Design (including LSC and ASC) | $900k | **P. Fulda (PI)**, S. Ballmer, L. Barsotti, C. Cahillane, G. Mansell, L. McCuller, D. Tanner | Funded |
| Optical Mode Sensing and Control | $500k | **J. Richardson (PI)**, S. Ballmer | Funded |
| Newtonian Noise Mitigation | $24k | **J. Driggers (PI)**, M. Evans, M. Landry, V. Mandic | Funded |
| Stray Light Mitigation | $37k | **A. Kontos (PI)**, L. McCuller | Funded |
| CE Beam Tube Experiment | $17.7M | **M. Zucker (PI)** | Funded |

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ET and CE talk at LVK Barcelona

# Summary

- The ET sensitivities are no realistic at low frequency
  - The foreseen ET will have a very limited scientific impact
  - Don't try to fix a limited infrastructure by complex technology
- We must streamline the design like CE is doing: a single ITF
- The ET infrastructure must be identical to CE to be competitive
  - L shape with the same length as CE
- Going (fully) underground has little benefit and a lot of drawback