

Scatter noise updates at LIGO Livingston

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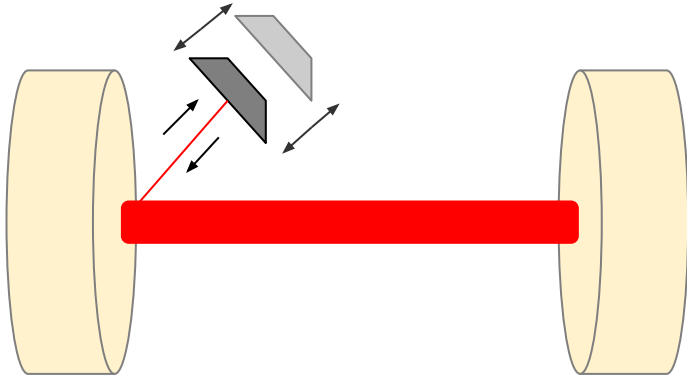
Anamaria Effler, Valera Frolov

LIGO Livingston

LVK March 2023

Detchar-Instrumentation

Scattered Light noise



$$\phi_{sc}(t) = \frac{4\pi}{\lambda} |x_0 + \delta x_{sc}(t)|$$

$$h_{sc} = K \sin(\phi_{sc}(t))$$

$$f_{shelf} = \frac{2v_{sc}}{\lambda}$$

Stray light at multiple locations

+

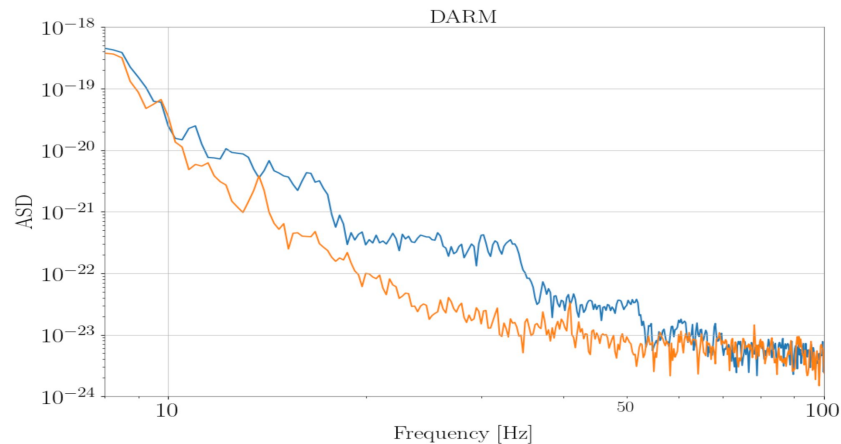
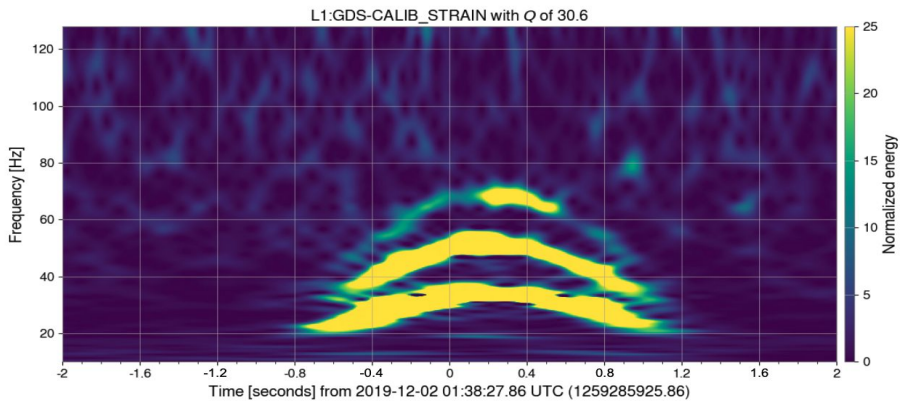
Optics motion during high microseism



Scattered Light noise

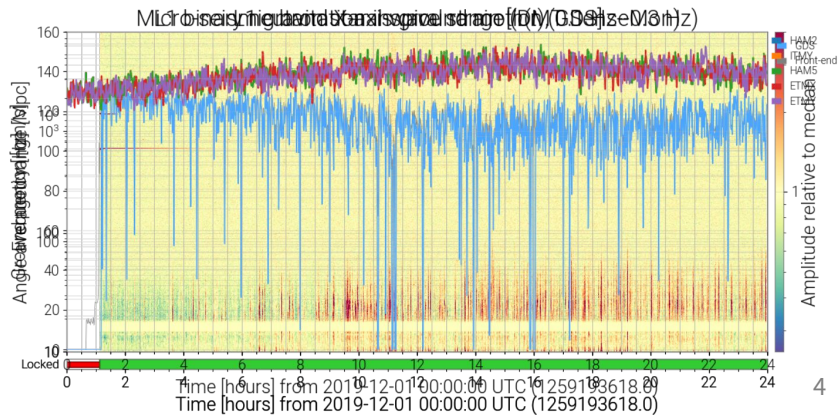
Slow Scattering

Slow Scatter



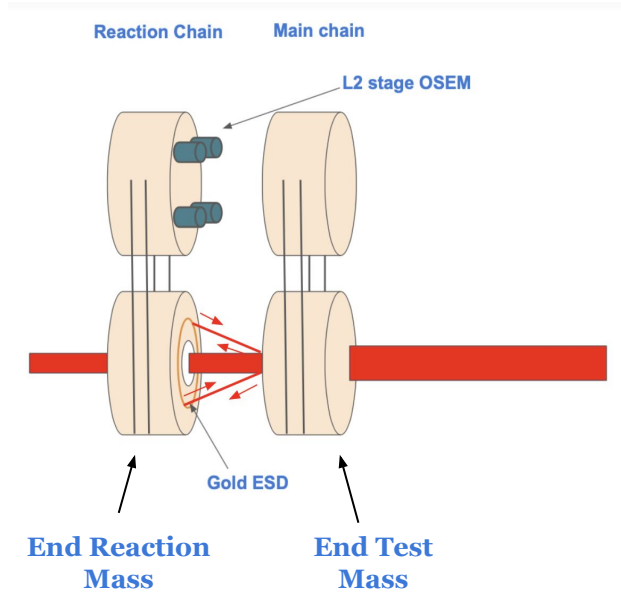
- Microseism (0.1-0.3 Hz), Earthquakes
- DARM noise in 10-120 Hz band
- Mask GW signals, cause false pipeline alerts

Microseism, Range, DARM spectrogram



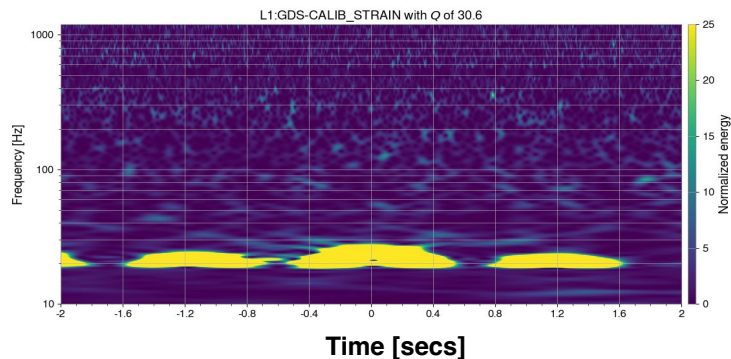
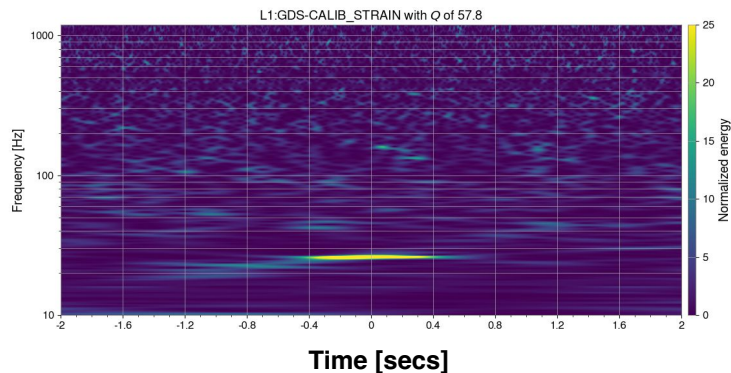
Slow Scatter since O3

- ESD backscatter, largest source of Slow scatter in O3 at LLO and LHO
- Fixed in Jan 2020 at both sites (RC tracking)
- Other potential sources?
- Not enough data (with high microseism) for Post O3 locks: Nov-Dec 2020 and May-June 2022



Slow Scatter since O3

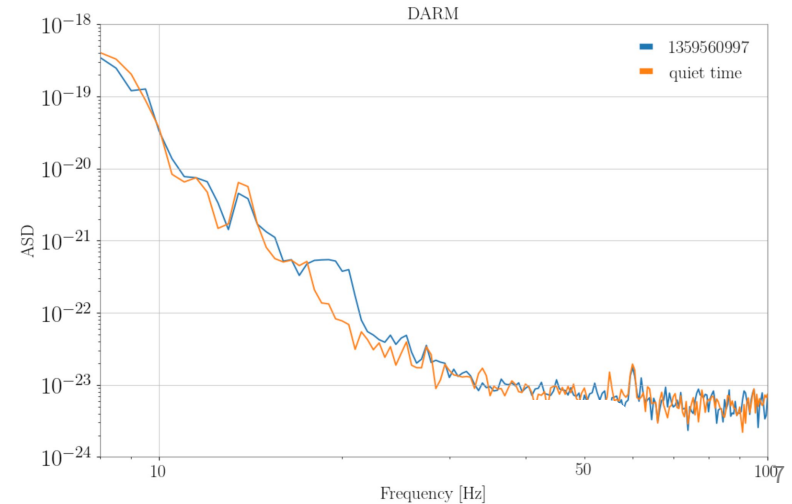
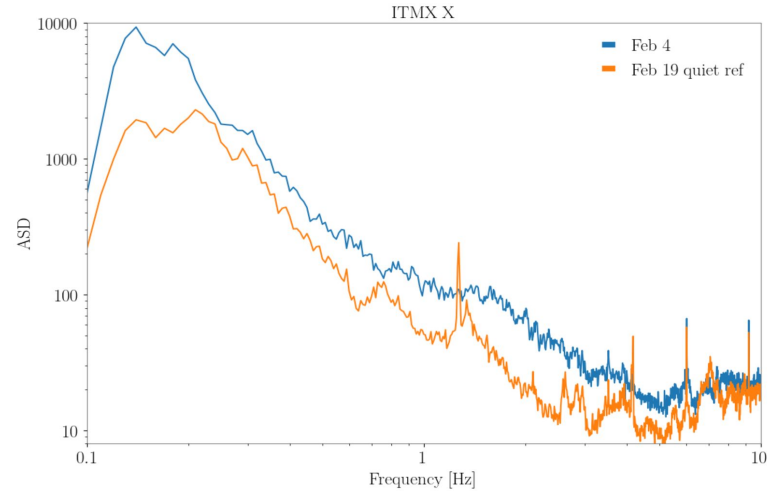
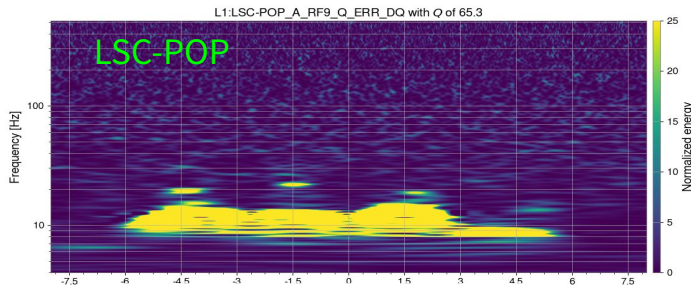
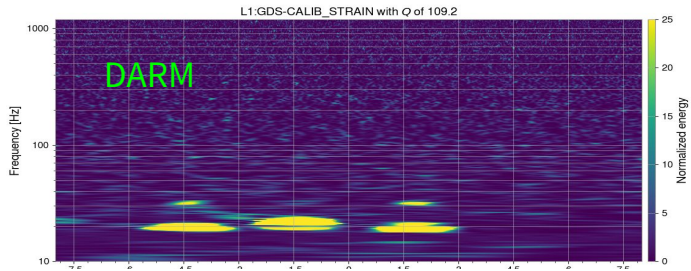
- Two “new” potential sources of slow scatter found in latest locks (Jan 2023 –)
- Lower microseism (~ 0.2) source:
 - Very likely at the corner station
 - Correlated with seismic band (0.1-0.3 Hz)
 - DARM noise in 10-40 Hz band
 - Present in O3
- Higher microseism (~ 0.35) source:
 - Likely at the end stations
 - Correlated with seismic band (0.3-1.0 Hz)
 - DARM noise in 10-50 Hz band
 - Not present in O3



Slow Scatter since O3

Lower microseism slow scatter:

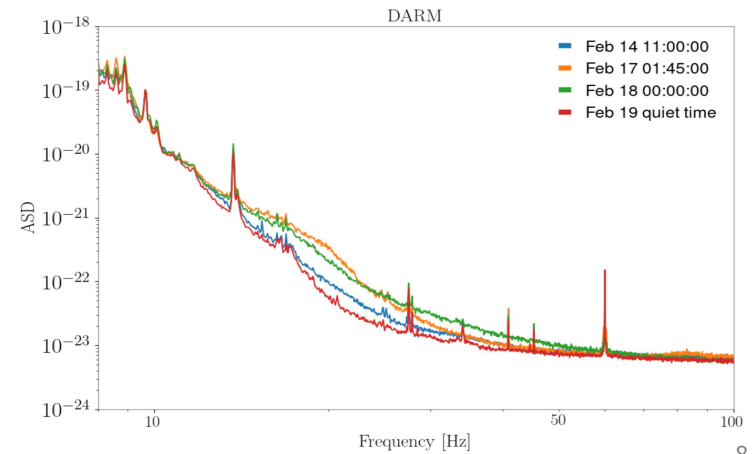
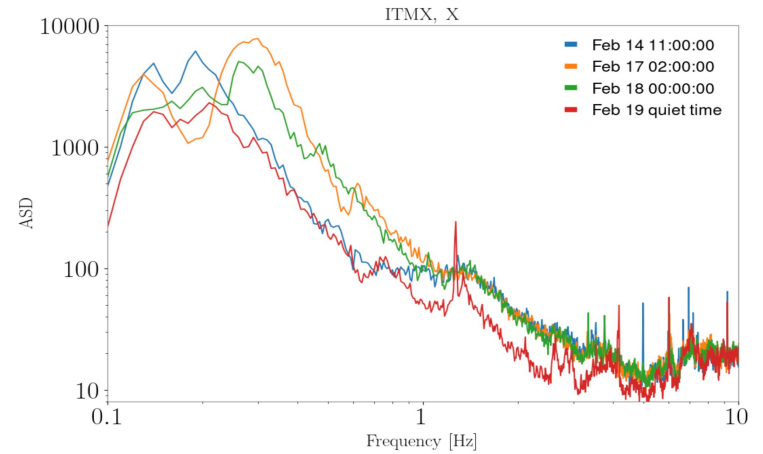
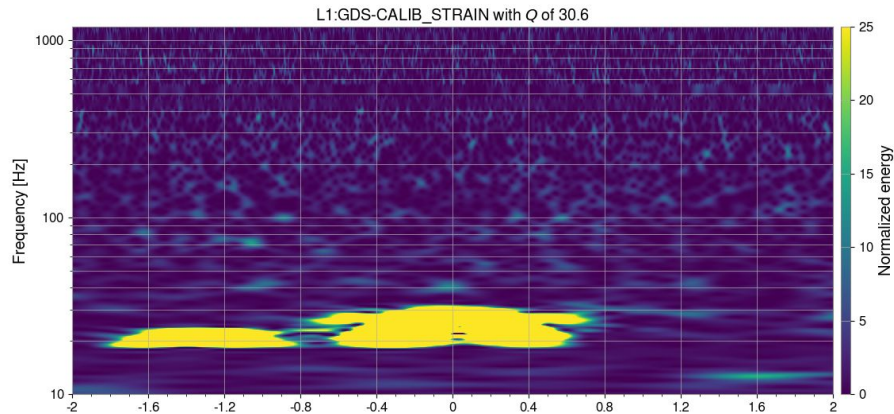
- Dominant scatter on Jan 26 and Feb 4, Feb 14 2023, days with increased microseism in 0.1- 0.3 Hz
- Noise witnessed by several corner channels:
 - LSC-REFL, LSC-POP, ASC-REFL
- Present in O3, noticeable after RC tracking



Slow Scatter since O3

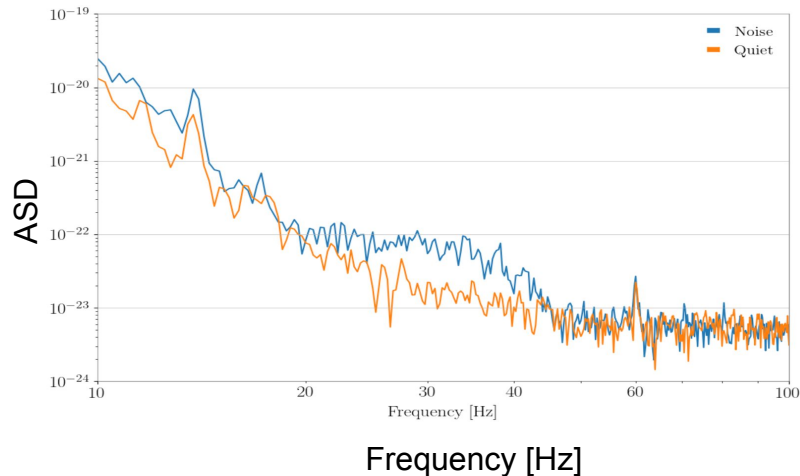
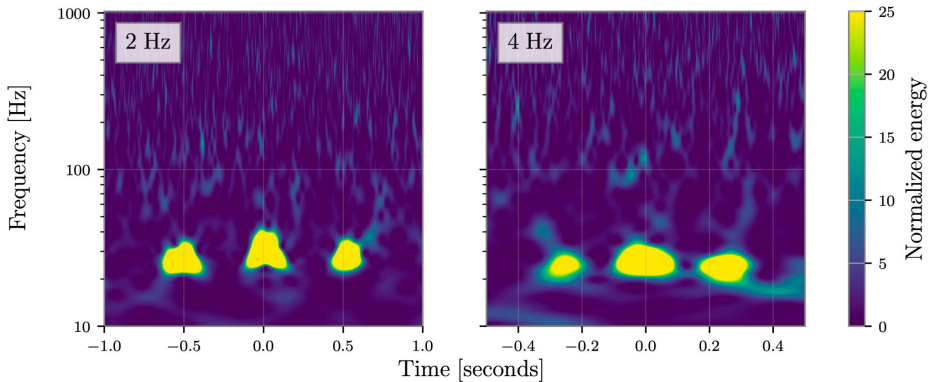
Higher microseism slow scatter:

- New, not present in O3
- Affected by ground motion close to 0.4 Hz (Feb 17, Feb 18)
- Not coincident in corner channels
- DARM frequency band impacted is 10-50 Hz
- The amplitude of DARM noise is higher compared to the noise during lower microseism scatter



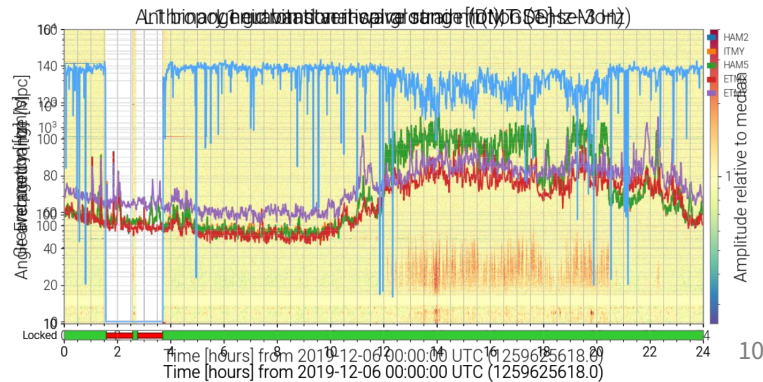
Fast Scattering

Fast Scatter aka daytime noise



- Anthropogenic ground motion (human activity) (1-3 Hz)
- Mostly 4 Hz, followed by 2 Hz
- Presence of microseism can create new populations ([G2200844](#))
- DARM noise in 10-60 Hz band
- Mask GW signals, cause false pipeline alerts

Anthropogenic, Range, DARM spectrogram



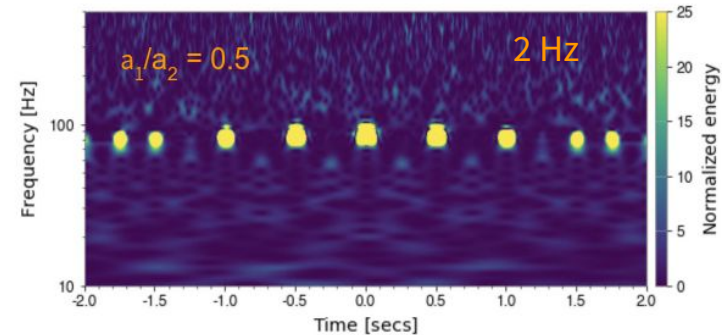
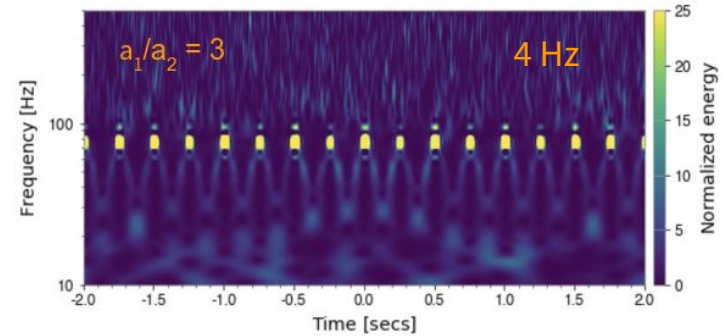
Fast Scatter in O3

- Anthropogenic noise, daytime, construction, logging, trains
- Evidence of coupling in corner station in O3 ([DCC](#))
- Depending on microseism, we can make 2 Hz or 4 Hz noise

$$h = darm + phase_noise(a_1 * v_{anthro} + a_2 * v_{micro})$$

With 2 Hz motion, you can make both 2 Hz and 4 Hz depending on microseism

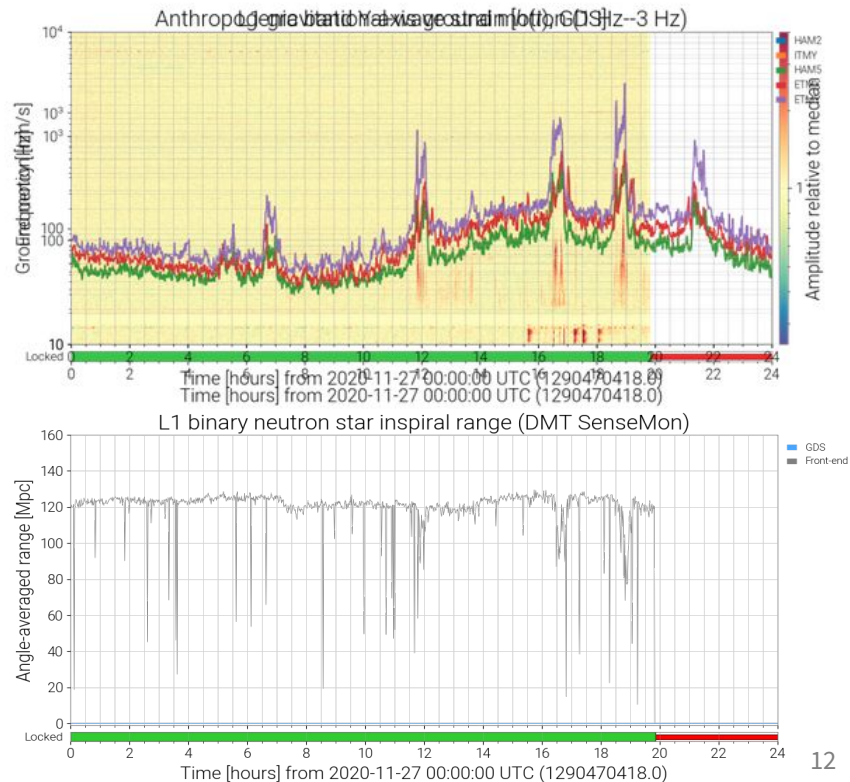
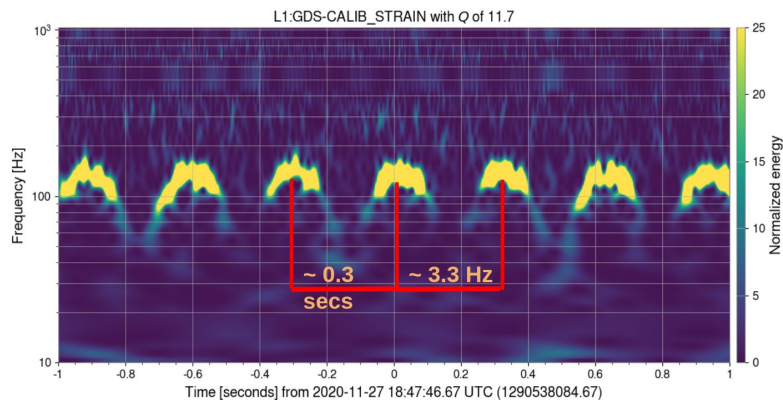
Rarely do we have both high anthro and high microseism



Fast Scatter since O3 (Nov -Dec 2020)

Post O3, Cryobaffle resonances around 4 Hz were found and damped in Sep-Oct 2020 ([DCC](#))

- Noise got worse in Nov-Dec 2020 lock
- Trains created noise as high as 200 Hz, started impacting range ([alog](#))
- Trains fast scatter changed from 4 Hz to 3.3 Hz



Fast Scatter since O3

- May 2022 Lock:
 - Fast scatter noise still present in the data
 - Trains still create DARM noise and range drops (alog [60240](#))
- July 2022: Arm Cavity Baffle (ACB) resonances found!
 - Sweep injections found ~ 1.6 Hz resonance at ETMY, ITMY, ITMX (alog [60927](#))

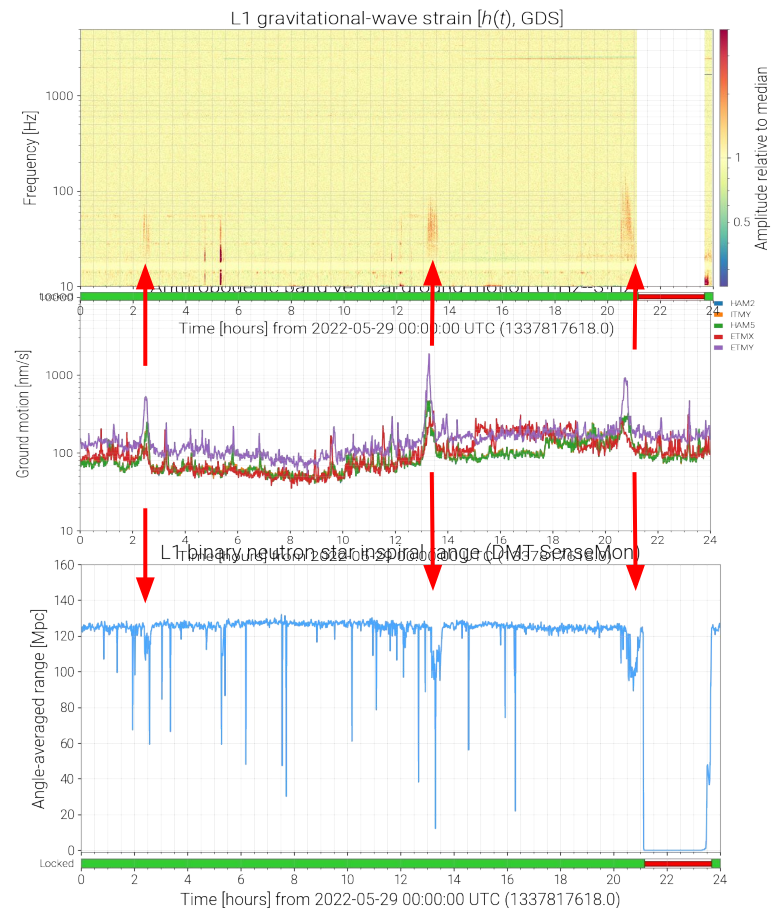
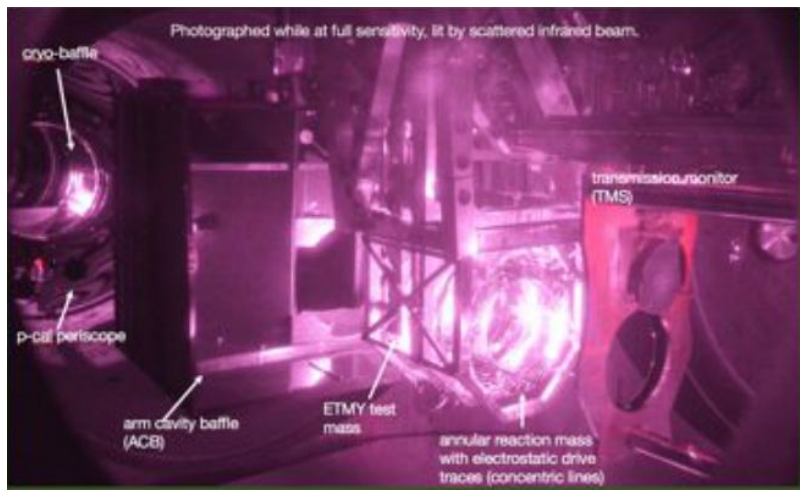
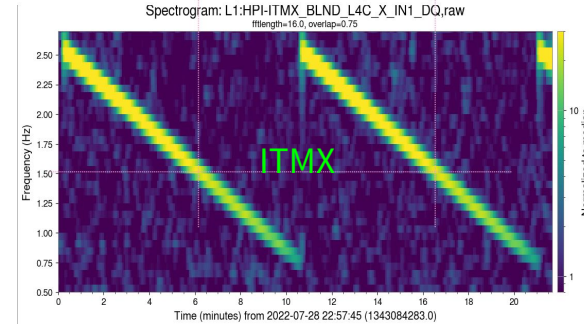
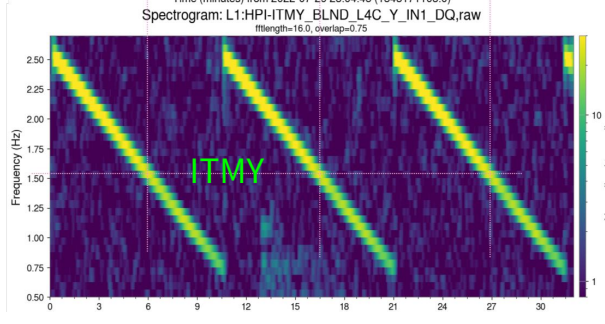
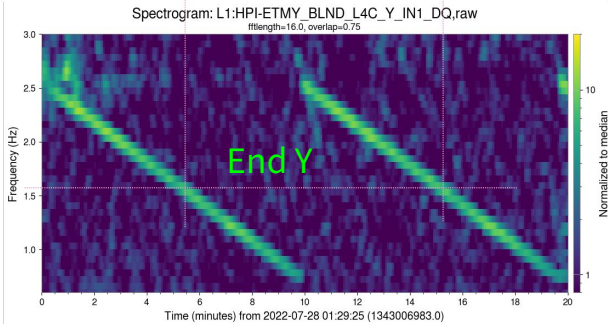
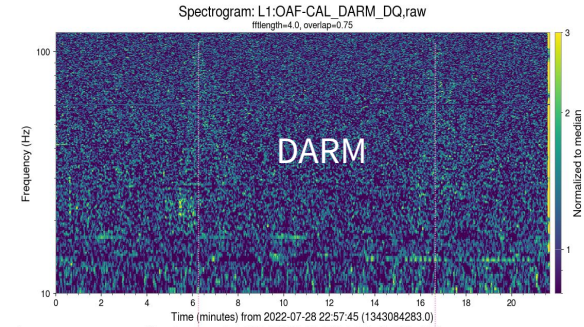
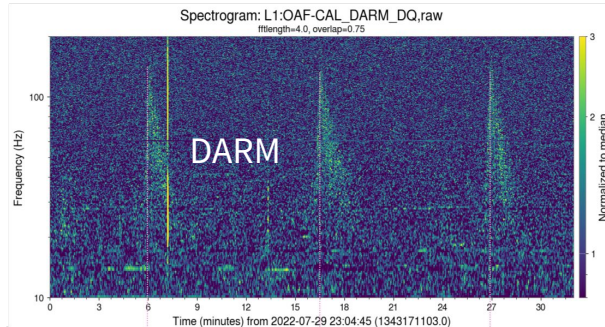
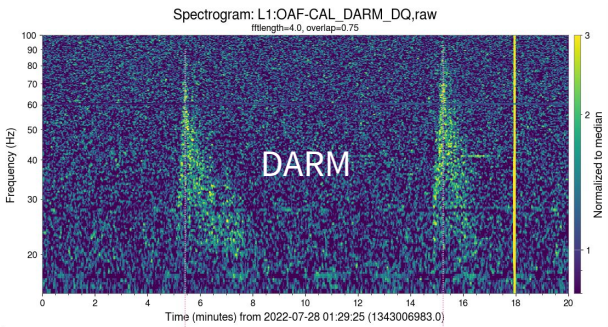


Photo ref: [DCC](#)

ACB Resonances

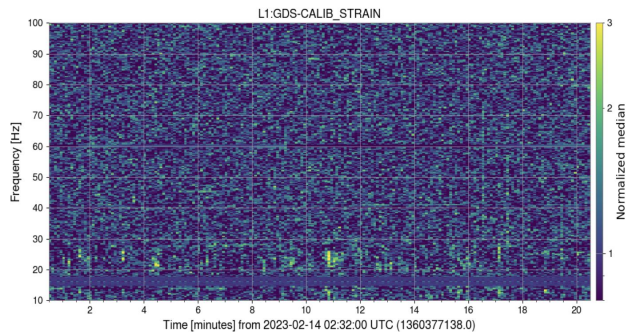


- Resonances close to 1.6 Hz in ACBs at End Y and Corner. Strongest at End Y, followed by ITMY and ITMX
- These ACB resonances were mechanically fixed in fall 2022
- Arm Cavity Baffle (ACB) will be on ISI in O5

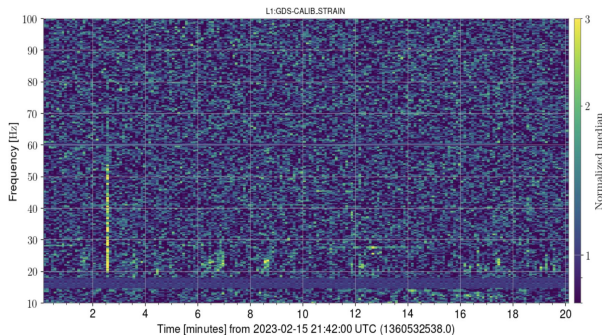
HEPI Sweep injections Feb 2023

- We repeated HEPI sweeps at End Y, End X and corner in Feb 2023
- Did not observe any noise in DARM (alog [63569](#))

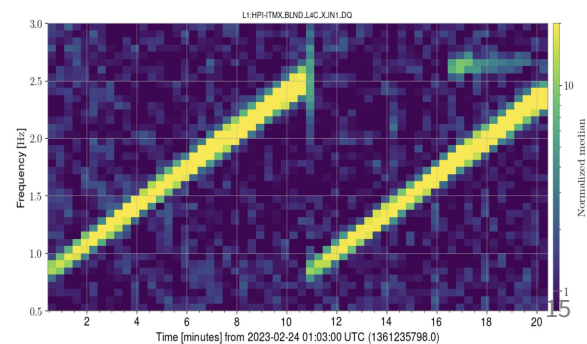
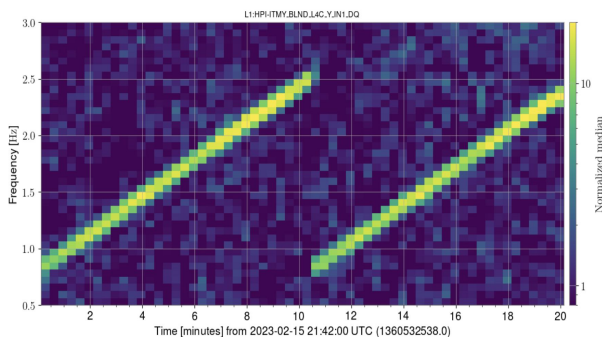
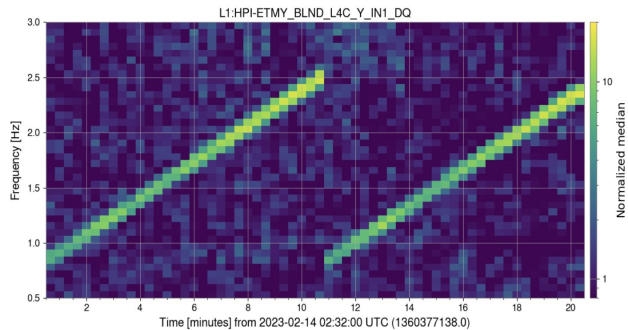
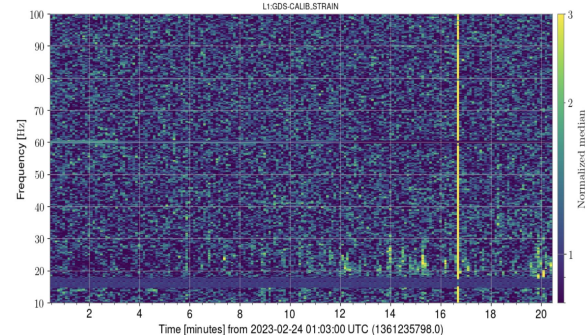
End Y



ITMY

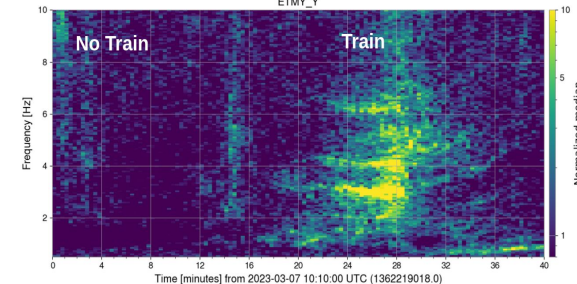
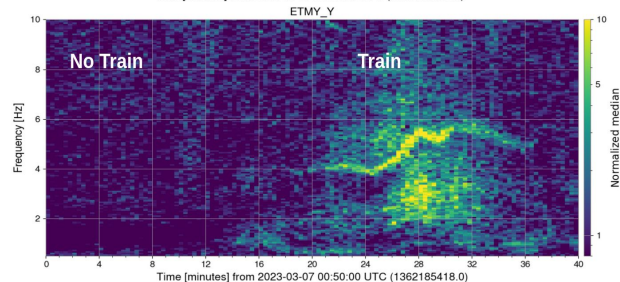
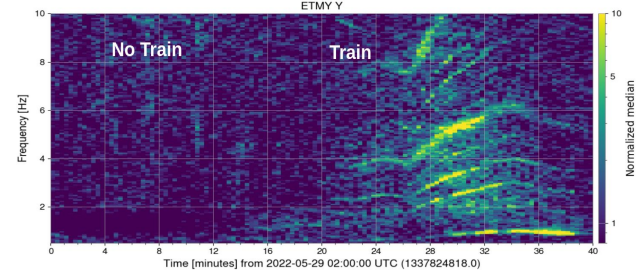
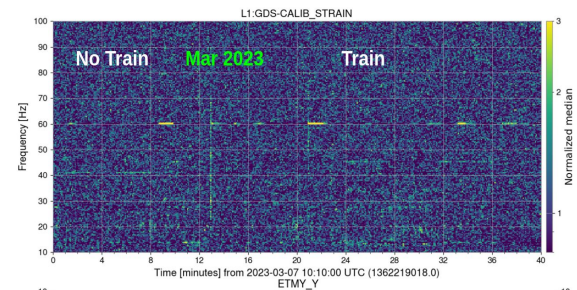
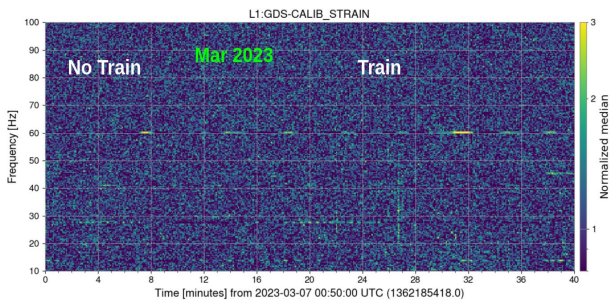
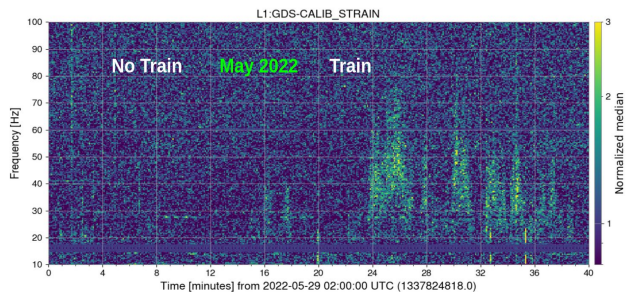


ITMX



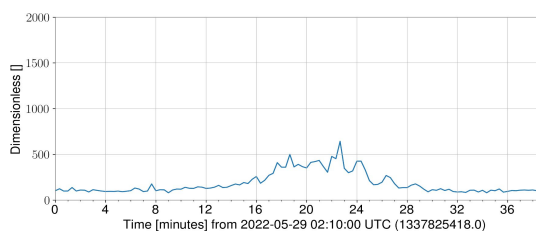
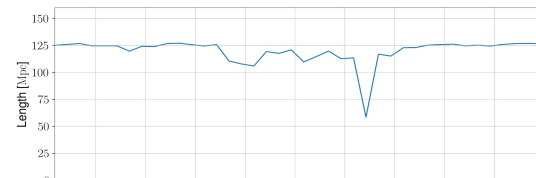
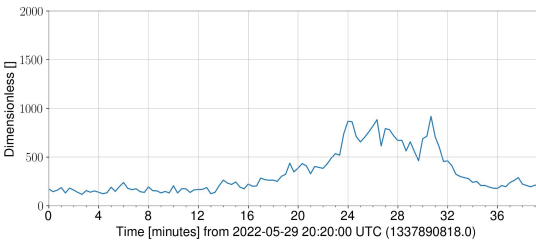
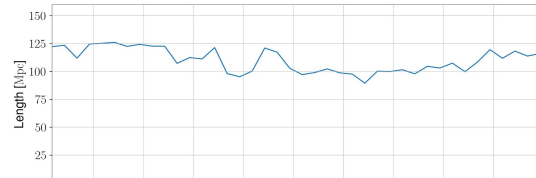
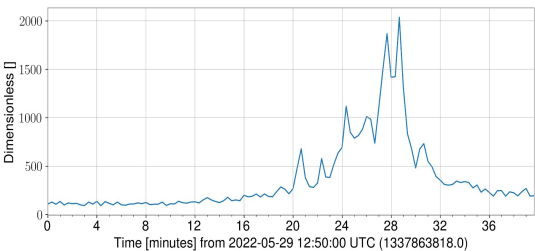
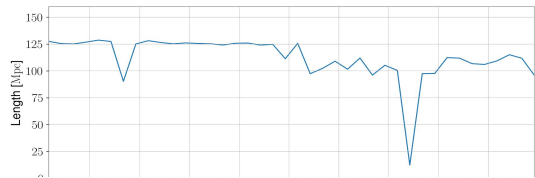
What about Trains?

- Trains in the current lock do not seem to create noise in DARM (alog [63895](#))
- Also check out the poster by Debasmita and Jane

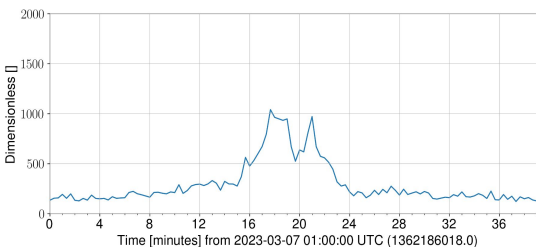
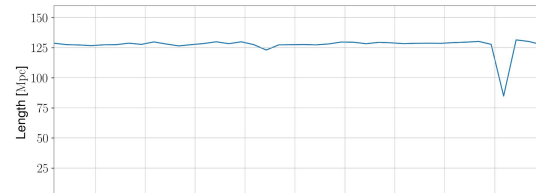
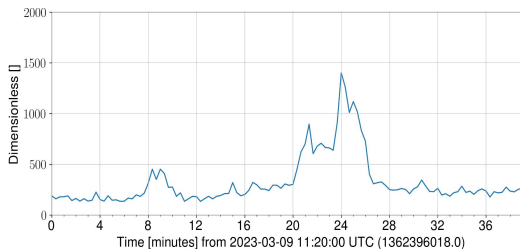
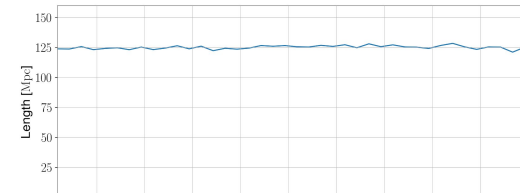
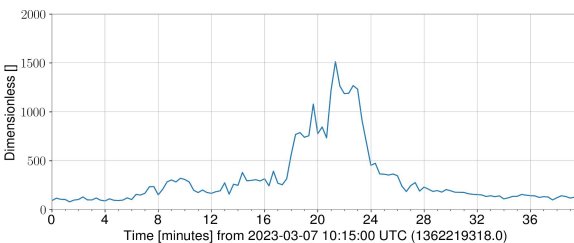
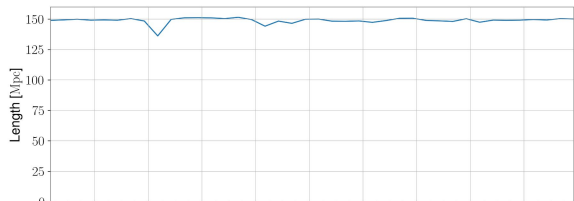


Before

Range and Ground motion during Trains in 1-3 Hz band



Now



References

Slow Scattering

1. Reducing Scattered Light in aLIGO detectors. Soni et al arXiv [2007.14876](#)
2. alogs [63668](#), [63343](#), [59404](#)

Fast Scattering:

1. alogs [63895](#), [60397](#), [60240](#), [55416](#), [54383](#), [54531](#)
2. [G2102369](#)

ACB Injections:

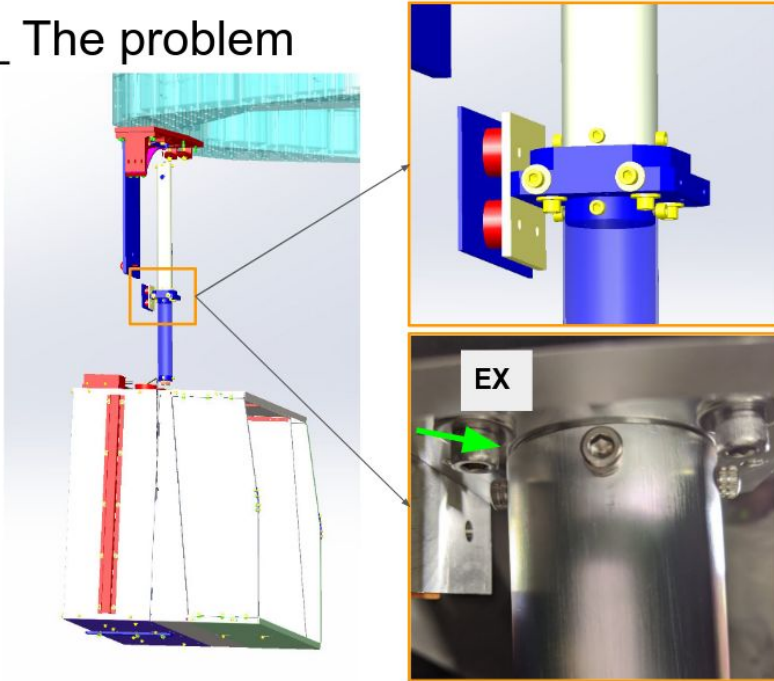
1. alogs [63569](#), [61612](#), [60927](#)
2. ACB [Hysteresis](#)

Thank You!

**Questions and
Comments**

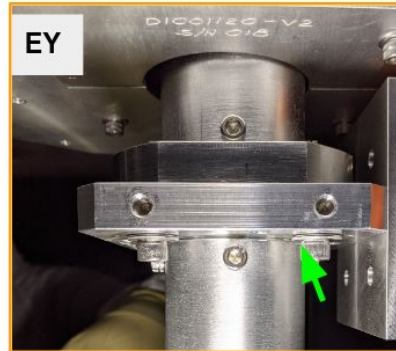
Extra Slides

1_ The problem



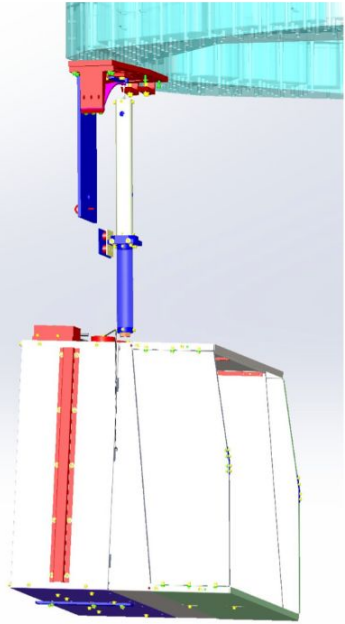
Visual inspection show a clear gap between the lower tube D1001009 and the connector plate D1002618 (green arrow), both at EX and EY. This means the lower tube (at least) is angled

See:
[EY photos](#)
[EX photos](#)

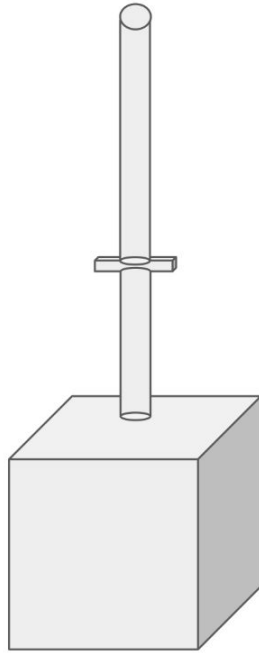


5

2_ Hypothesis/Mechanism

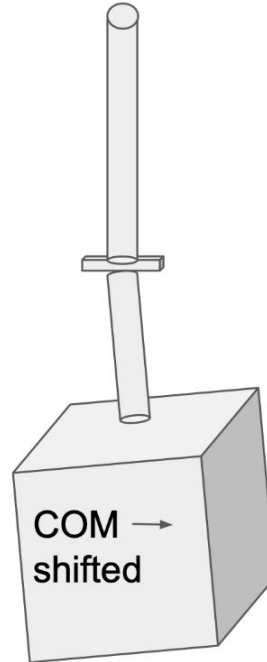


Hanging right



1)

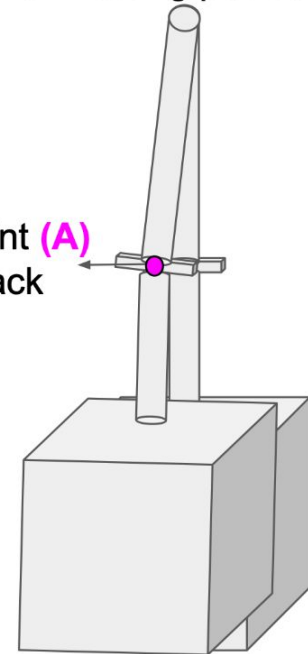
Crooked, after baffle swing
(differently each time ?)



2)

Rotates around suspoint to
new resting position

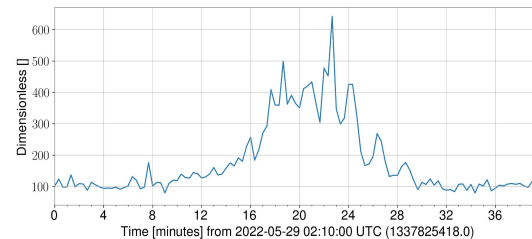
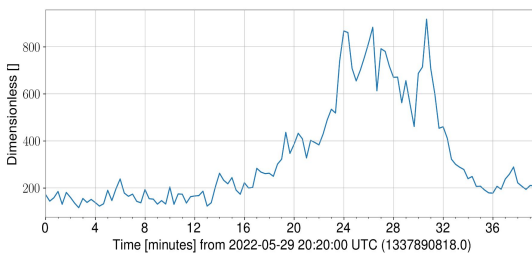
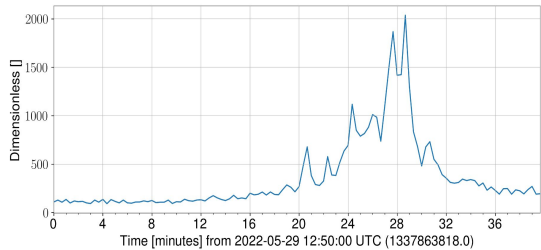
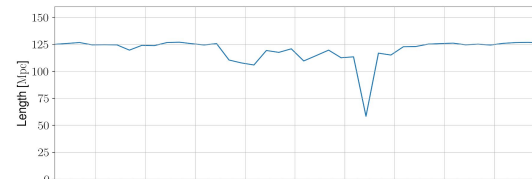
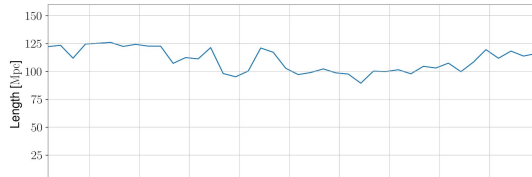
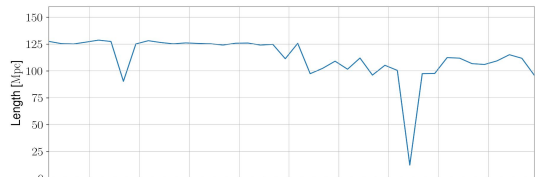
This point (A)
shifts back ←



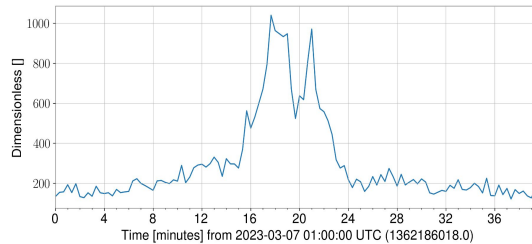
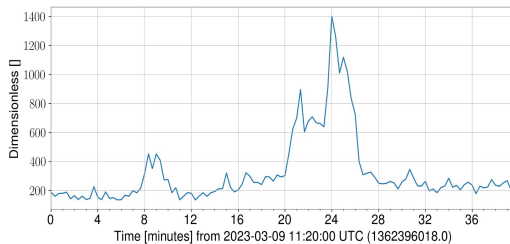
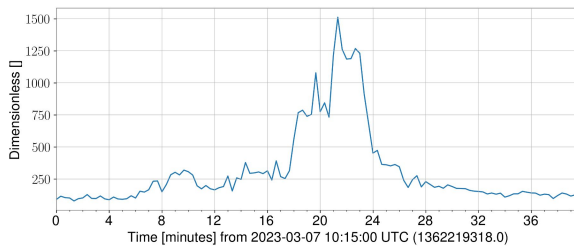
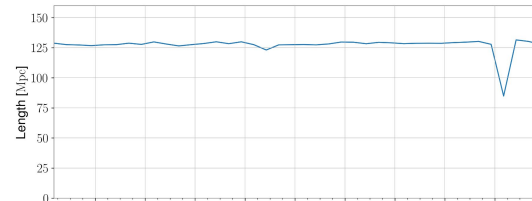
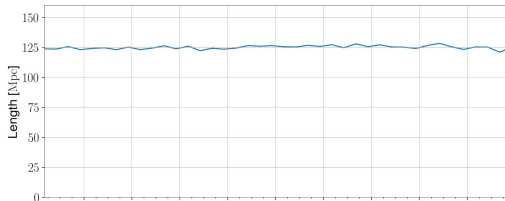
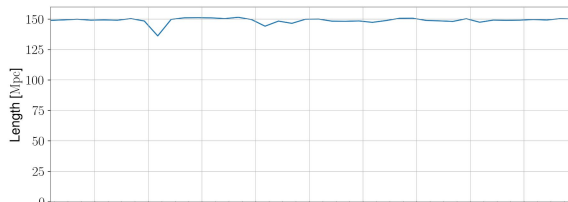
3)

Before

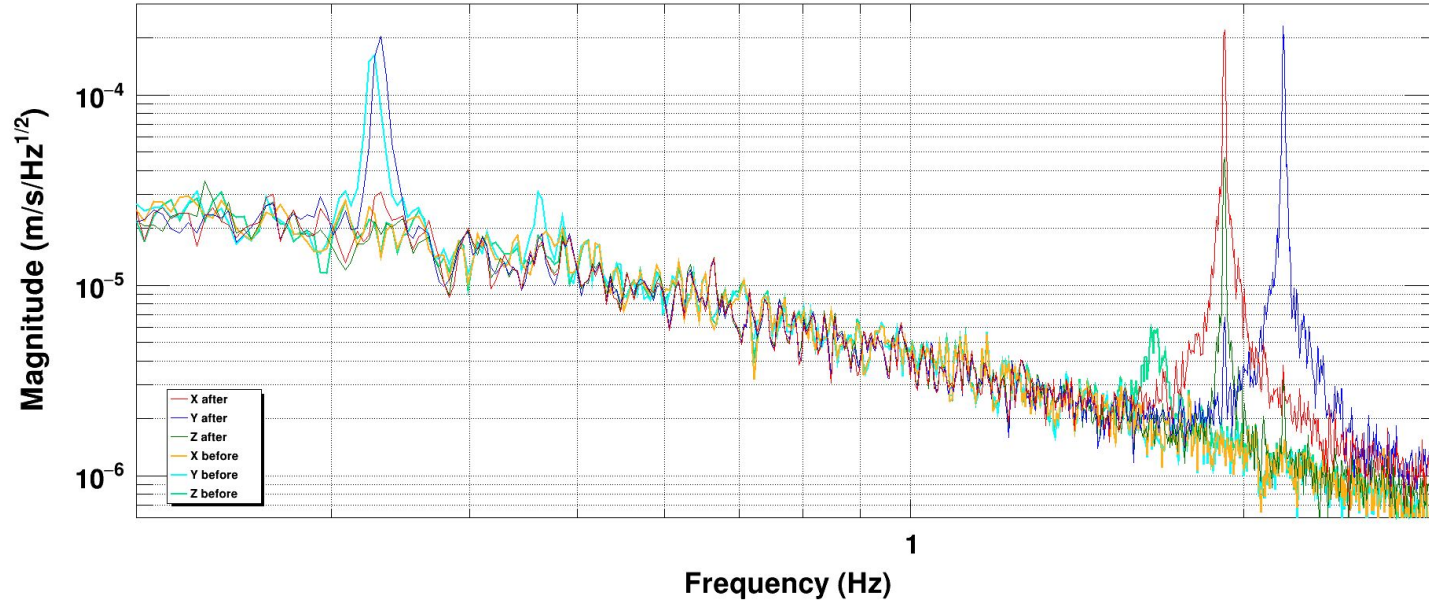
Range and Ground motion during Trains in 1-3 Hz band



Now



Accelerometers on EX ACB, before/after wedge - rubbing



*T0=19/09/2022 10:00:00

alog [61565](#)