Scattering noise at LLO

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Overview

- Introduction
- ETM-AERM Scattering
- R zero tracking
- ETM-TMS Scattering

Scattering noise

- Stray light, scatters of mirrors
- Bounces off moving components during high ground motion
- Rejoins the main beam, inducing a phase noise

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

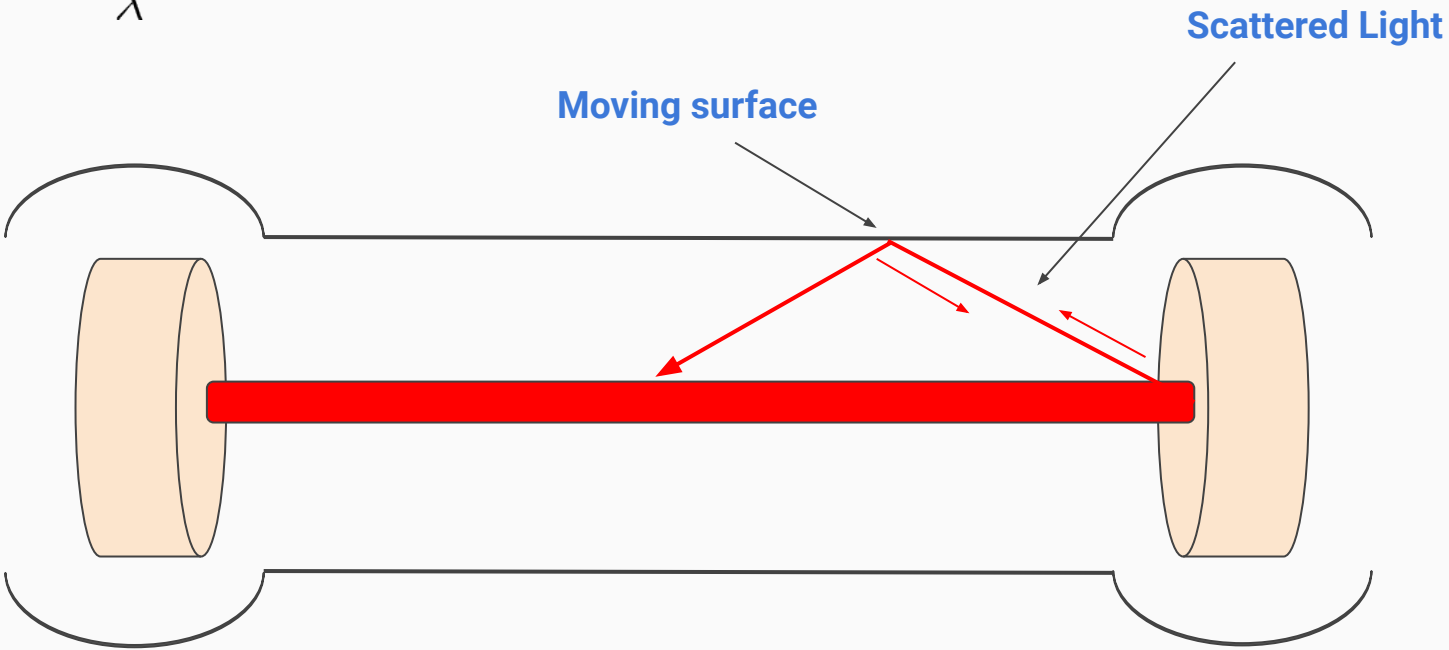
$$h_{sc} = K.sin(\phi_{sc}(t))$$

$$f_{fringe} = \frac{2v}{\lambda}$$

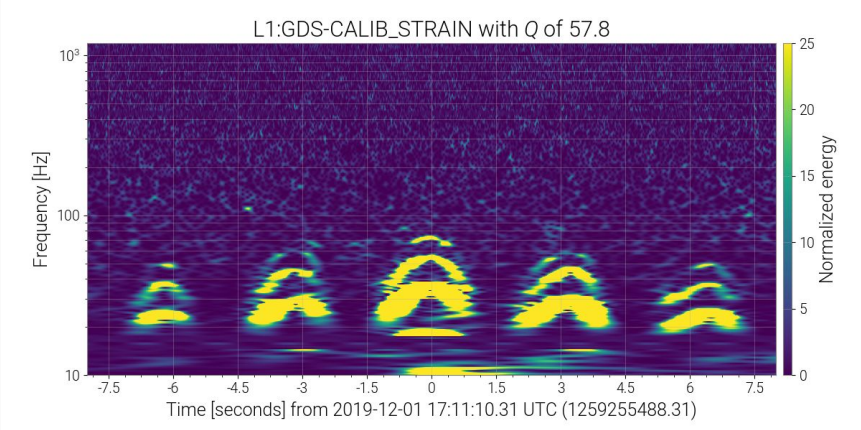
Light scattering

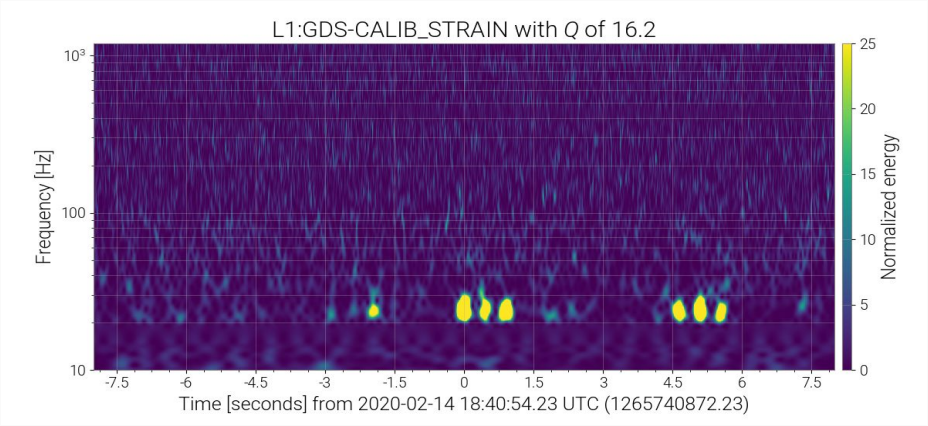
$$\phi_{sc} = \frac{4\pi}{\lambda}(x_0 + \delta x_{sc}(t))$$

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



Slow scattering and Fast Scattering in O3.





Slow scattering

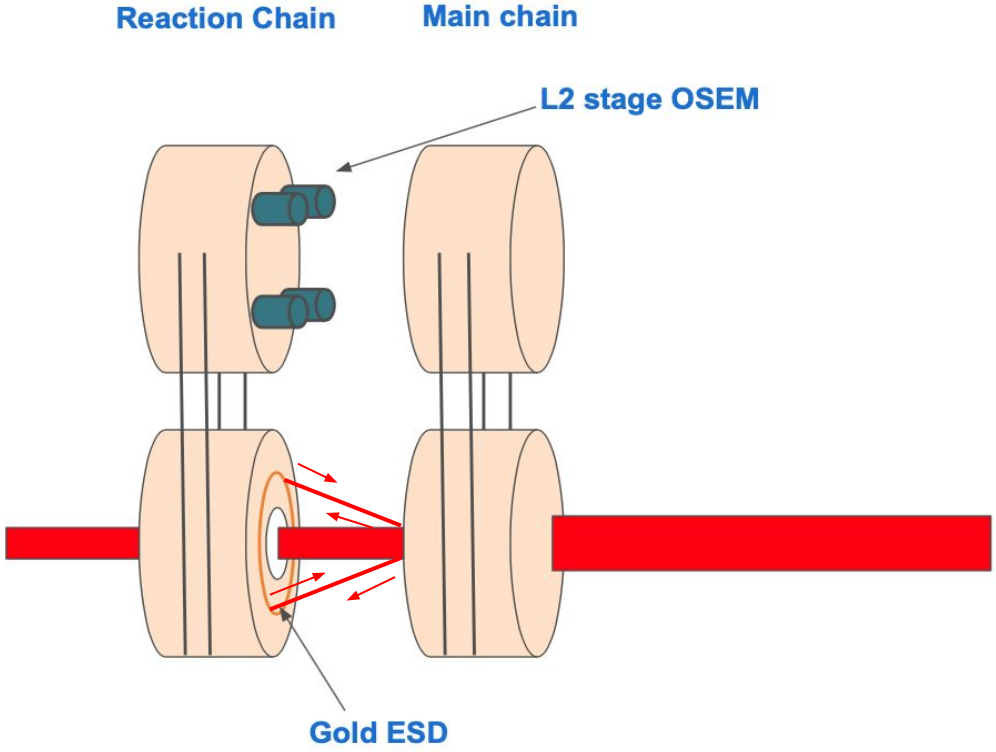
- Two different couplings of Slow scattering
- ETM-AERM relative motion and ETM-TMS relative motion

Fast scattering

- Exact coupling is unknown
- Different frequency and glitch morphology than slow scattering

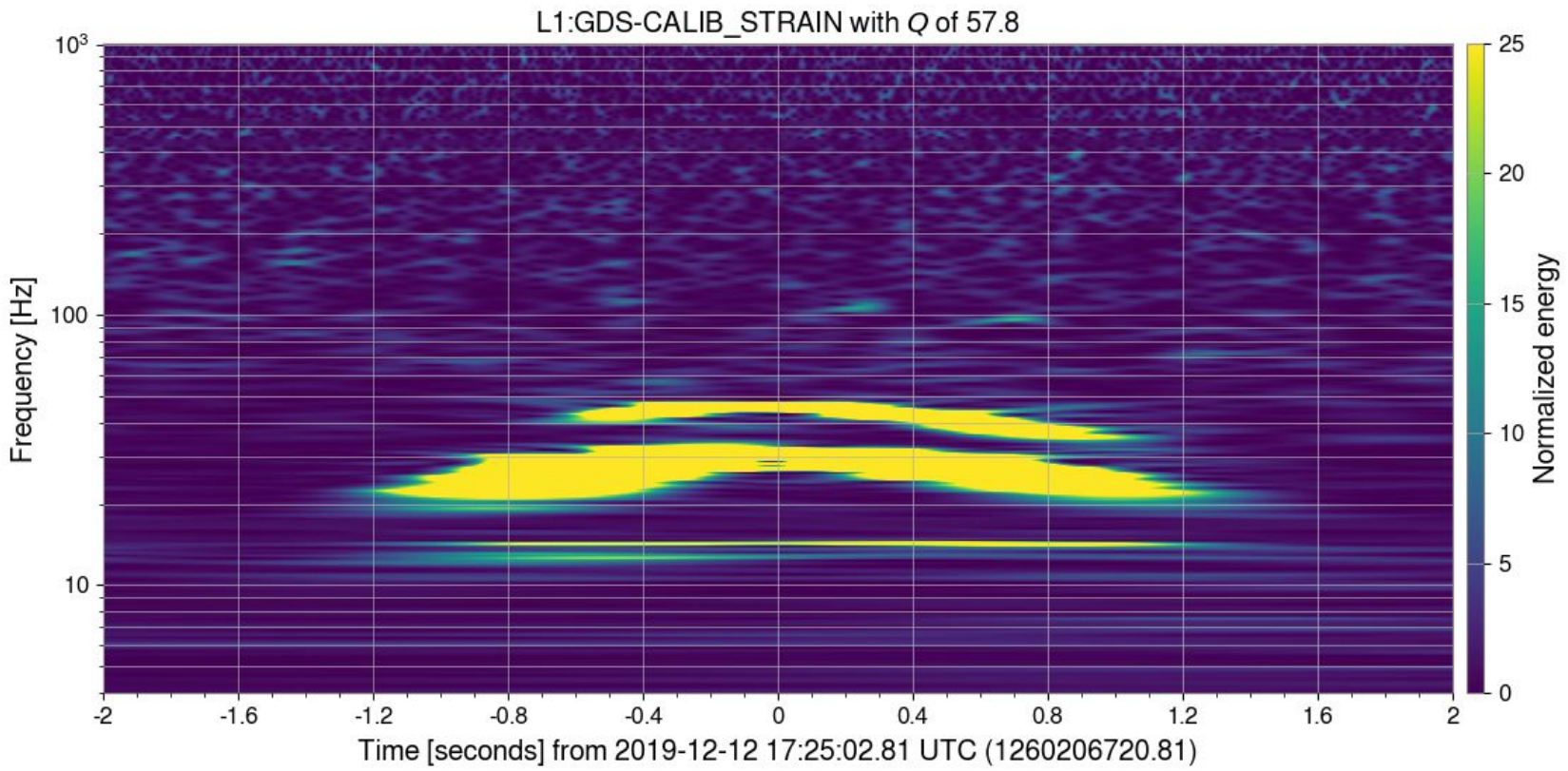
ETM-AERM Scattering

ETM-AERM scattering

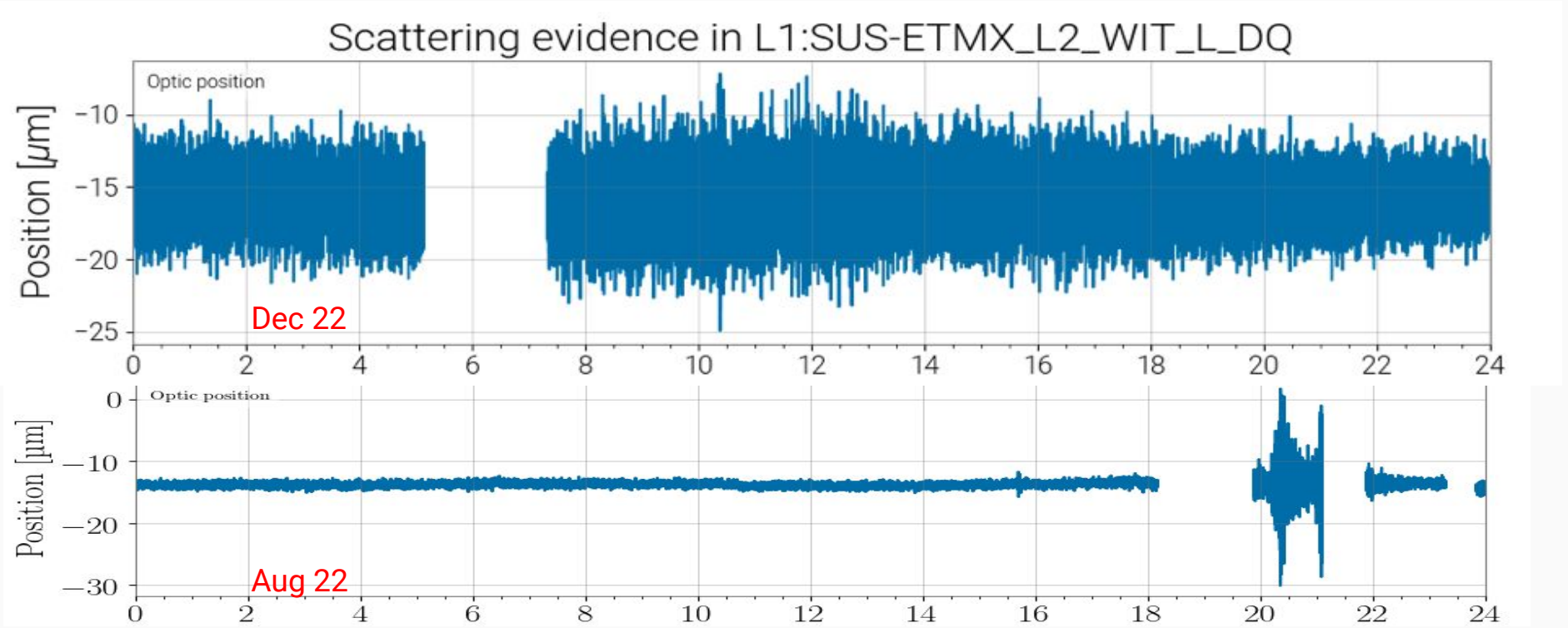


- During high ground motion, control drive sent to Reaction chain pushes on the test mass chain (main)
- This is done to keep laser beam resonant between the ETM and ITM
- Relative motion between the chains
- A fraction of light hits the Gold ESD, reflects back and joins the main beam after ETM transmission with an altered phase
- Scattering arches in h(t)

Scattering arches



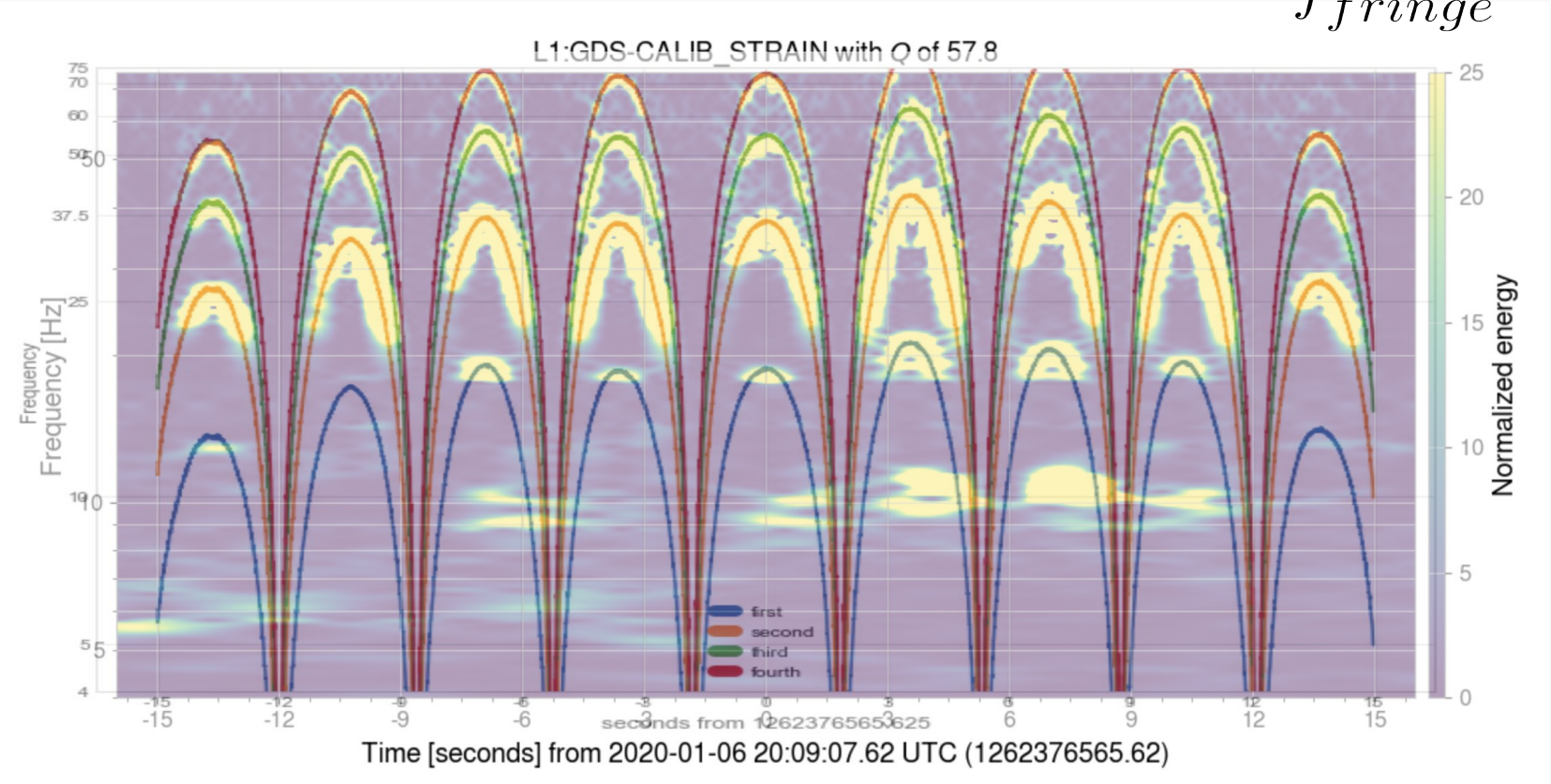
L2 stage motion as a predictor of scattering noise



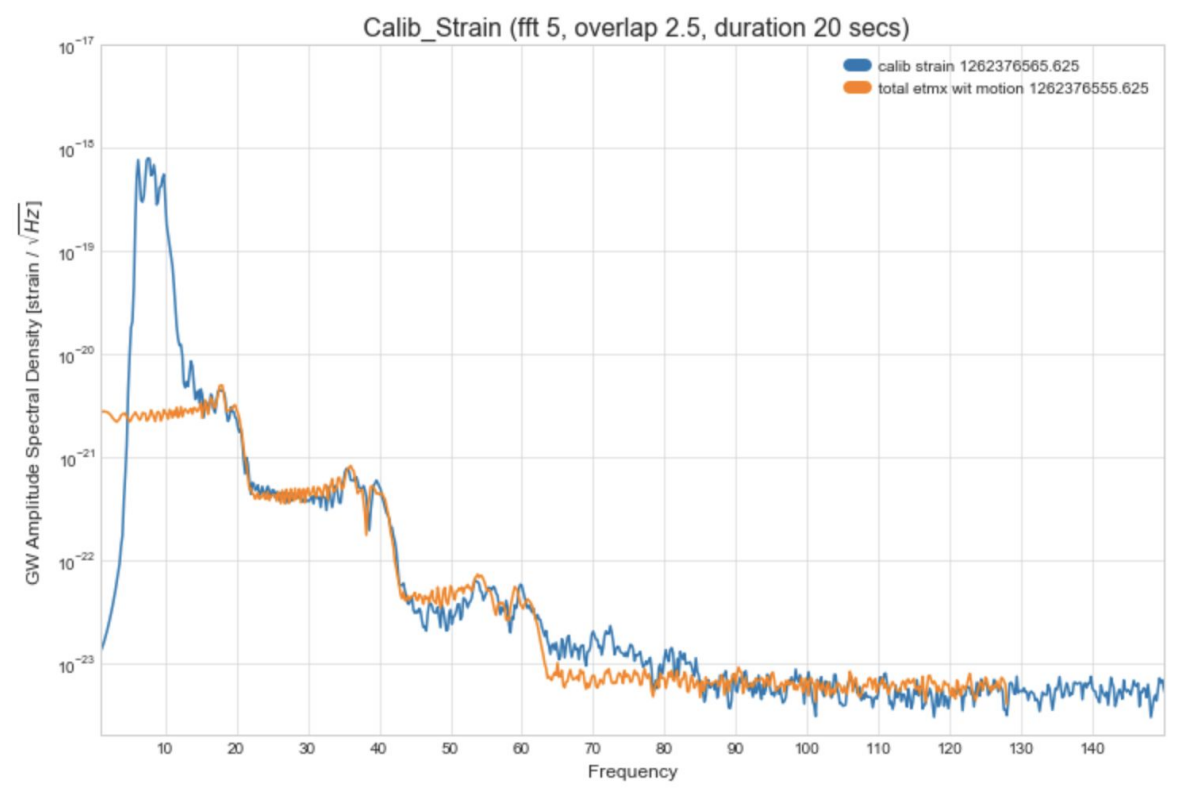
We had tons of scattering triggers on Dec 22, and very few Aug 22.

Fringe frequency of L2 stage motion overlaid on scattering arches.

$$f_{fringe} = \frac{2v}{\lambda}$$



L2 stage motion spectra overlaid on darm spectra



$$h(f) = \frac{\lambda T_{end}\sqrt{f_r}}{8\pi L}\mathcal{F}[sin(\frac{4\pi}{\lambda}\delta x_{sc}(t))]$$

f_r is the fraction of light power incident on the ESD.

First shelf f_r = 1.6e-7

Second shelf f_r = 8e-9

Third shelf f_r = 8e-11

Hiro's study

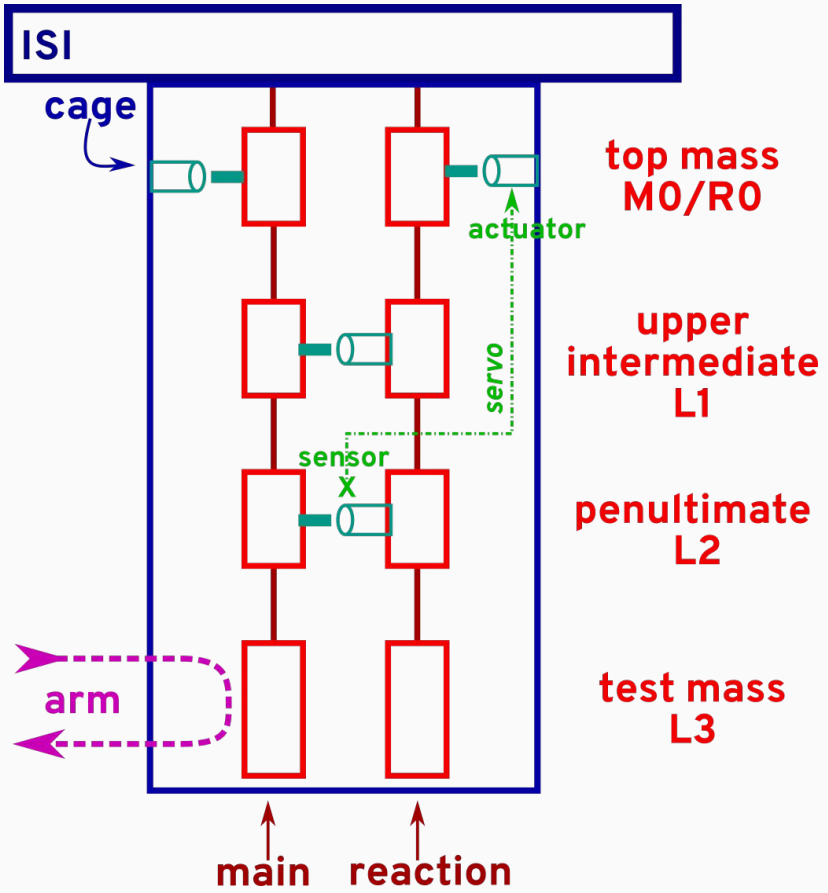
Reaction chain (RC) tracking.

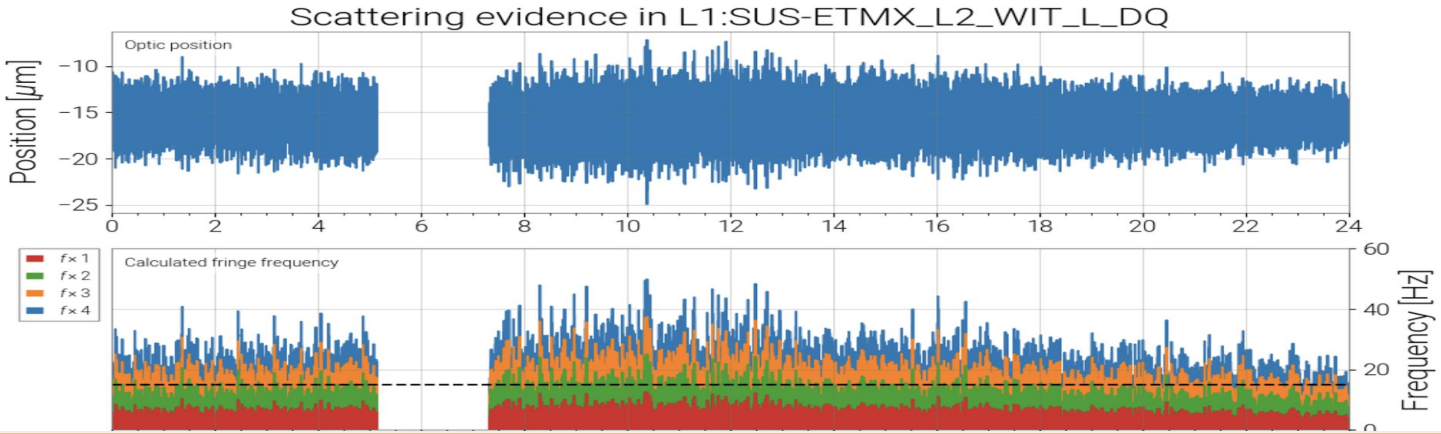
Taking the motion from L2 stage and feeding it to R0 stage. This way the relative motion between the test mass chain and reaction mass chain is reduced.

Robert's alog

Implemented on January 7, 2020, at LLO. Anamaria's alog

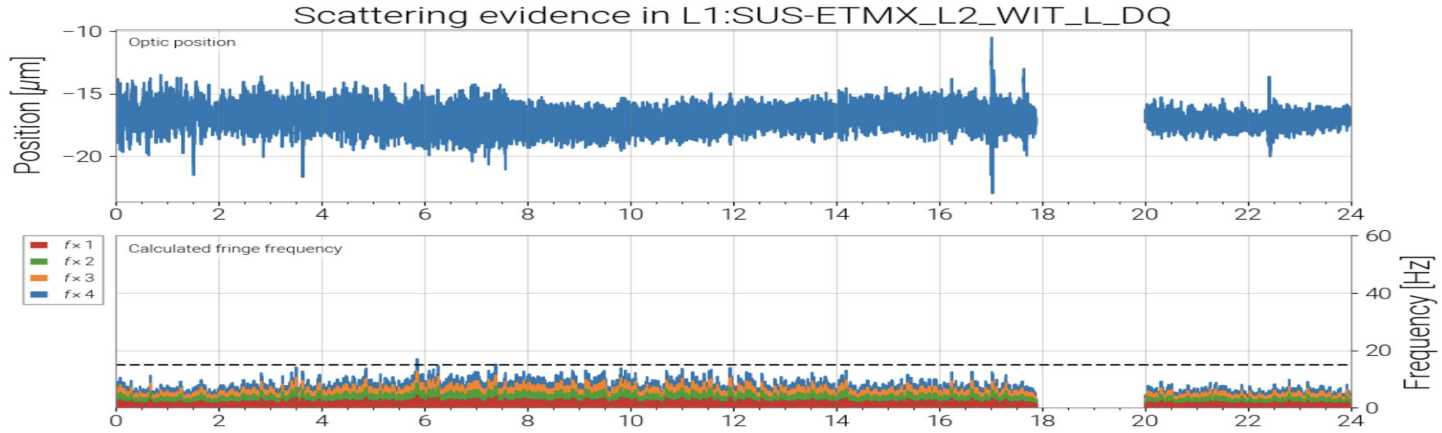
In the next few slides, we show the improvement in scattering noise post RC tracking implementation





Dec 22
Pre RC

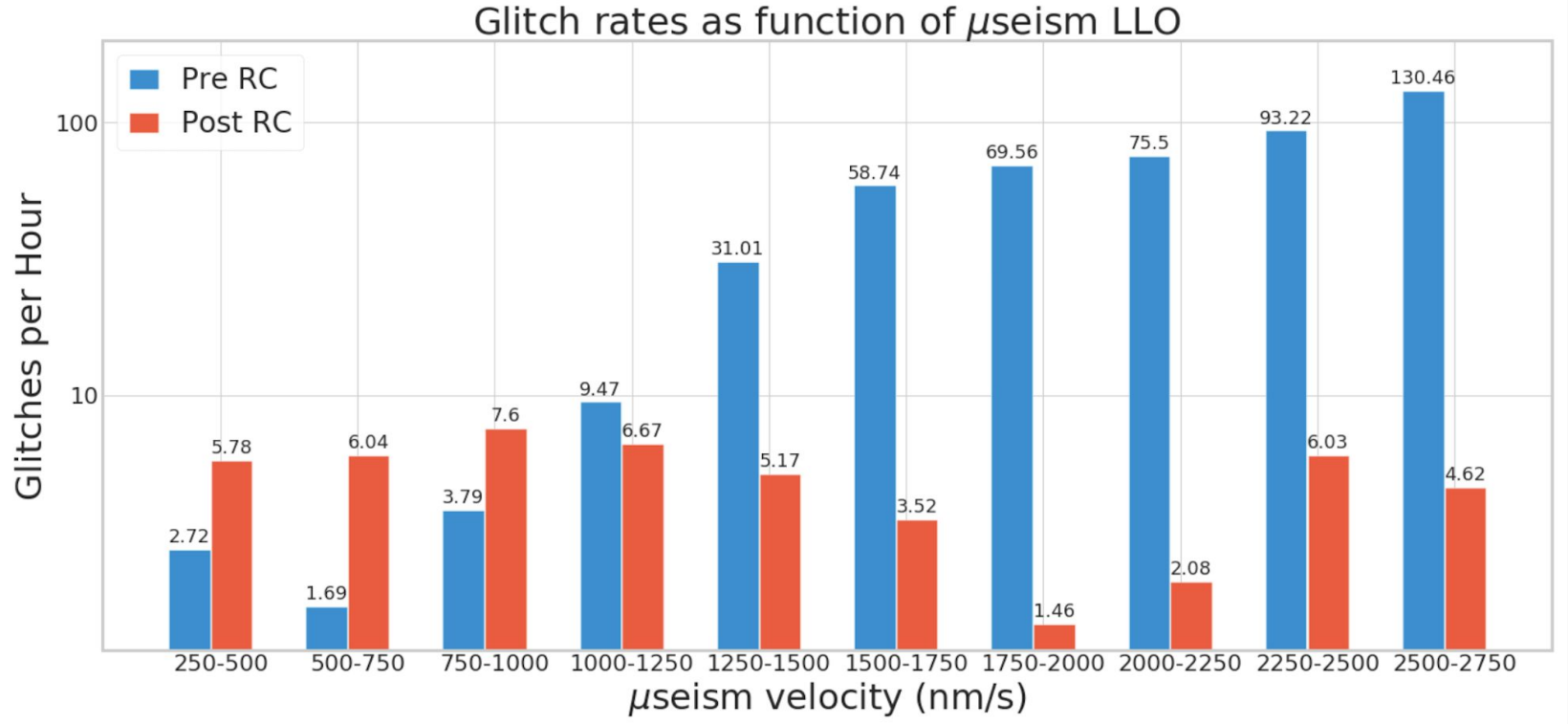
L1:SUS-ETMX_L2_WIT_L_DQ



Feb 21
Post RC

These two days have similar levels of microseism ground motion

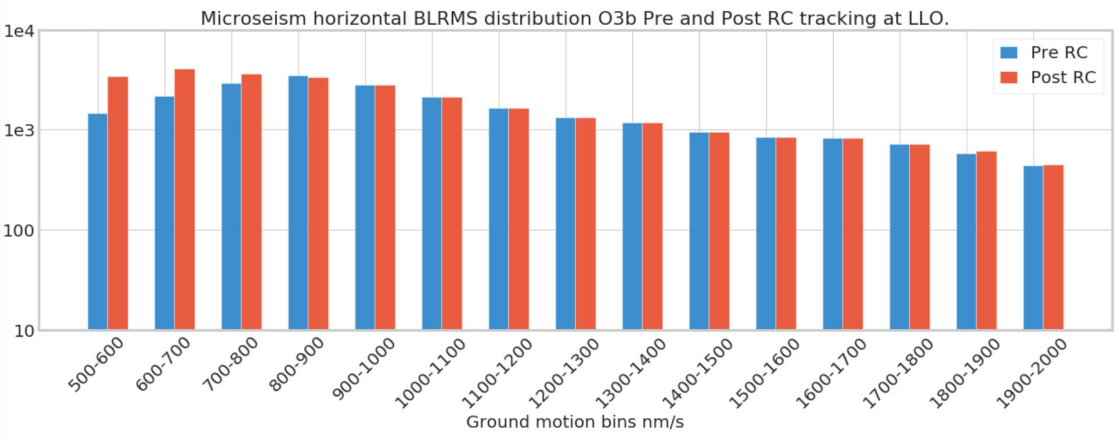
Glitch rate comparison



Corey's alog

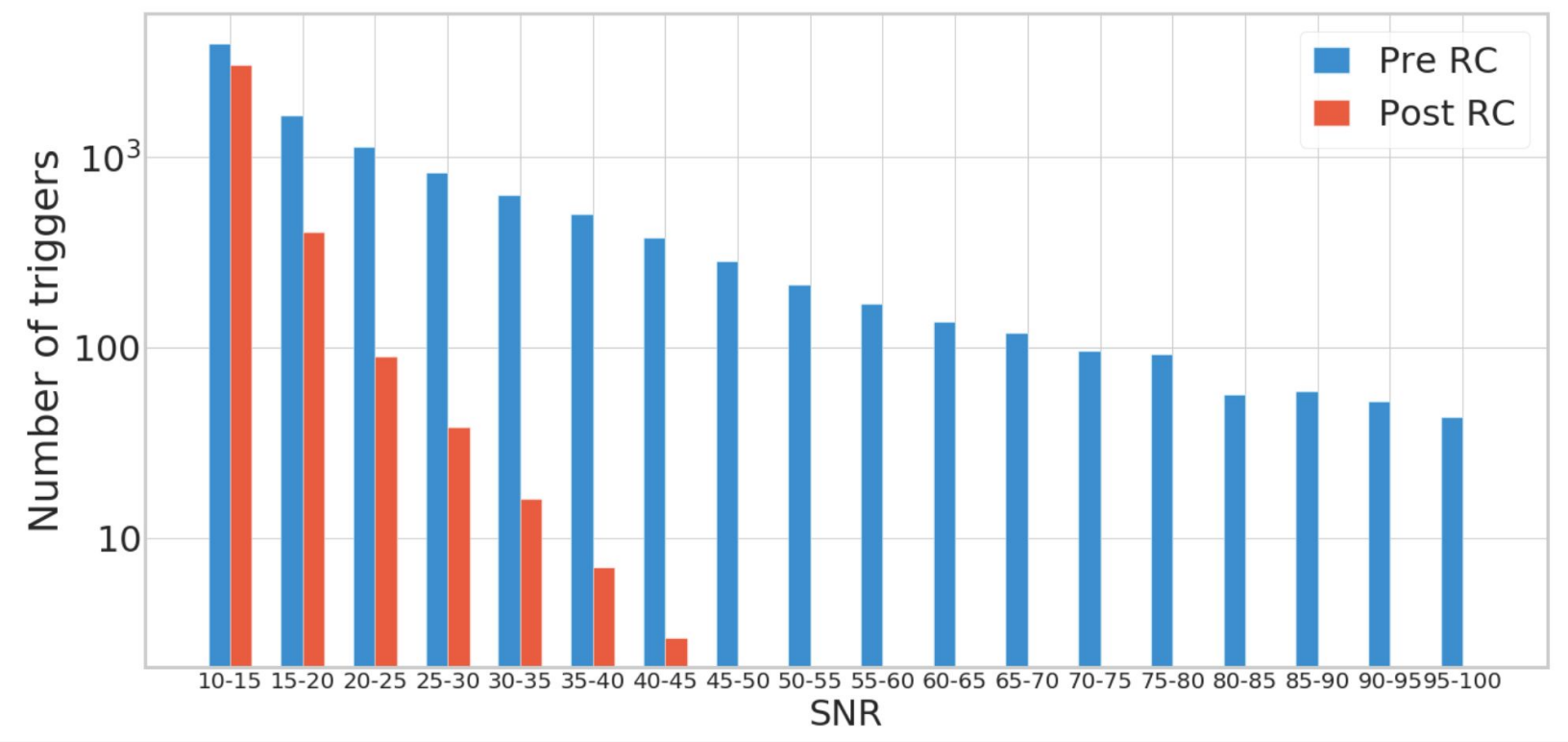
Ground motion

- Compare the SNR (signal-to-noise ratio) of scattering triggers before and after the implementation of RC tracking, **for similar levels of ground motion**
- We consider only those periods when the ground motion was similar Pre and Post RC tracking and compare the SNR for only those time segments in the next slide
- For similar levels of ground motion, the SNR of scattering triggers should fall post RC tracking



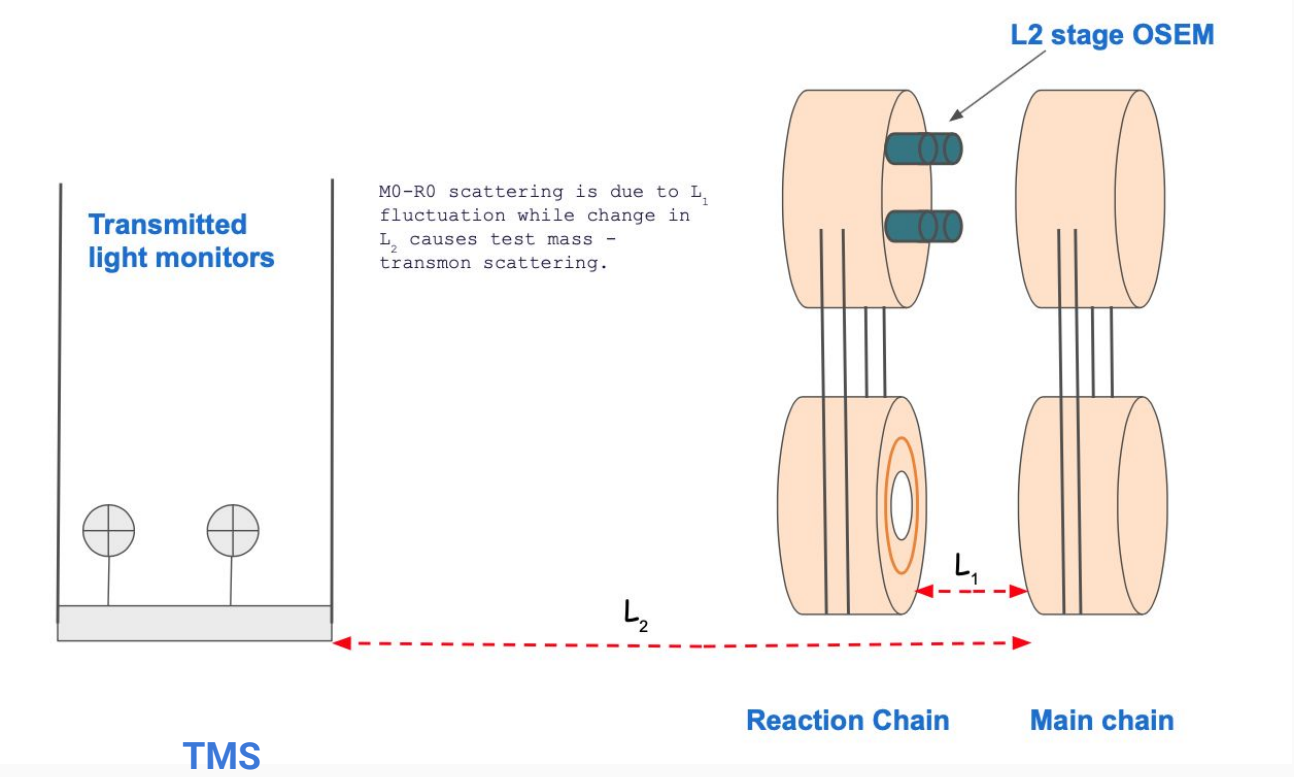
Equal ground motion Pre and Post RC tracking

Scattering SNR comparison Pre and Post RC tracking.



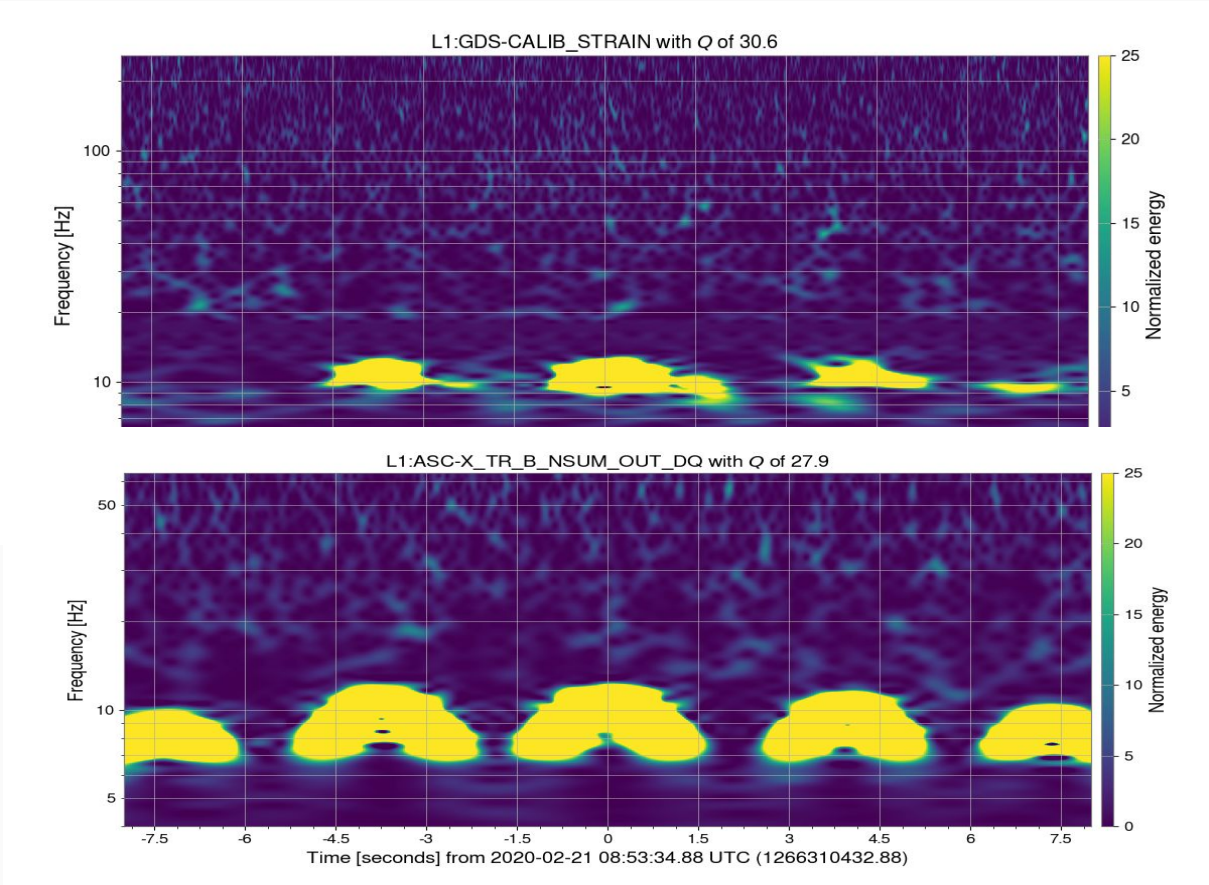
ETM-TMS scattering

ETM-TMS scattering



- A small fraction of light is received by the Photodiodes located behind the End test mass mirrors.
- Some of that light gets reflected back to the test mass mirror and joins the main beam thereby inducing phase noise.
- This noise depends on the relative motion between the test mass and the TMS.
- The noise shows up as arches in h(t) as well as the transmons

ETM-TMS scattering



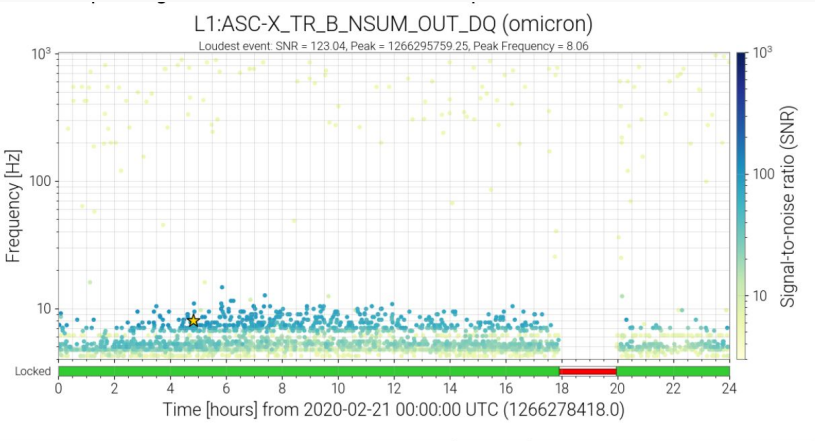
ETM TMS scattering

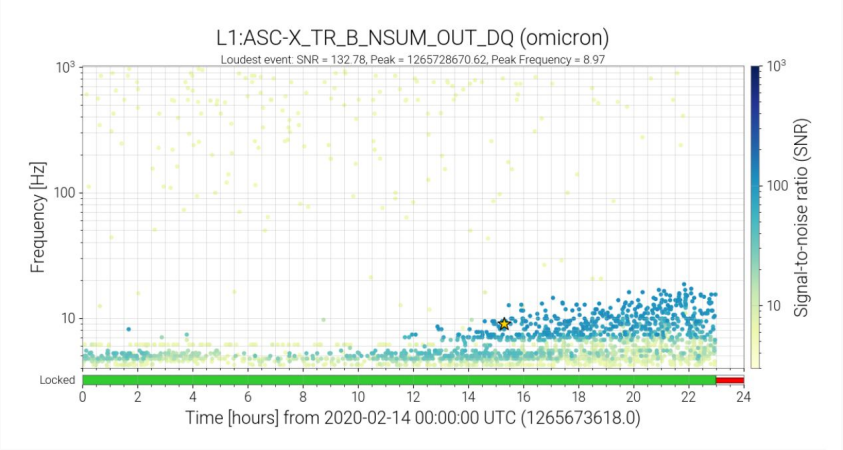
- The equation which dictates the frequency of arches in h(t) and transmons is

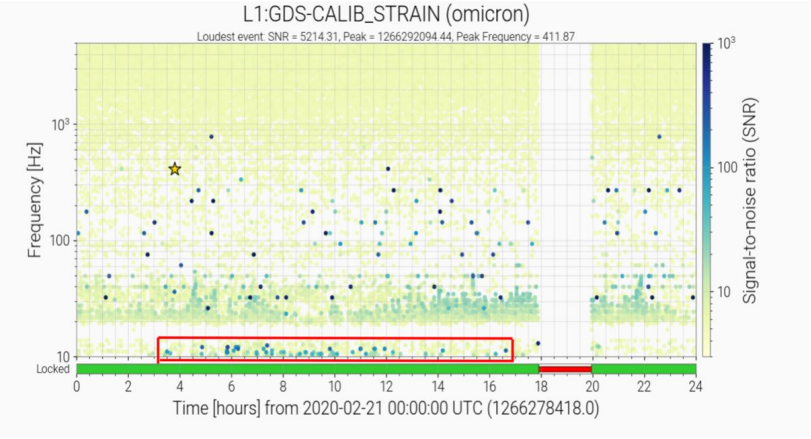
$$f_{fringe} = \frac{2v}{\lambda}$$

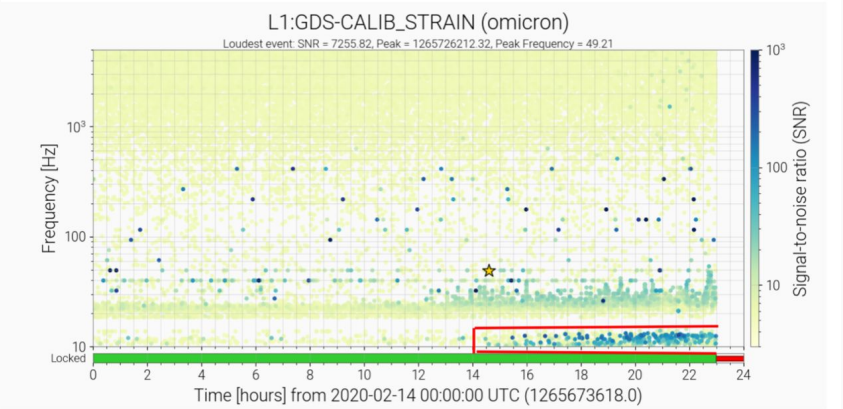
- Where v is assumed to be the relative velocity between the test mass and the TMS.
- For the arches to show up in h(t), this relative motion should be above 5 microns, so as to make noise above 10 Hz. Anything below does not show up in the h(t) spectrogram due to low sensitivity below 10 Hz 1263859478.88
- This greater than 5 micron relative motion occurs during high microseism (above 2μm/s) coupled with high anthropogenic noise
- alog

High microseism ground motion on Feb 21 and Feb 14

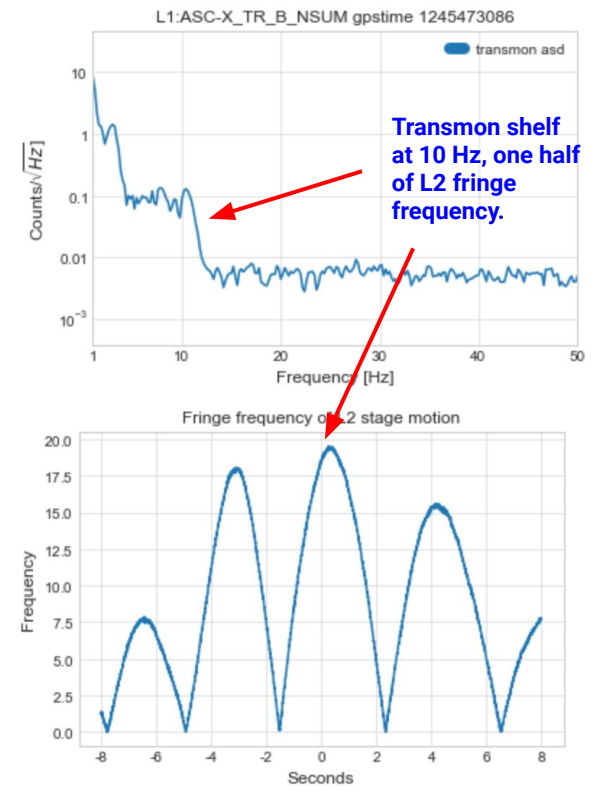


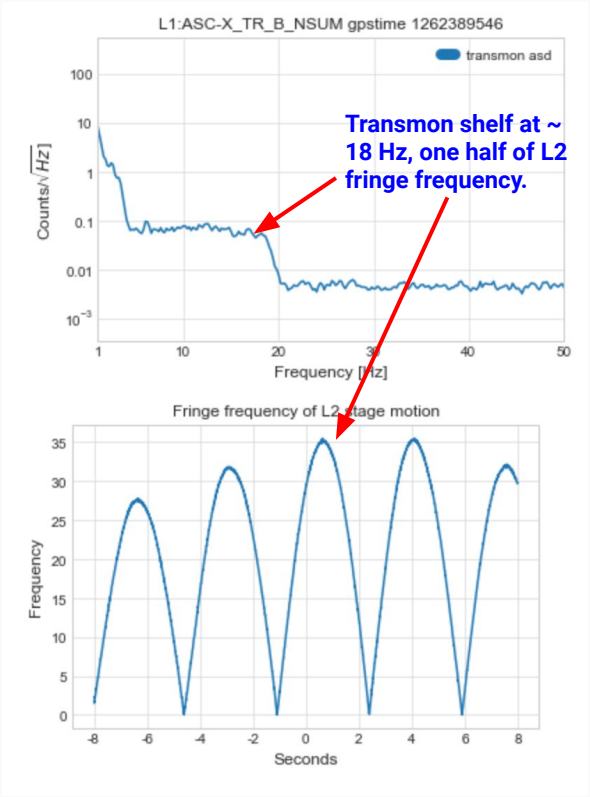






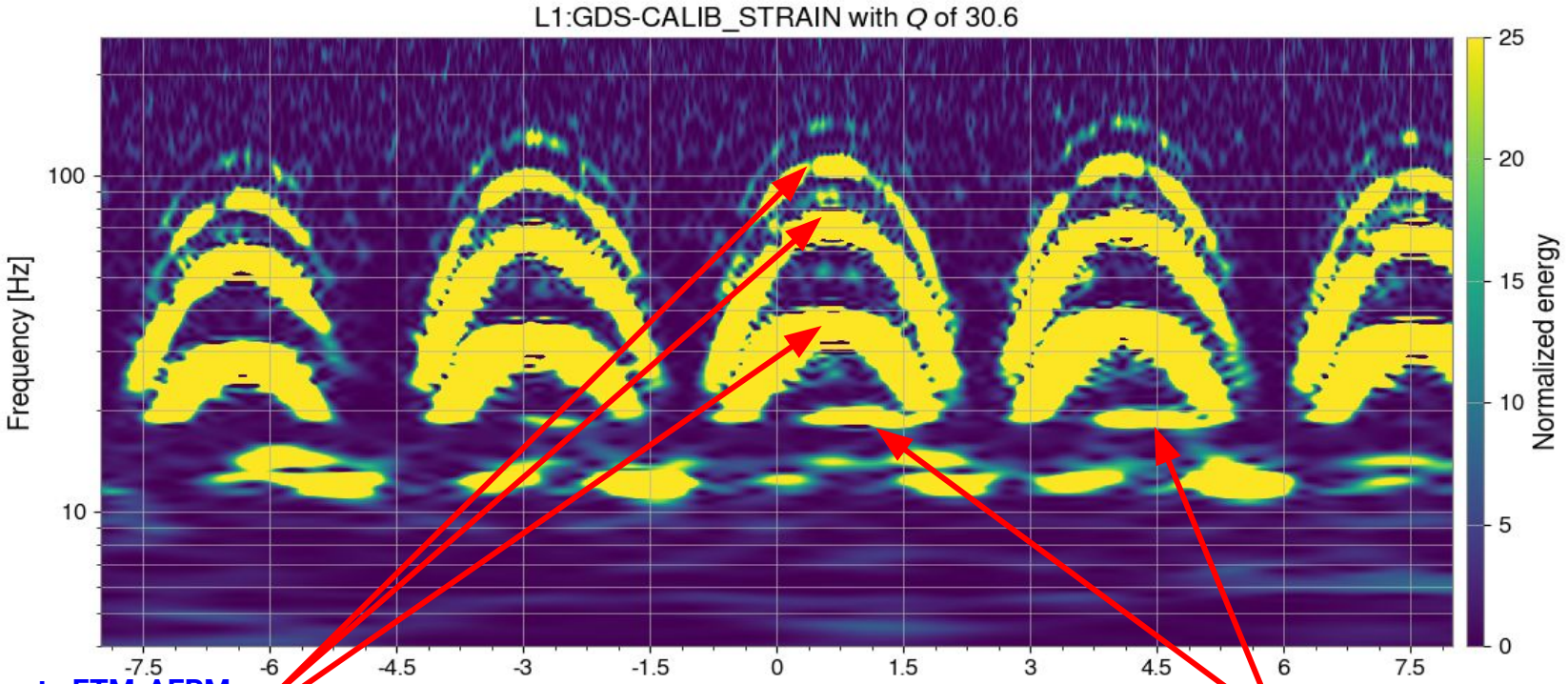
Transmon shelf





- Pre RC tracking the relative motion between ETM and TMS is one-half of ETM and ERM.
- Scattering arches due to ETM-TMS coupling are at one-half the frequency of ETM-AERM coupling.

Pre R0 ETM Transmon Scattering.

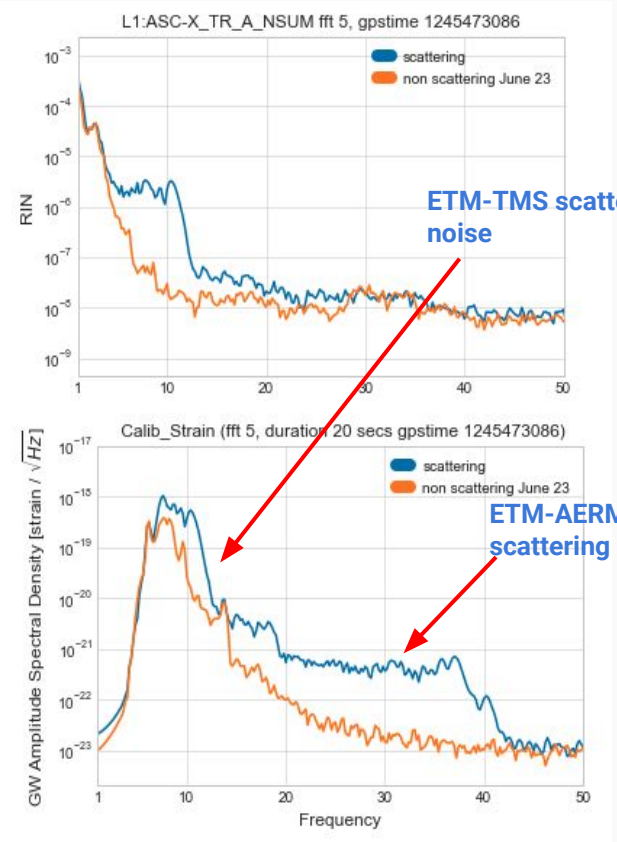


Due to ETM-AERM scattering
f1 ~ 40 Hz

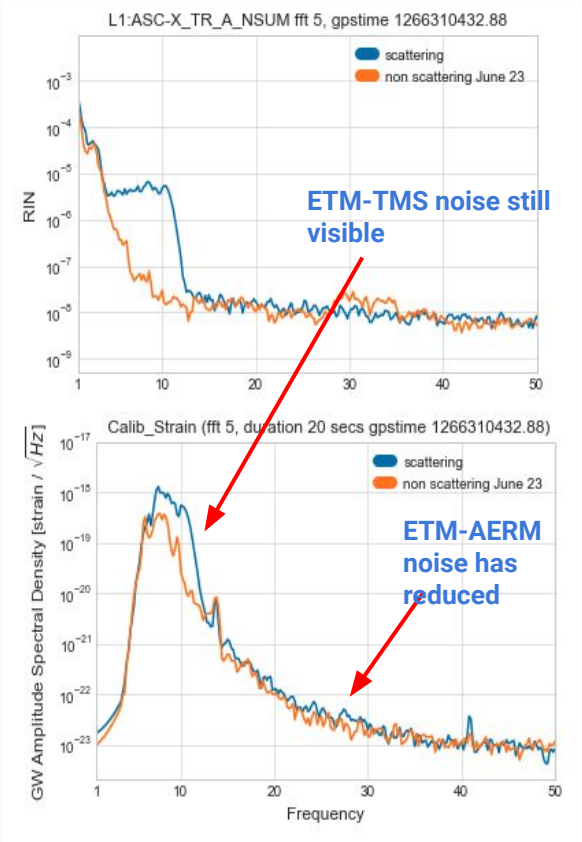
Due to ETM-transmon scattering
f ~ 20 Hz

Transmons as witness of slow scattering

- ETM-AERM and ETM-TMS scattering both occur simultaneously, since both couple through the common test mass motion.
- Scattering in transmons thus serves as a witness of ETM-TMS scattering as well as ETM-AERM scattering.

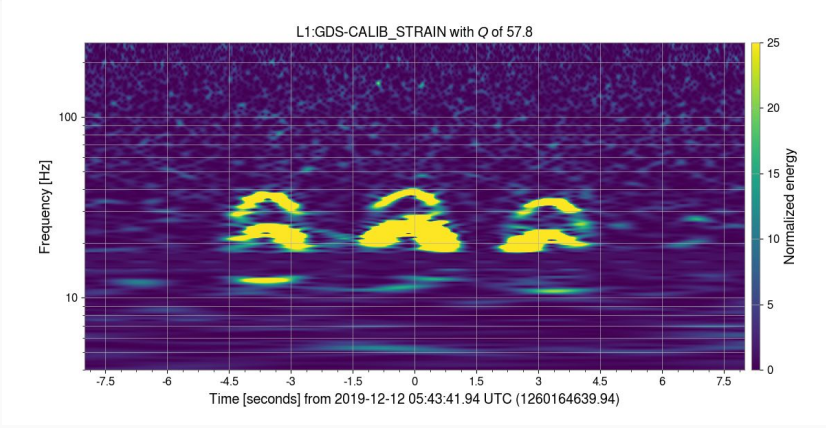


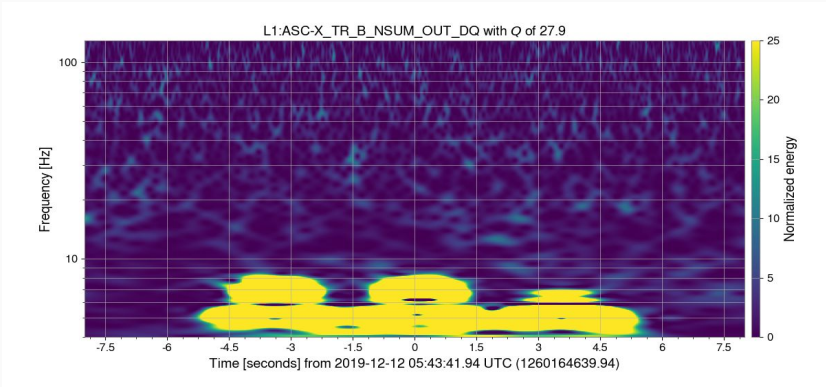
Pre RC



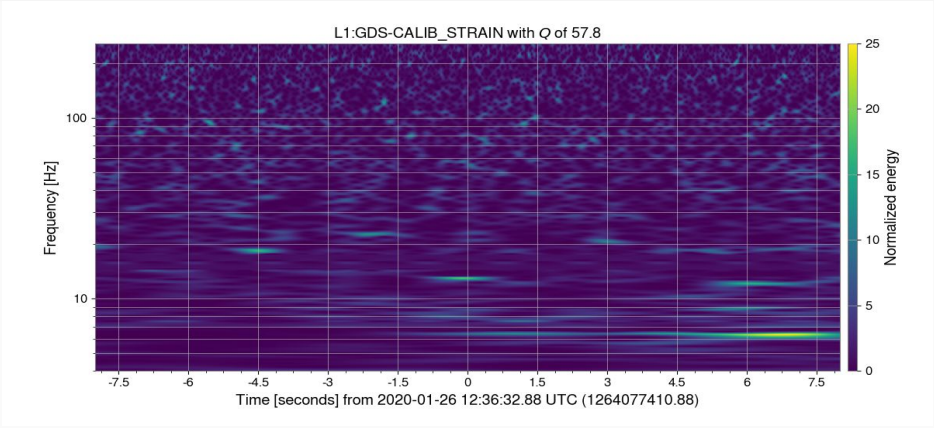
Post RC

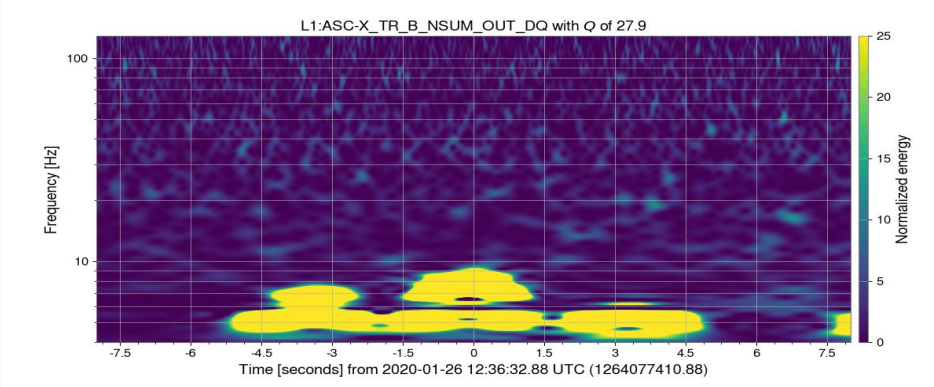
Transmons as witness of slow scattering





Pre RC





Post RC

Possible solutions to reduce ETM-TMS coupling

- Split the drive between X and Y end.
- Transmon tracking?

Thank You.

Questions?