

Live noise budget

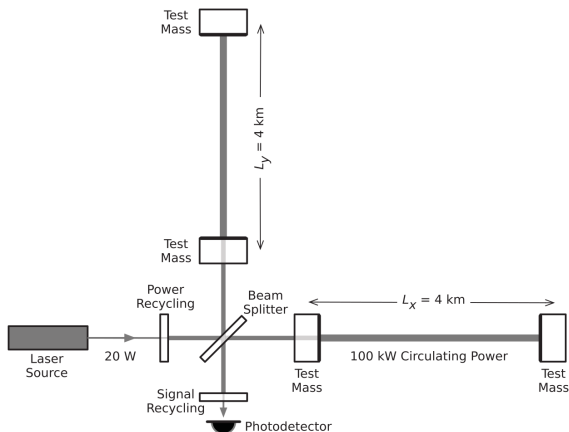
Ronaldas Macas and Sheila Dwyer

July 13, 2018



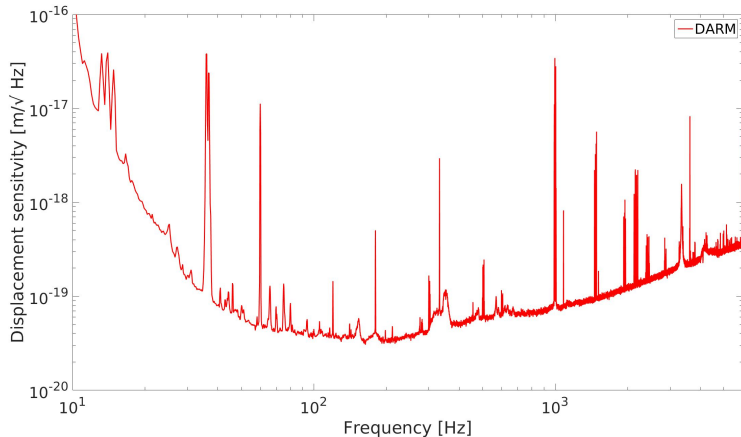
What is DARM?

DARM - Differential ARM - length difference between X and Y arms



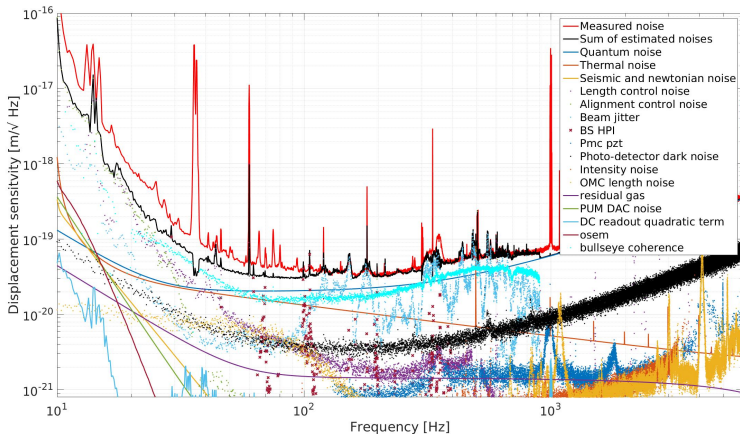
What is DARM?

DARM - Differential ARM - length difference between X and Y arms



Live noise budget

Live noise budget - sum of all known noises



Live noise budget: Earthquake example

5.8 magnitude earthquake hit Montana on July 5th, 2017.

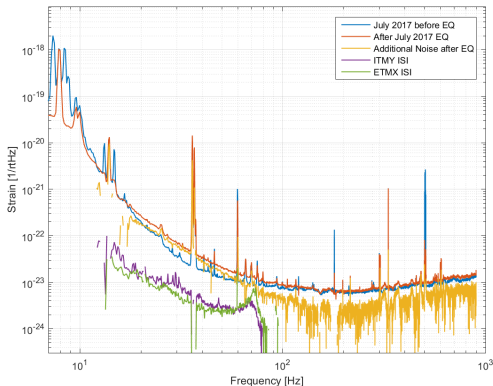
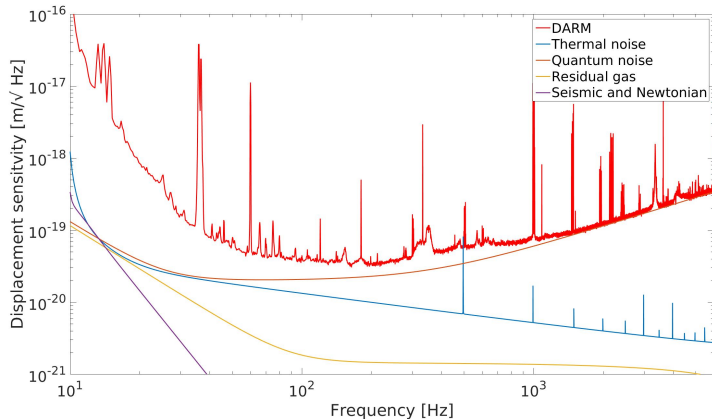


Figure 1: DARM before the earthquake (blue) and after (orange), where yellow indicates excess noise. Green and violet represent noises that were observed only *after* the earthquake [▶ Sheila's 38854 aLOG](#)

1. Fundamental noise

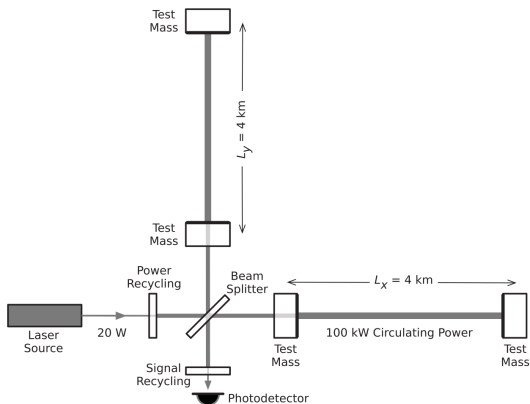
Fundamental noise

- Noise that determines the ultimate design sensitivity is called *fundamental* noise
- Cannot be reduced without a major instrument upgrade



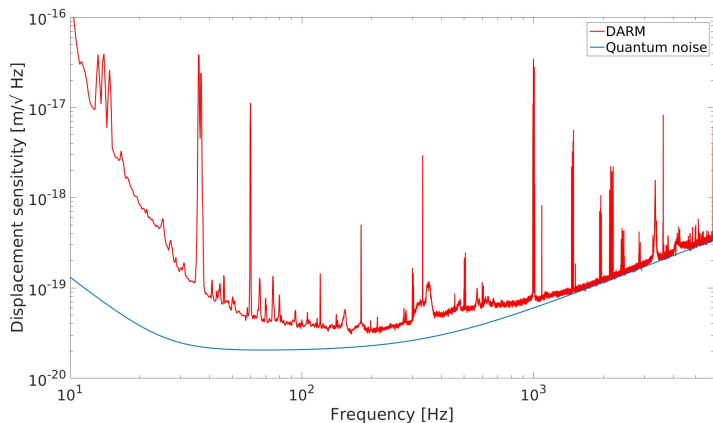
Fundamental noise: Quantum

- *radiation pressure noise* - laser amplitude noise in arm cavities
- *shot noise* - laser amplitude noise on the photodetector



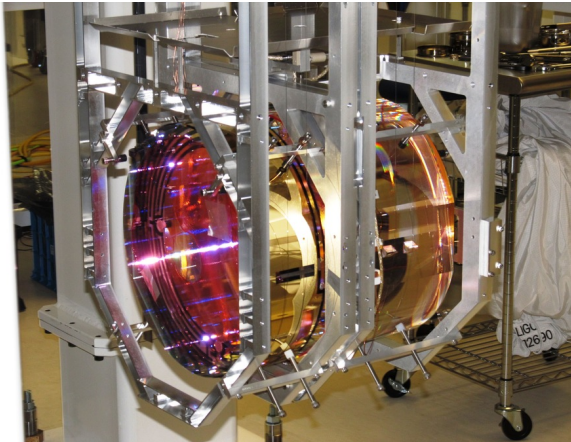
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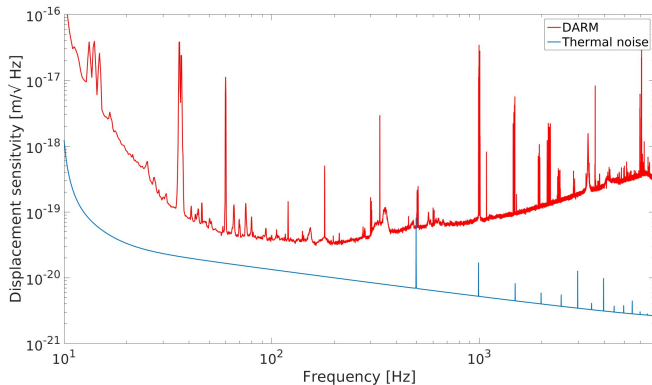
Fundamental noise: Thermal

- *suspension noise* - thermal vibrations cause motion of test masses
- *coating Brownian noise* - thermal fluctuations of the optical mirror coatings



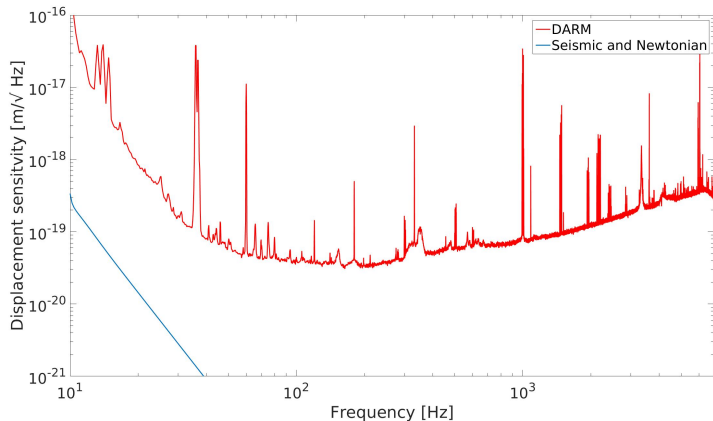
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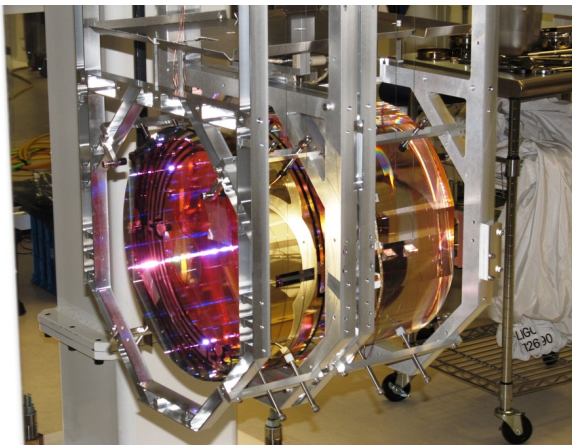
Fundamental noise: Seismic and Newtonian gradient

- *seismic noise* - ground motion in the order of $10^{-9} m/\sqrt{Hz}$
- *Newtonian gradient noise* - fluctuations of local gravity field



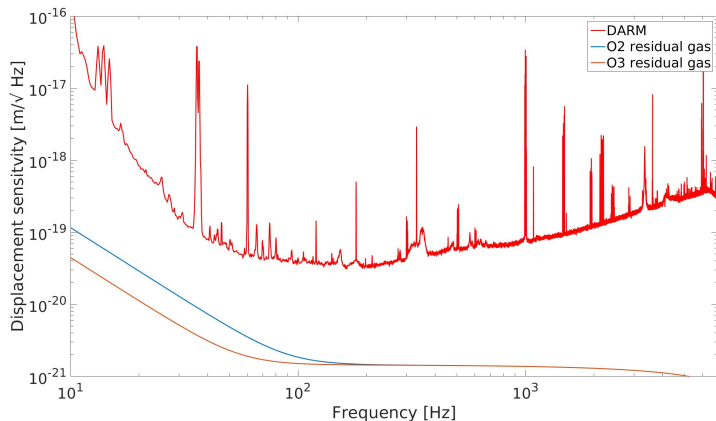
Fundamental noise: Residual gas

- *squeezed film damping noise* - trapped molecules between reaction and test mass moves mirrors
- *phase noise* - residual gas interferes with laser beam in arms



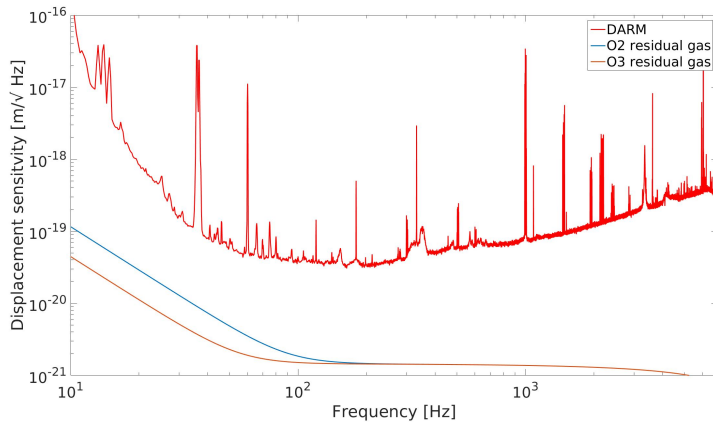
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Residual gas noise

- added live pressure data
- updated residual gas composition
- included reduced squeezed film damping noise for O3



2. Environmental noise

Environmental noise

Definition

Noise that highly depends on environment and tends to change over time is called environmental noise

Examples

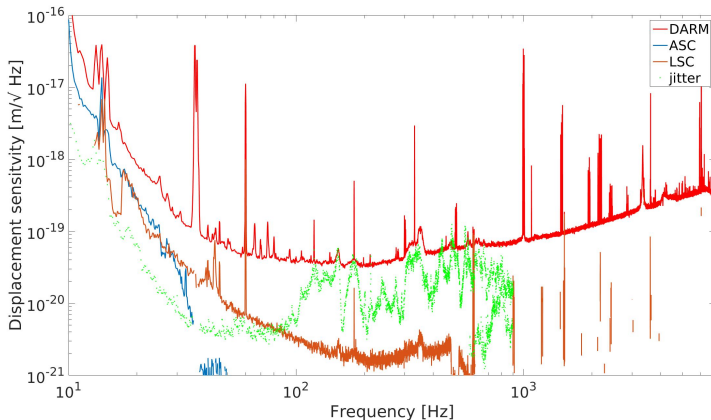
- *wind*
- *acoustic*
- *magnetic*



3. Technical noise

!!!!!! TECHNICAL NOISE !!!!!

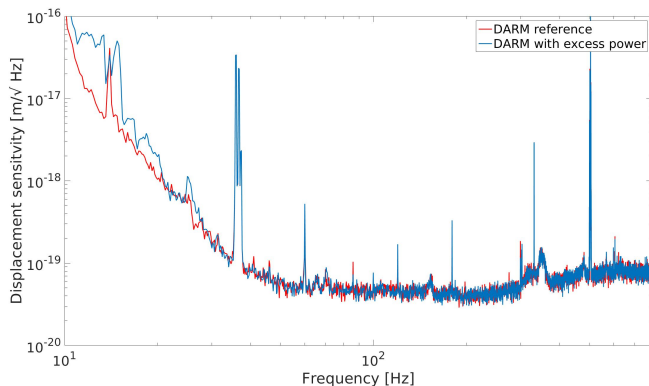
- Noise that arises from electronics, control loops, charging noise and other effects is called *technical* noise
- Can be reduced once identified and carefully studied



Technical noise estimation: excess power projection

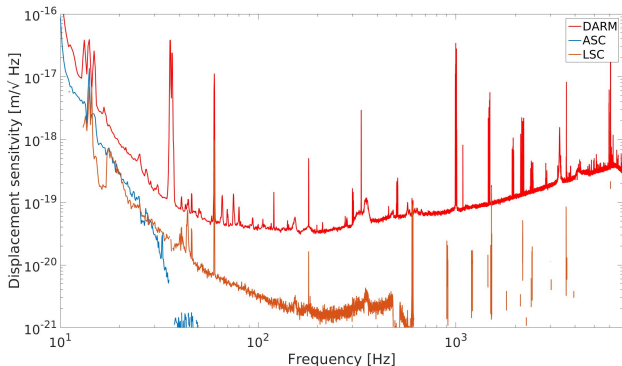
Excess power projection

- drive individual part of a detector (i.e. give excess power)
- measure noise coupling to DARM
- project the coupling to the un-driven system



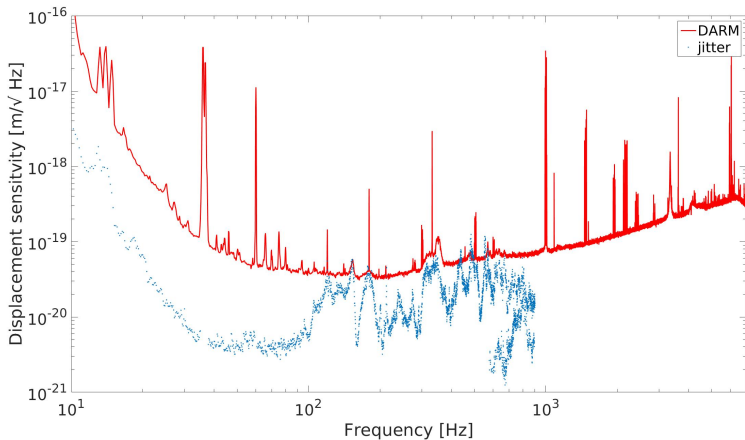
Technical noise: length and alignment controls

- keeping the interferometer in lock requires precise control systems
- some control systems have substantial amount of noise that couples to DARM
- example: **length** and **alignment** control systems



Technical noise: jitter

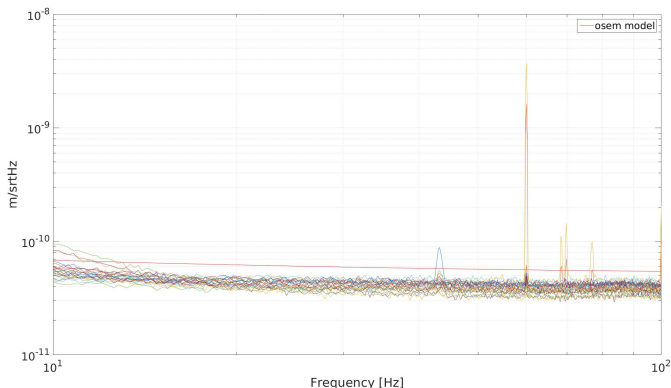
Pointing fluctuations of the laser (jitter) was a problematic noise source for Hanford during Observing Run 2



Osem noise

Osem sensor noise - noise in sensors that control top mass damping to the quad suspensions

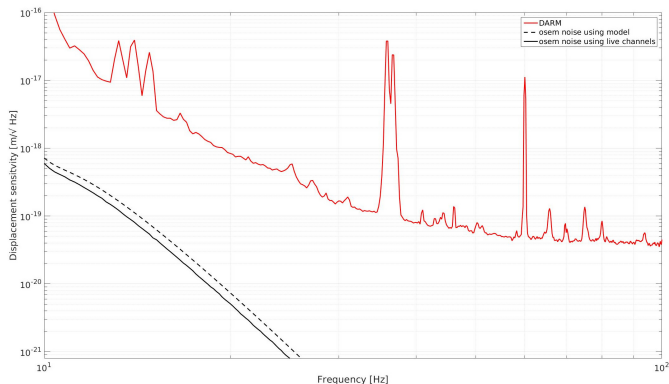
- 4 masses, 6 sensors each → 24 live data channels
- using suspension model that projects top mass damping down to mirrors



Osem noise

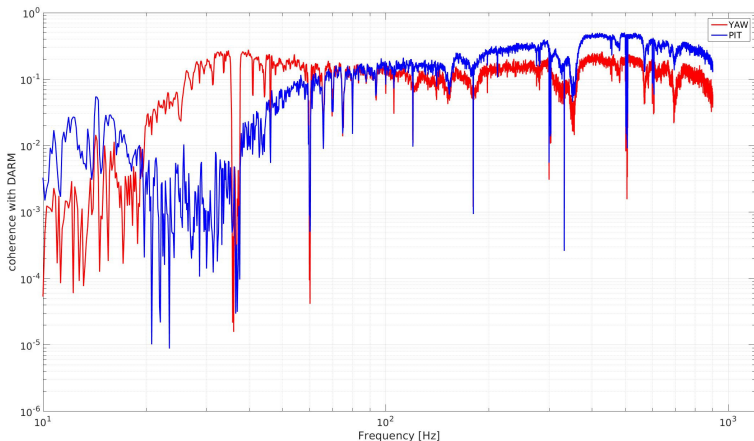
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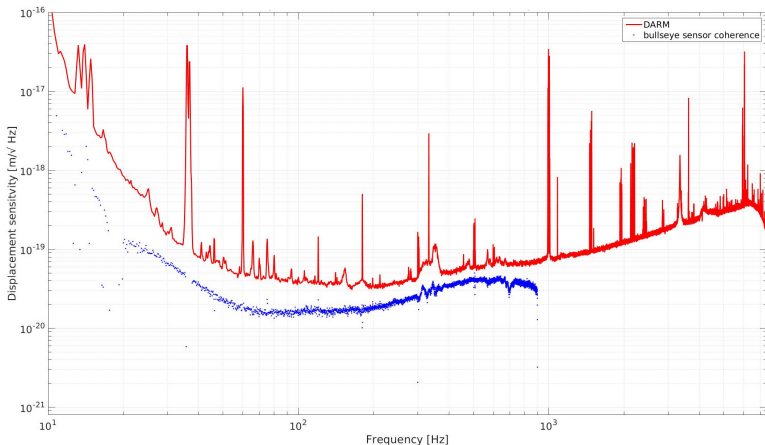
Bullseye sensor coherence

- a coherence based projection of jitter from the bullseye sensor upstream of the PMC
- we believe that jitter is caused by the turbulent flow of water over the crystals in the high power oscillator



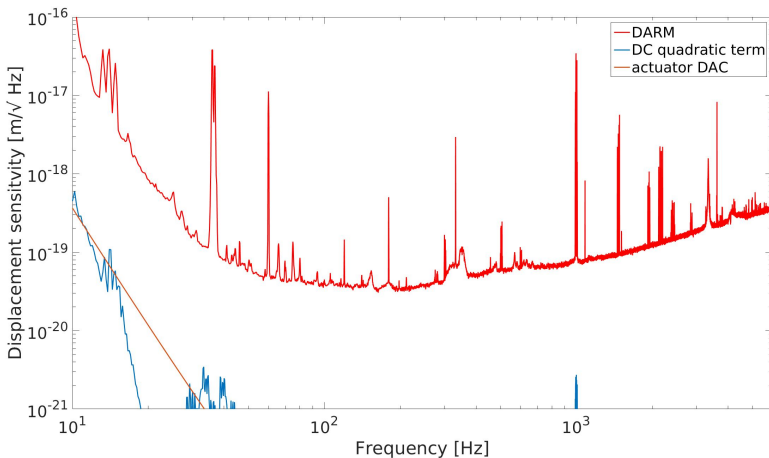
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Other noises

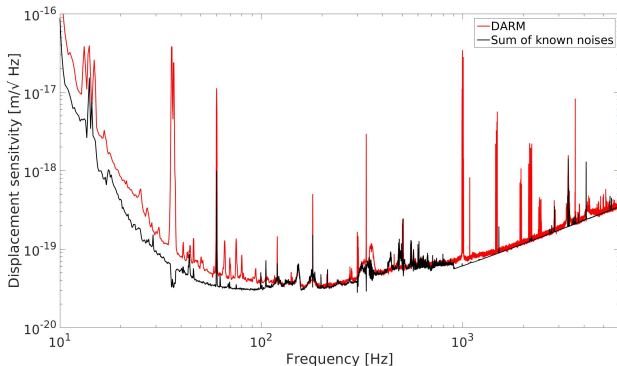
- quadratic response of DC readout [▶ Sheila's 25053 aLOG](#)
- actuator DAC noise [▶ Suspension model by Jeff K. \[DCC: G1100968\]](#)



Noise budget: unknown noise in 10-100Hz range

Contributions from known noise sources (black) agree well with DARM (red) except in a low frequency range

- charge noise?
- scattered light noise?
- something else?



Summary of LIGO noise

DARM is a measurement of detector sensitivity

Detector sensitivity is ultimately limited by fundamental noises

- Quantum noise
- Thermal noise
- Residual gas noise
- Seismic and Newtonian gradient

However, there are other noises that impact detector sensitivity

- TECHNICAL NOISE
- Environmental noise

There is a mystery noise below 100Hz that cannot be explained

To-do list

- 1 export NB to summary pages
- 2 include additional noises
 - coil driver
 - laser frequency
 - radio frequency
 - stray fields
 - light scattering
 - squeezer
- 3 use it for LLO (?)

Summary of the LSC fellowship

Live noise budget code has been restructured

Added or updates the following noises

- actuator DAC noise
- DC readout quadratic term
- osem noise
- bullseye coherence
- residual gas noise
- sensing noise calibration (in progress)

The project is in good shape to start using it for commissioning/O3