

# September 2021 scattering mitigation and PEM update

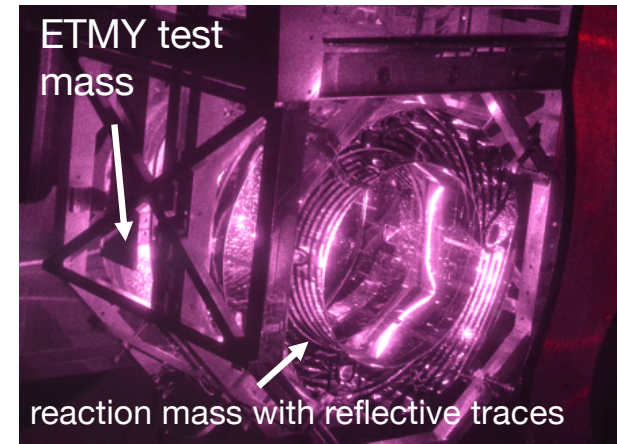
Robert Schofield, Philippe Nguyen, Anamaria Effler, Siddharth Soni, Valera Frolov, Arnaud Pele, Jane Glanzer, Adrian Helmling-Cornell, Alena Ananyeva and the SLiC team,

Photograph lit by scattered main beam light during high-sensitivity operation

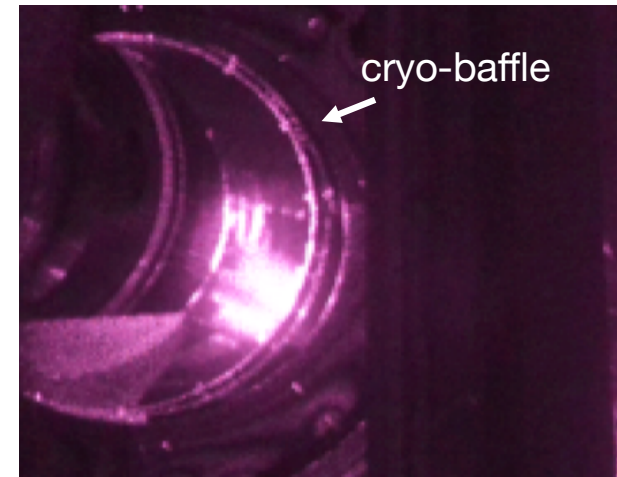
LIGO-G2101943

# Mitigating 03b scattering noise for 04

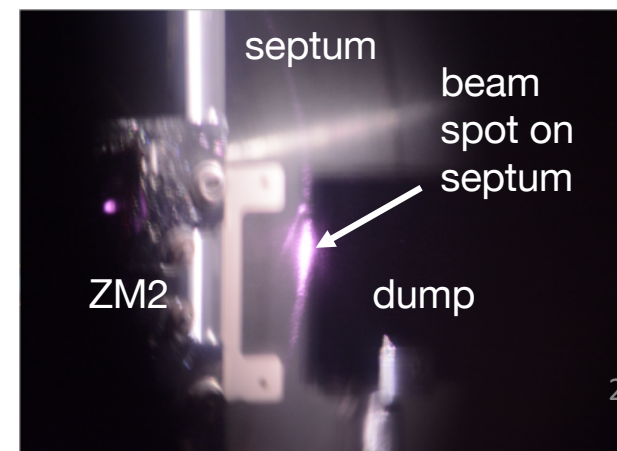
**1) Noise mainly associated with microseismic peak motion: mitigated during 03b by moving reaction mass with test mass (RC tracking).**



**2) Noise mainly associated with  $>1$  Hz motion, e.g. trains and wind, fast-scattering, up-converting.**



**3) Noise mainly associated with  $>10$  Hz motion in HAM5,6 region, not up-converting.**

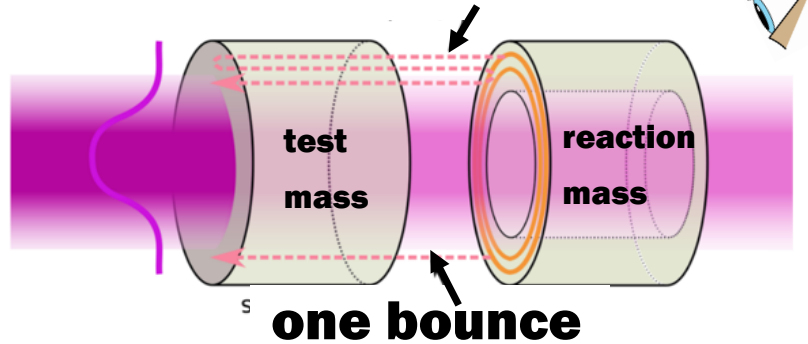




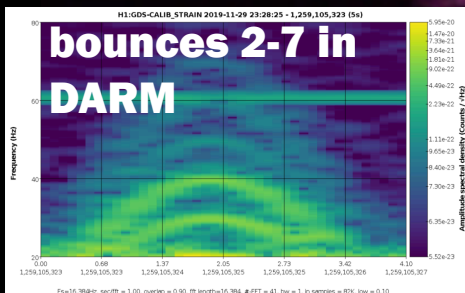
# Video monitoring of chambers proved useful for scattering noise localization

Movies showing flickering around EY test and reaction mass helped identify the source of noise mitigated by RC tracking.

two bounces from ESD traces



<https://youtu.be/JghBSjQ2xV4>



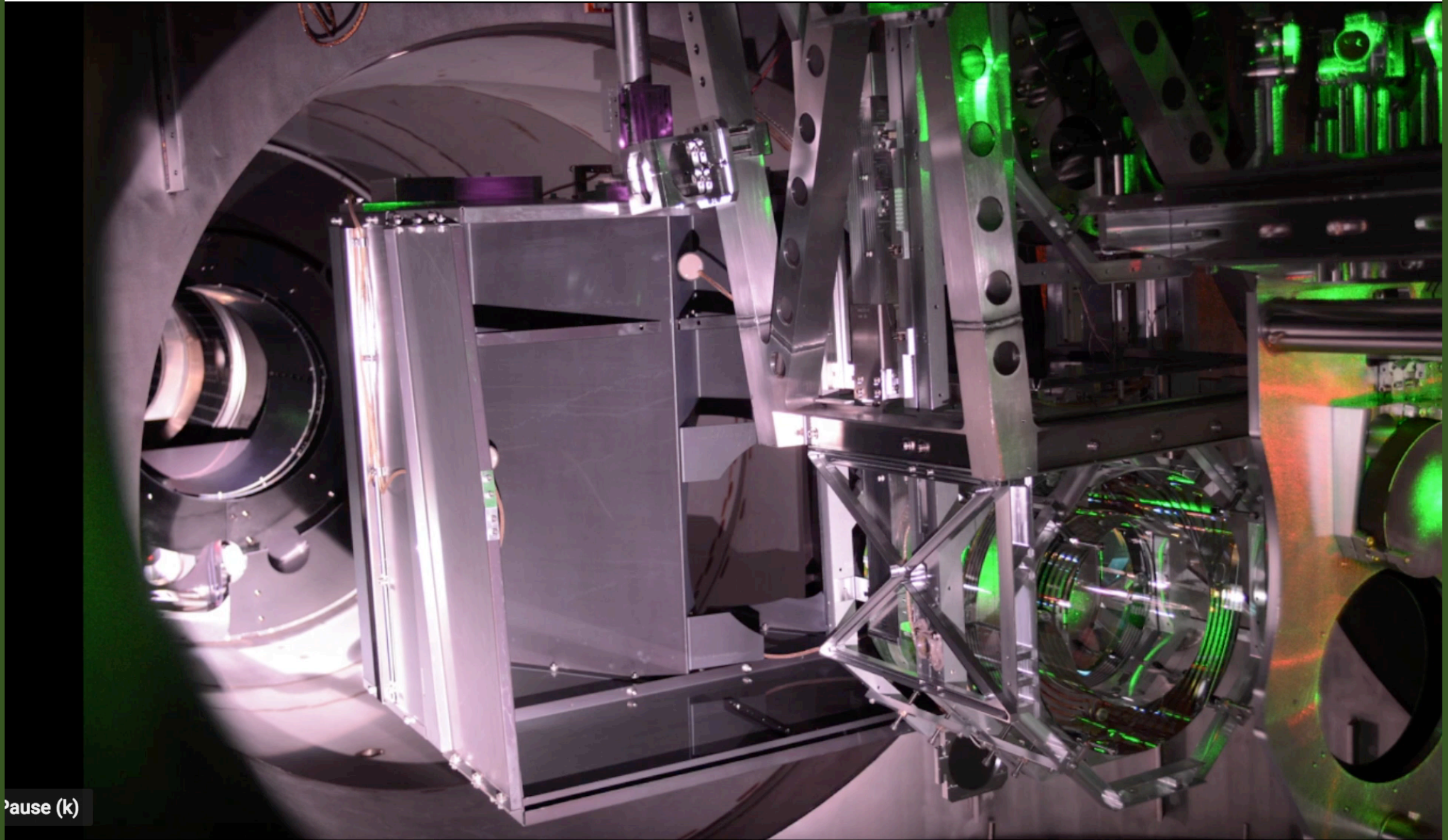
ETMY  
test mass

annular reaction mass  
with reflective ESD traces

LHO ETMY, NO INJECTIONS, SPED UP 10X

# Video of EY test and reaction masses

<https://youtu.be/JghBSjQ2xV4>



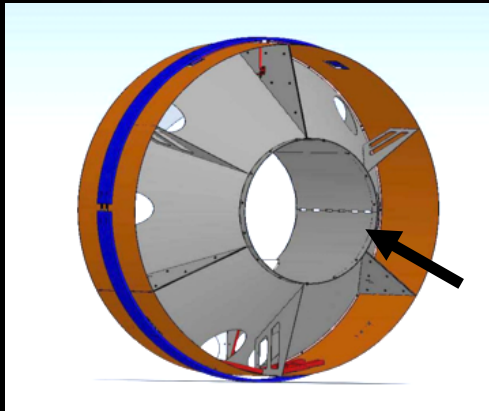
Pause (k)



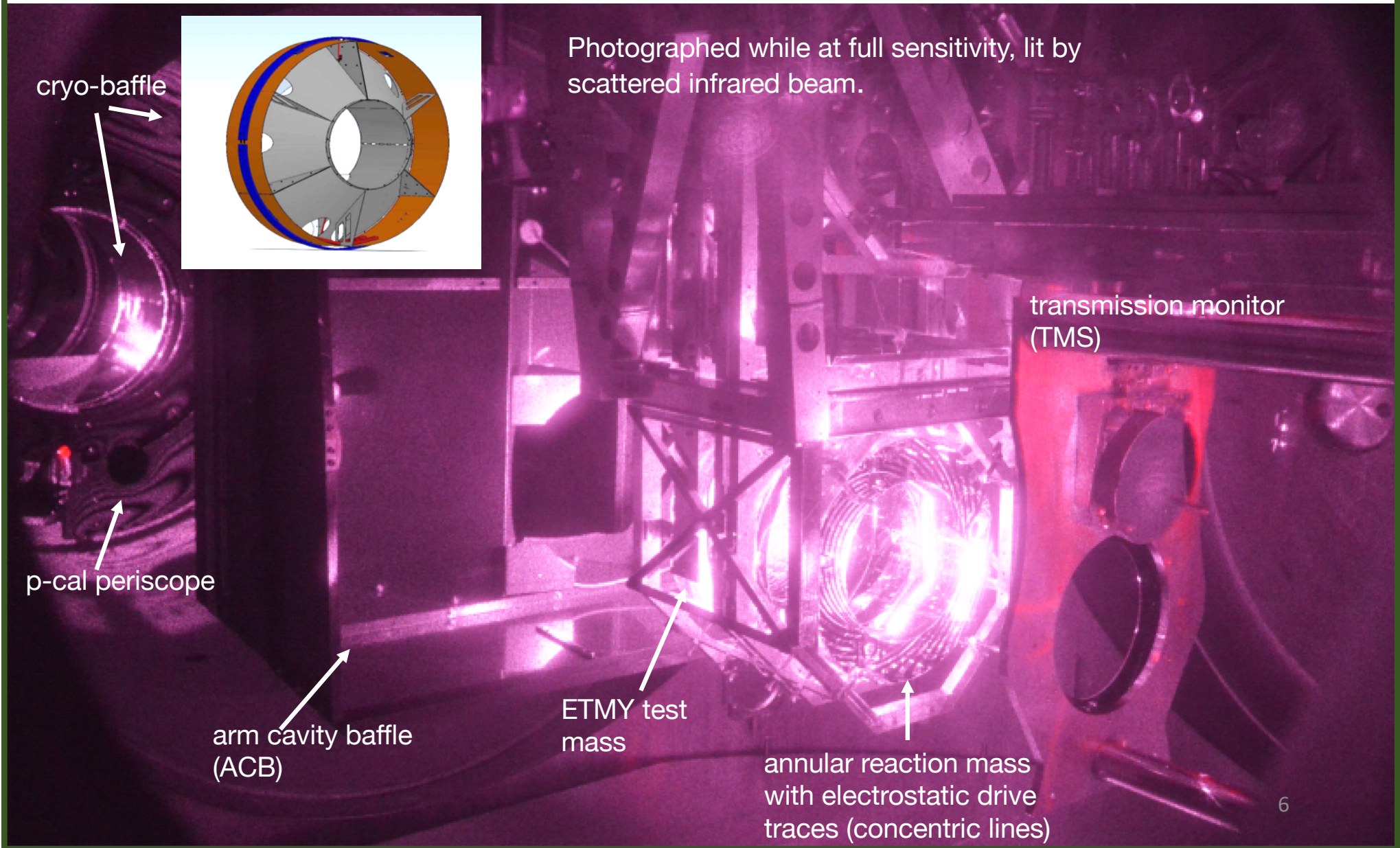
# **Flickering in videos indicates micron scale or greater motion – potential scattering noise**

**At the end of O3, I looked for flickering in EY chamber associated with LHO wind scattering noise, and saw flickering at cryo-baffle**

<https://youtu.be/ZSNVuvWRpI0>



# Manifold/Cryopump Baffle: “Cryo-baffle”



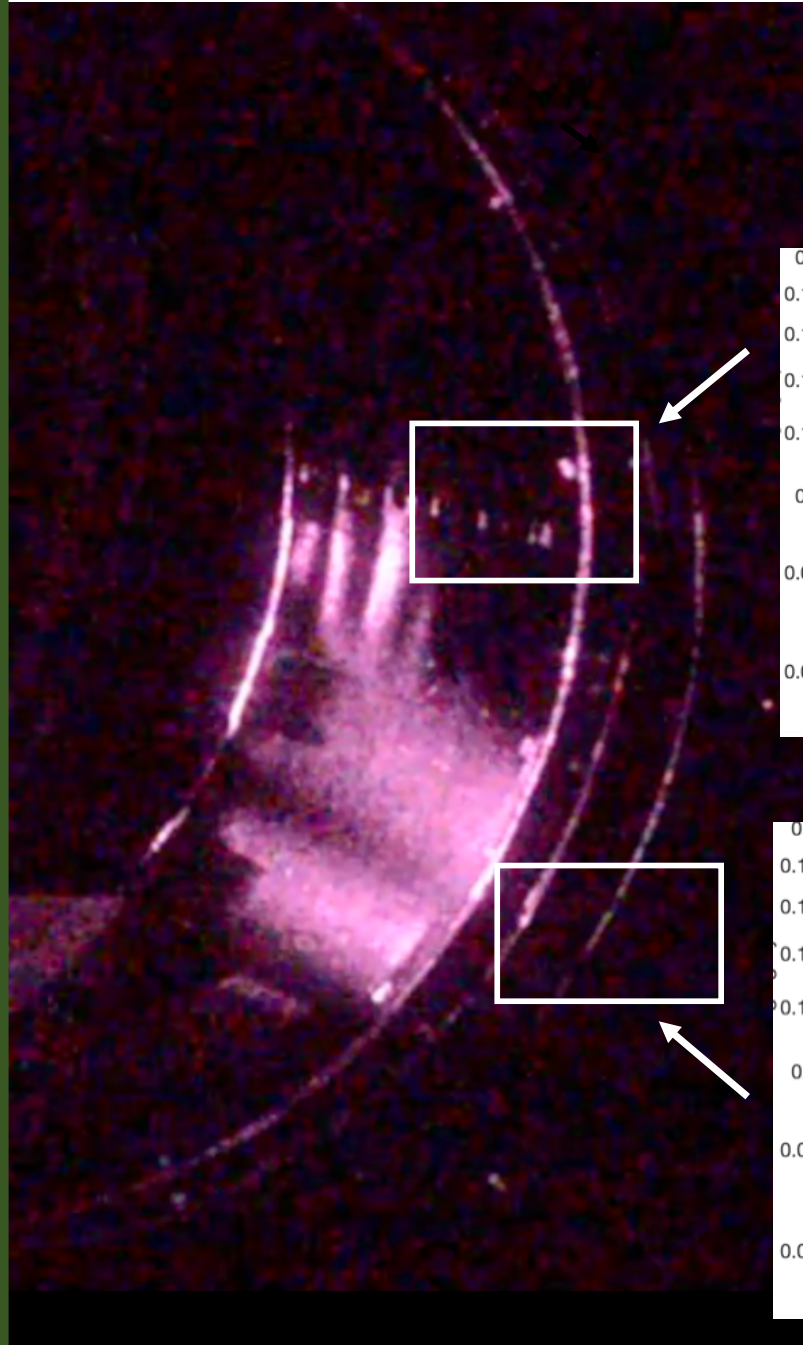


# Movie of cryo-baffle during impulse

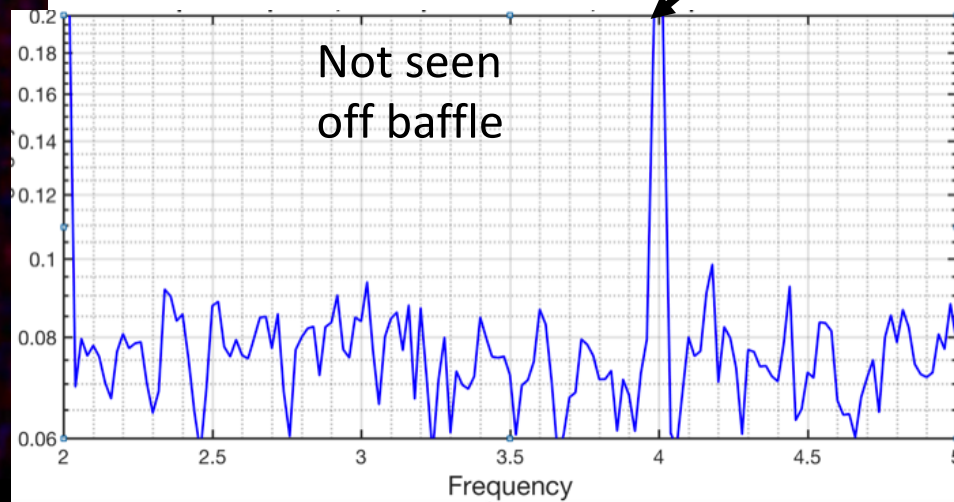
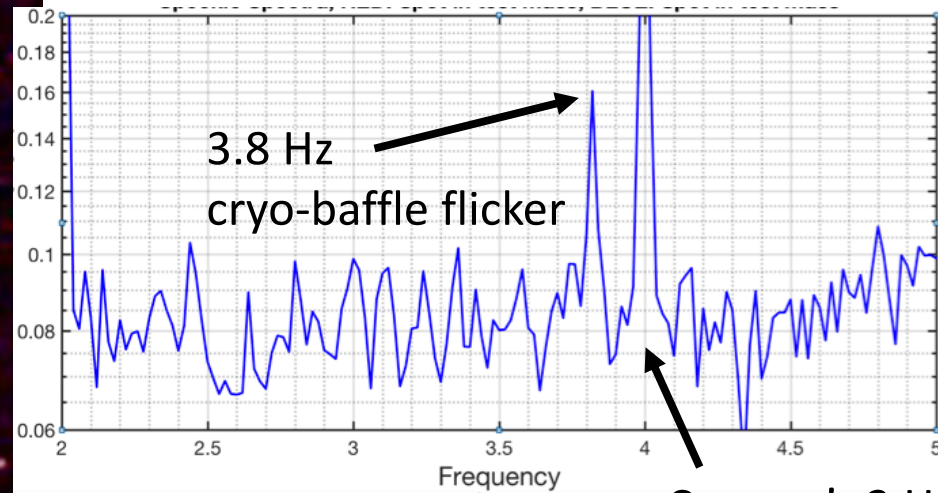
<https://youtu.be/ZSNVuvWRpI0>



# Flickering frequency matched noise in DARM



## Flicker spectra during high wind at LHO

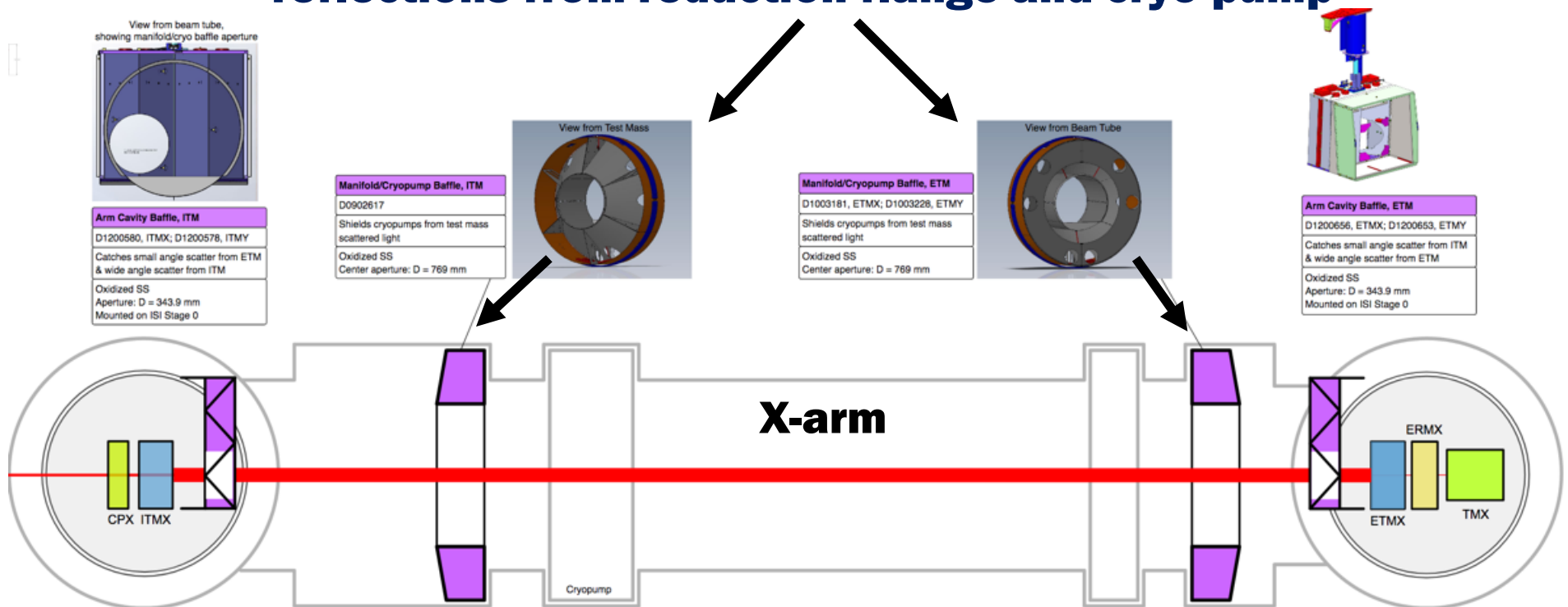




# Similar ~4 Hz scattering noise at LLO EY also found at other cryo-baffle locations

Anamaria and Valera found that ~4Hz shaking produced DARM noise at 3 of 4 cryo-baffle locations, one in the CS

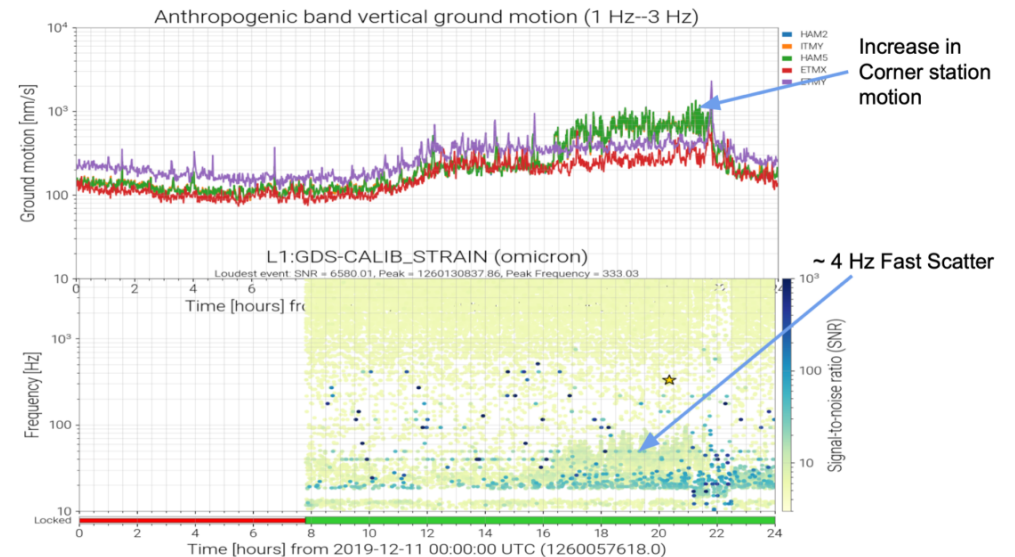
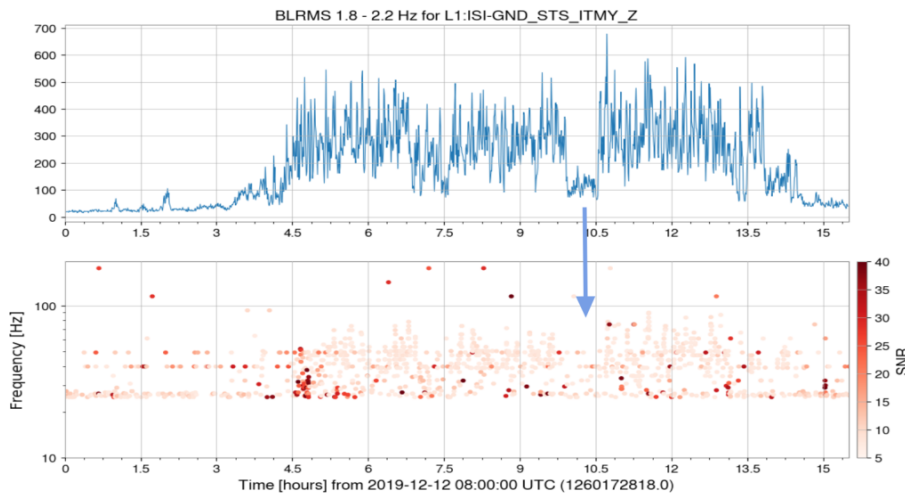
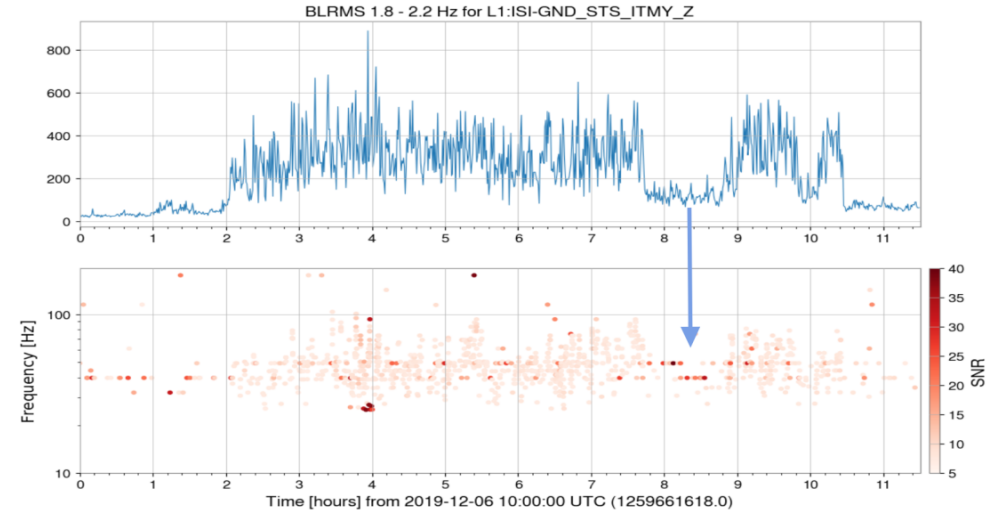
4 cryo-baffles, one for each test mass, to minimize reflections from reduction flange and cryo-pump



# An LLO CS cryo-baffle likely made noise in O3

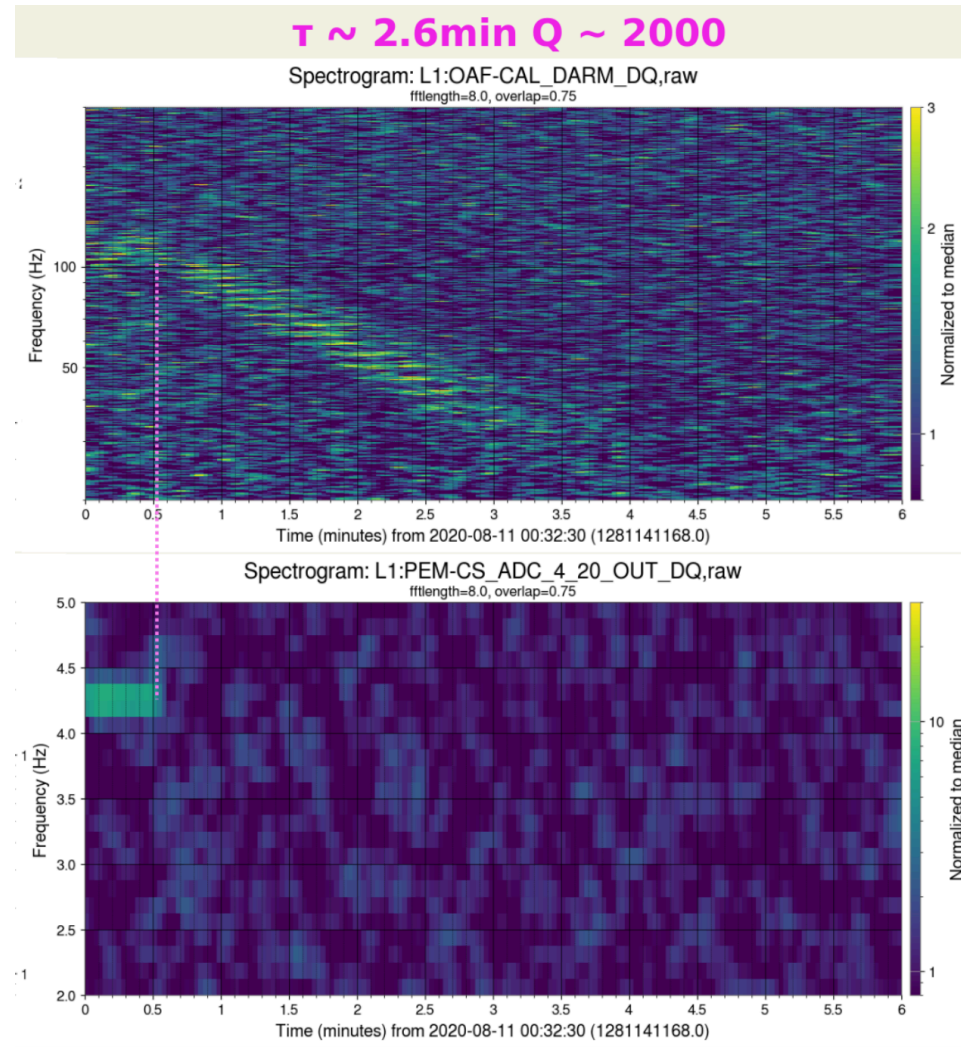
## Sidd sees evidence that some 4 Hz scattering noise was produced by motion at the corner station

- Evidence of correlation between anthropogenic ground motion at Corner station at LLO and 4 Hz Fast Scatter
- This correlation noticed for several days in O3
- Increase in ground motion caused by road work/logging near the site
- Also see [G2100972](#), alog [56668](#)



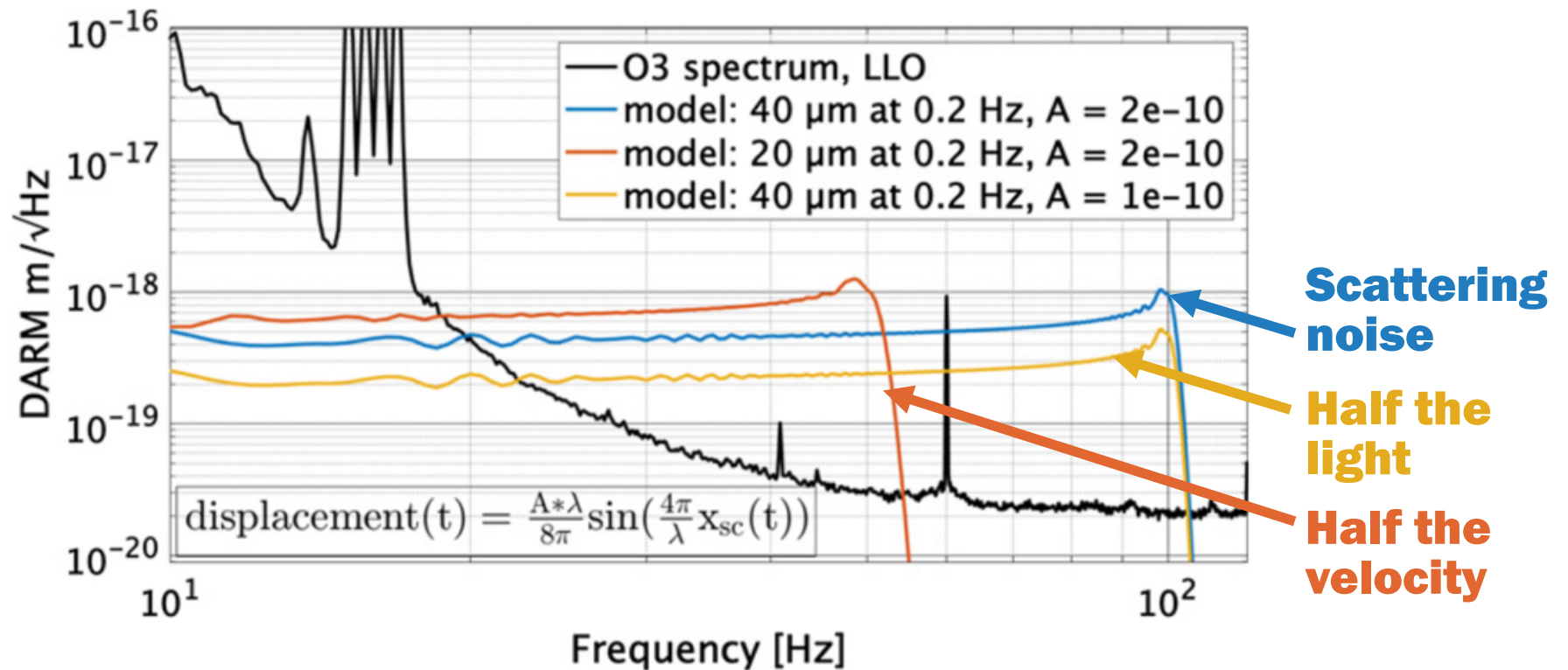


# Qs of ~1000 measured at LLO and LHO



**Explains how nanometers of ground motion can be amplified to microns, producing up-converting fringe wrapping noise**

# How to mitigate scattering noise – reduce light or reduce reflector velocity?

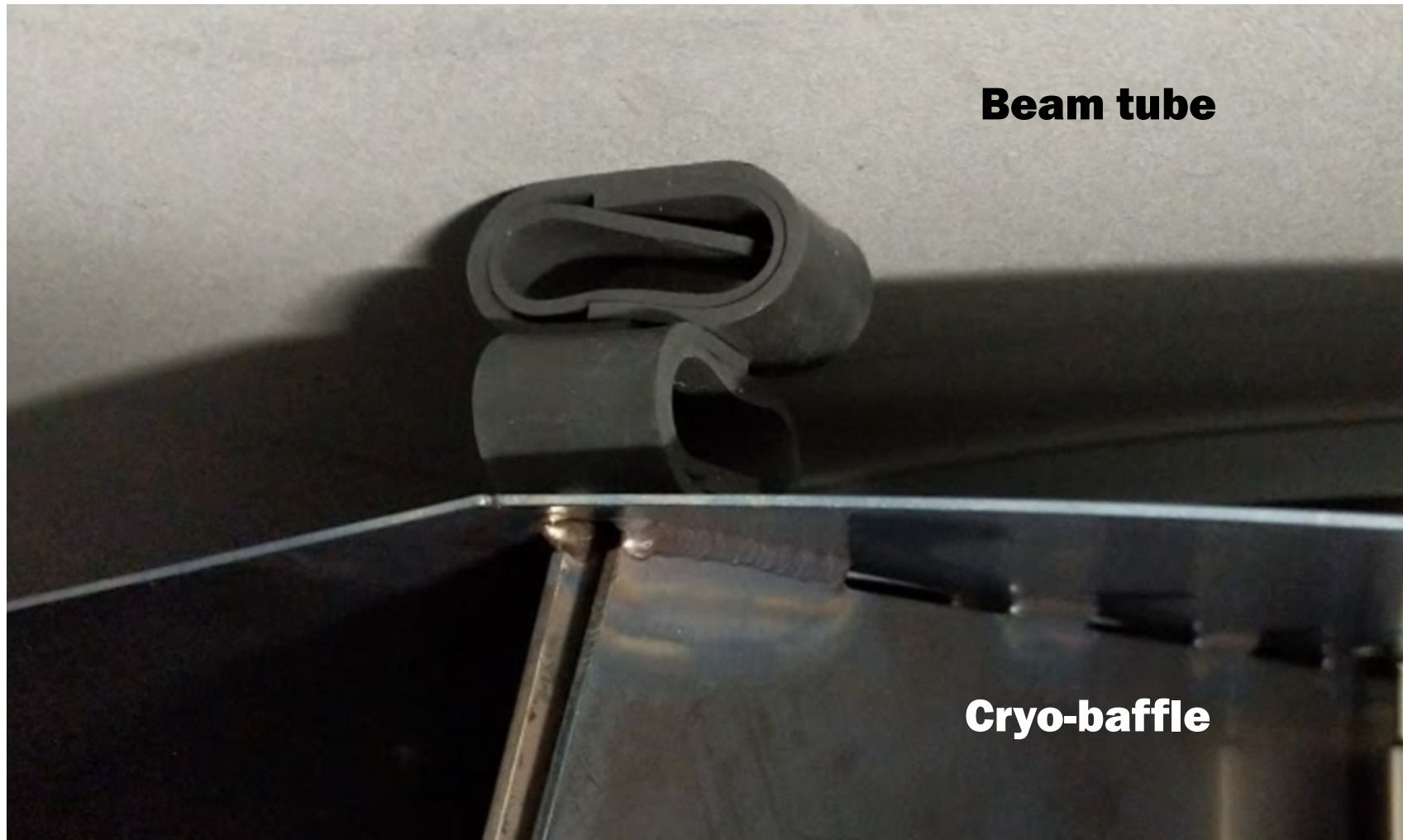


From PEM paper: P Nguyen et al 2021 Class. Quantum Grav. 38 145001

**Q so high that velocity reduction would be easy, so tried damping (reflector velocity at resonance is ~proportional to its Q)**



## **Damping test at LLO**



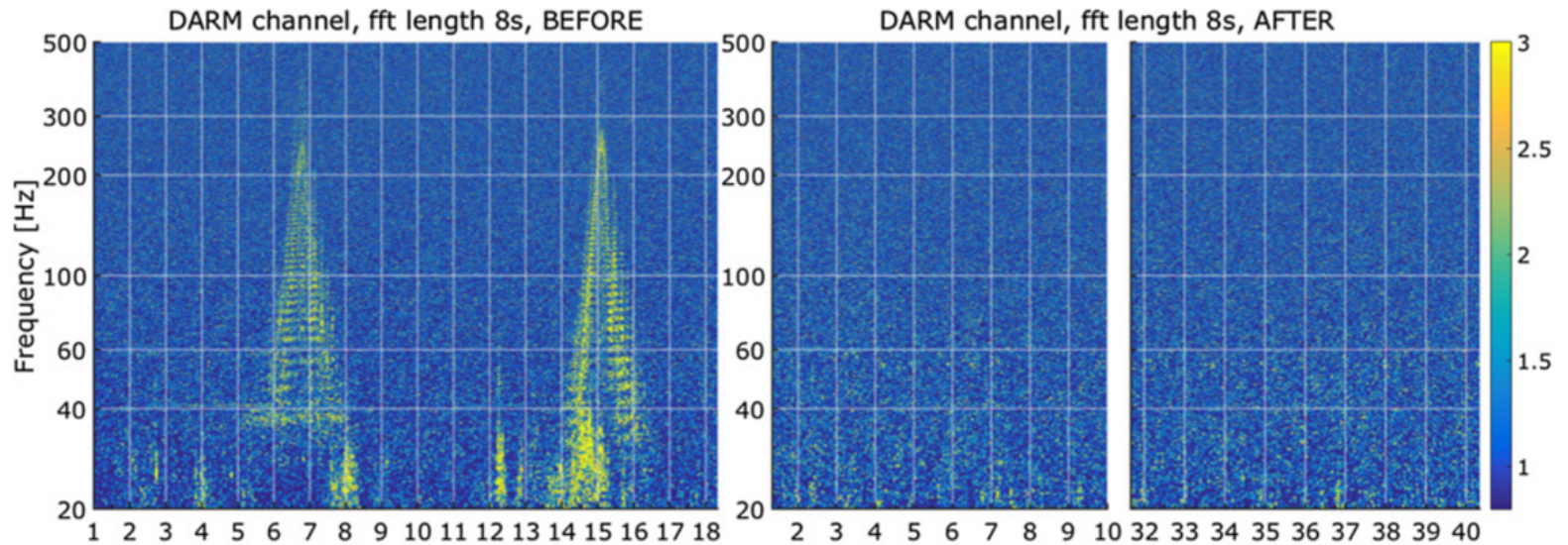
**One of four of Arnaud's figure 8 Viton dampers installed at LLO  
ETMY Cryo-baffle**

# No noise evident in DARM after damping!

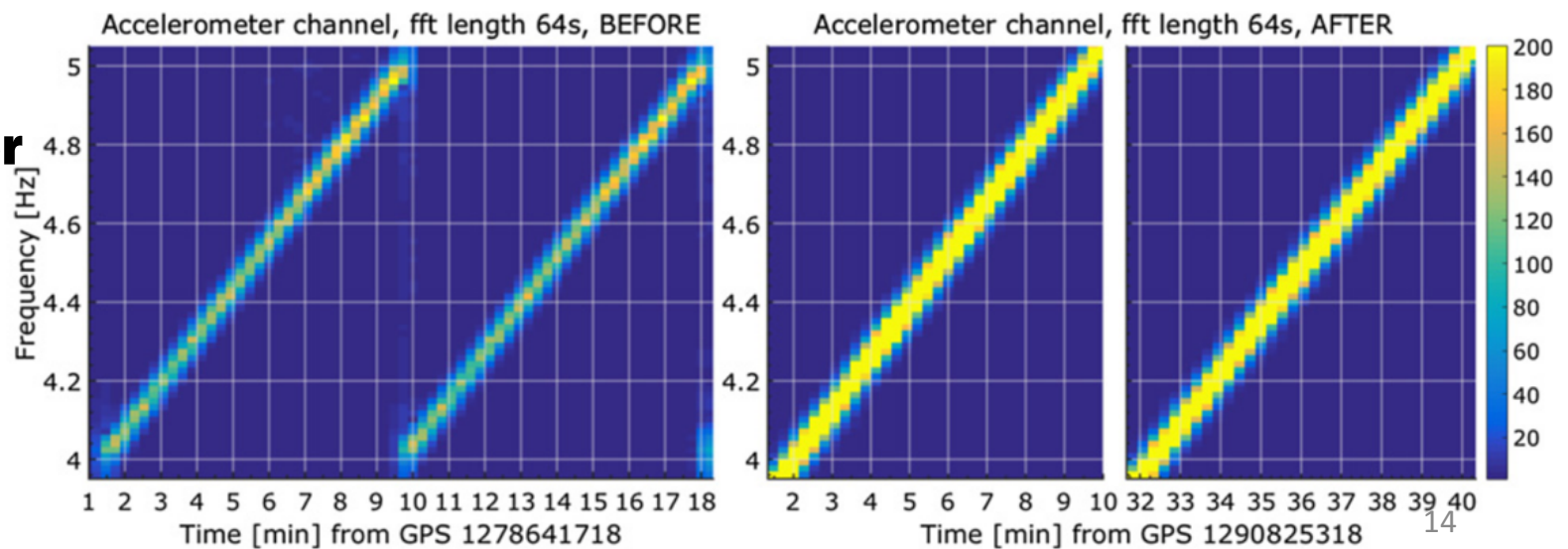
**Before**

**After**

**DARM**



**Accelerometer  
showing  
shaker sweep**





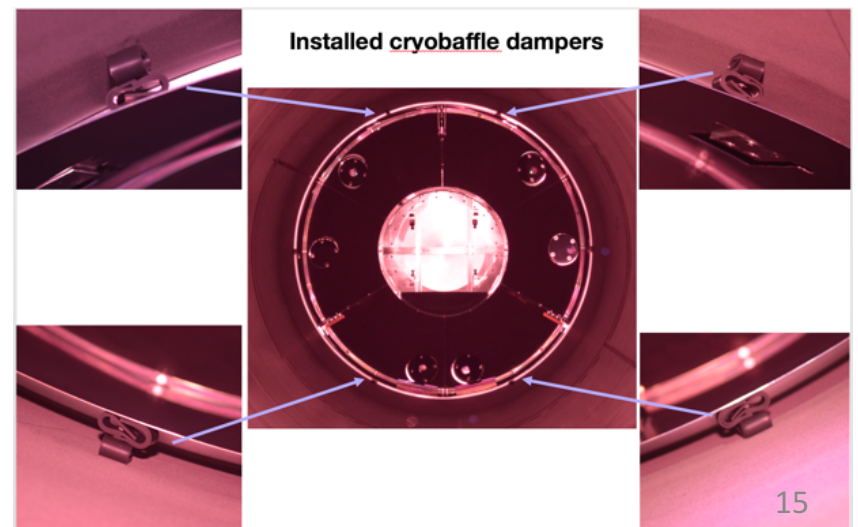
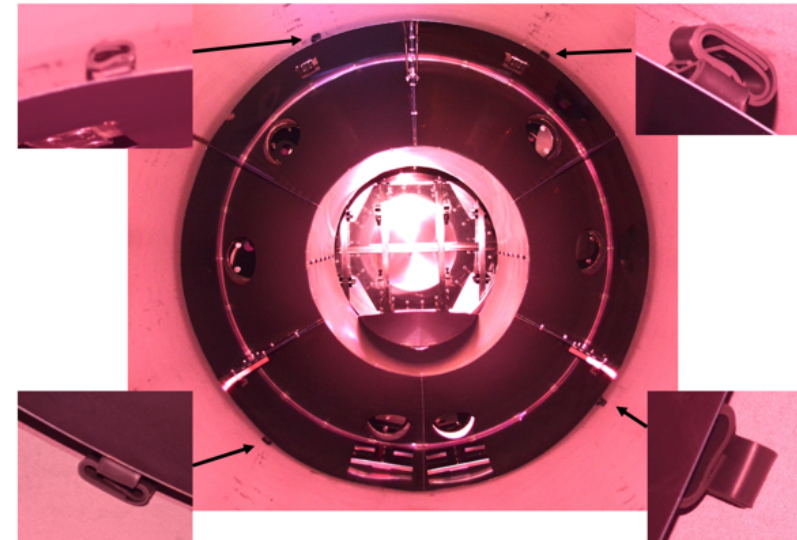
# Current status of cryo-baffle damping

Plan to do all 4 at each site

**LLO: ETMY, ITMX, ITMY**



**LHO: ITMX and ITMY**

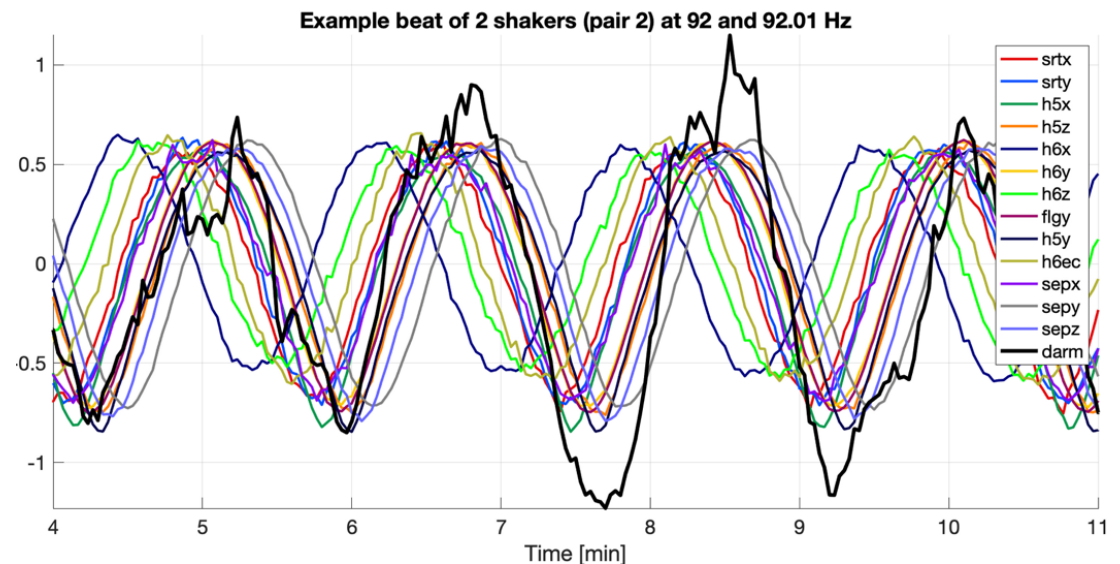
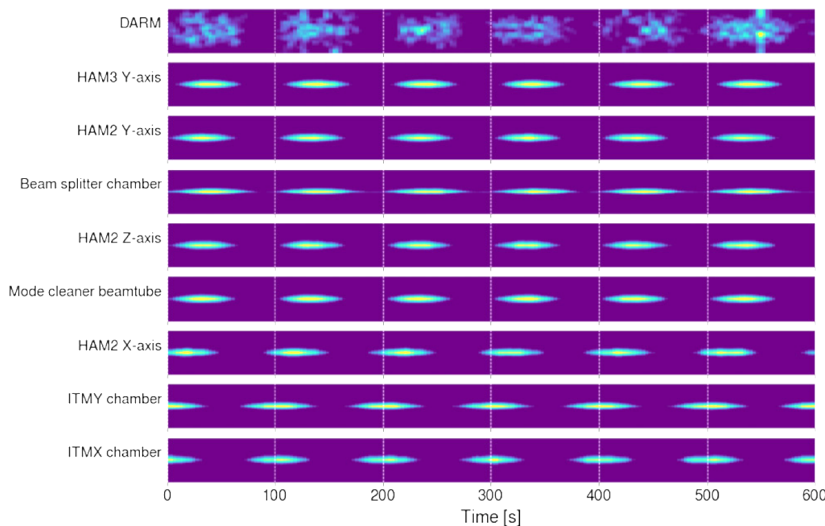


# HAM 5/6 scattering noise: old and new evidence that it is from the septum

**1) For impulse injections at both LHO and LLO, the DARM noise coincides with arrival time of the impulse at the septum accelerometers but not as well as others**

**2) A beam spot was found on the HAM5 side of the septum at LHO**

**3) New: the beating shaker technique points to the septum at LLO**

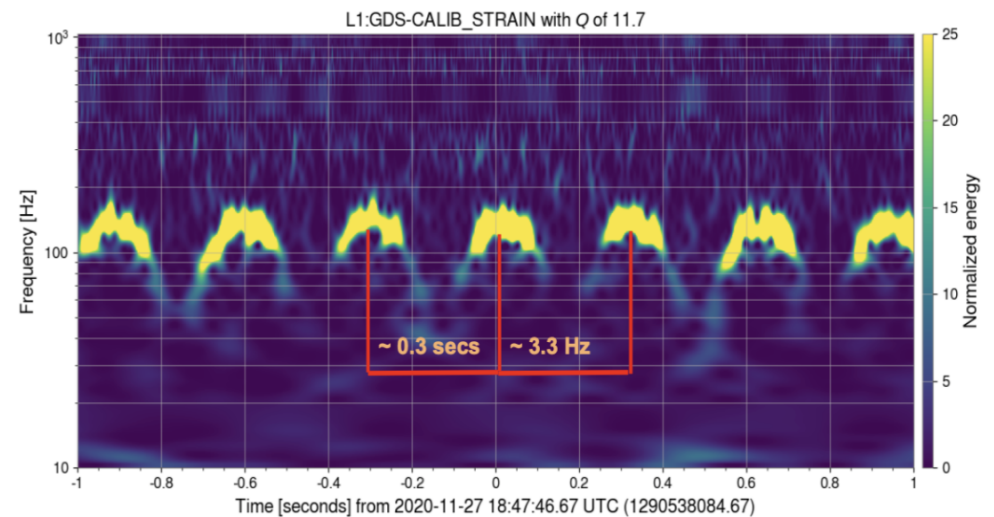
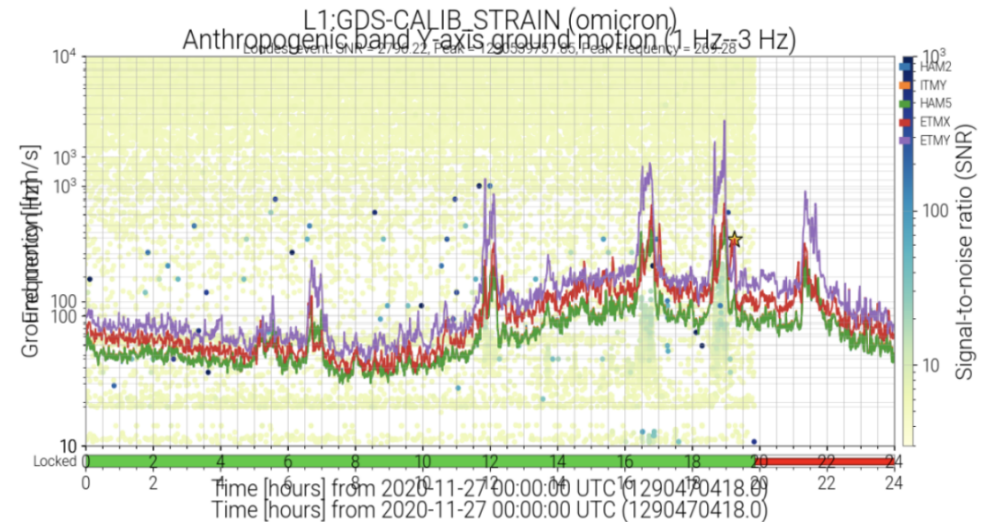




# Post-O3: new 3.3 Hz noise at LLO

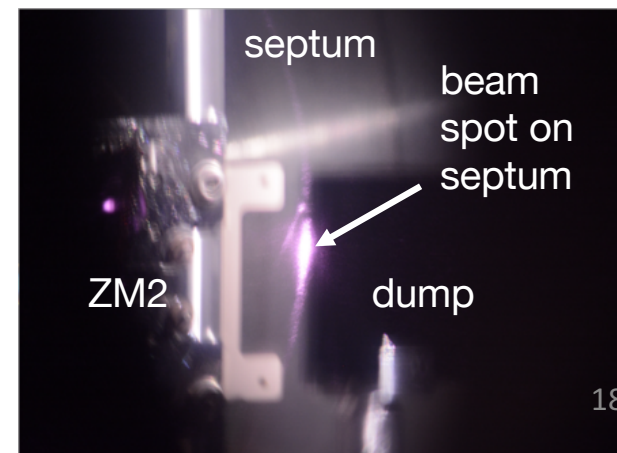
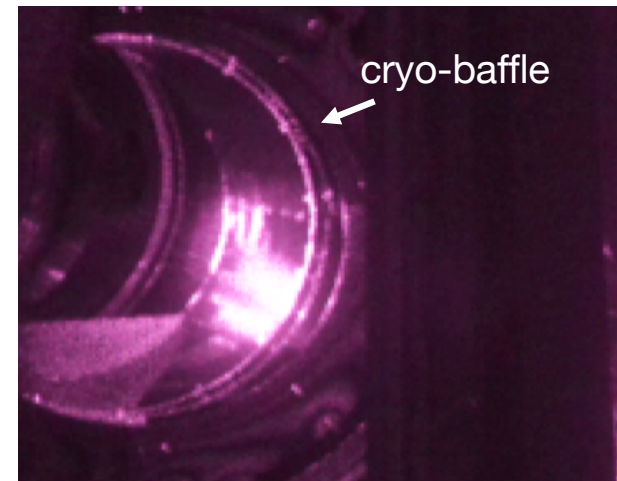
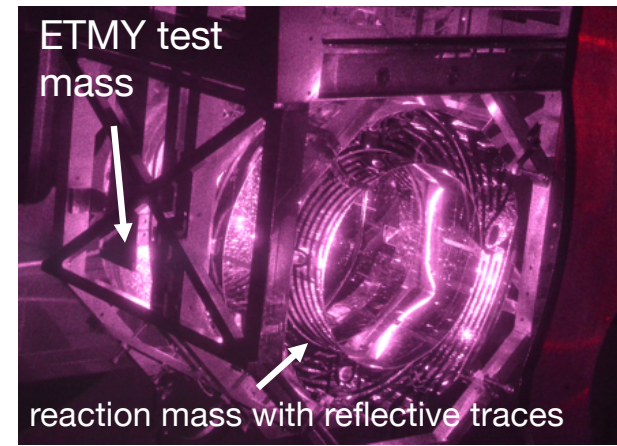
## Unlikely to be cryo-baffles - not excited by shakers at 3.3 Hz

- During O3, trains have mostly been observed with 4Hz fast scatter. Post O3, 3.3Hz fast scatter has been spotted during the time of trains
- Nov 27th 2020 → two loud trains that correlated with an increase in DARM noise
- Very similar fast scattering glitches were seen on Dec 2nd 2020 which also had an increase in noise in the 1-3Hz band due to a train
- Further investigation and more data required to determine the cause of this new 3.3Hz fast scatter seen post O3
- Alog [54383](#)



# Mitigating O3b scattering noise for O4

- 1) Noise mainly associated with microseismic peak motion: **mitigated during O3b by moving reaction mass with test mass (RC tracking).**
- 2) Noise mainly associated with  $>1$  Hz motion at all stations, e.g. trains and wind. up-converting: **cryo-baffle damping test successful and damping ongoing at each site.**
- 3) Noise mainly associated with  $>10$  Hz motion in HAM5,6 region, not up-converting: **HAM5-6 septum baffling ongoing. Not yet demonstrated to work.**
- 4) New LLO 3.3 Hz noise: **study ongoing.**





# Some of the additional scattering mitigation activities: nozzle (viewport) baffles

Camera viewport



# Nozzle baffles for PCal beam ports, ports with beams and other ports opportunistically

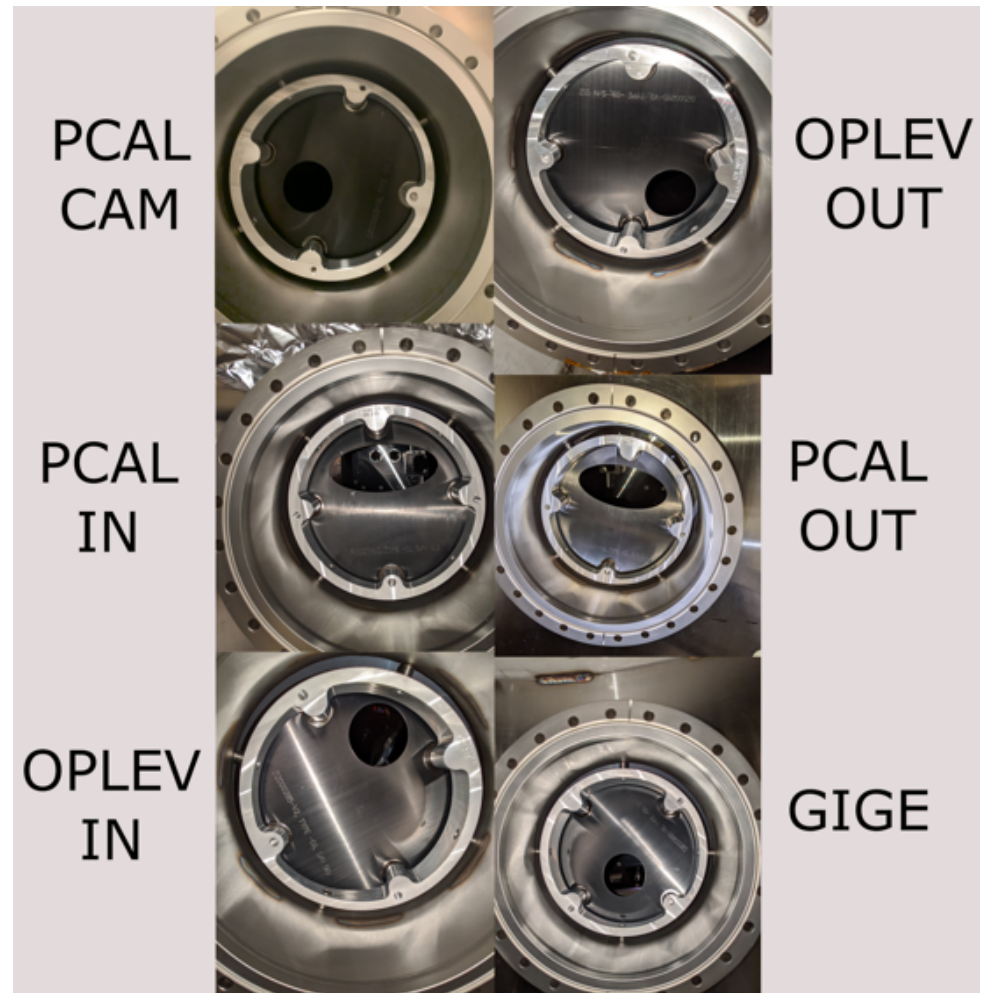
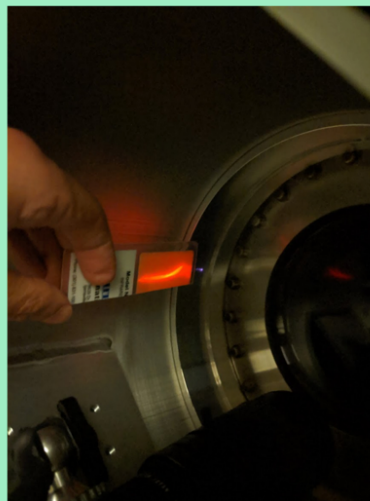
**Vibration coupling at EX increased over EY vent, old 55 Hz again showing in DARM. May be associated with new beams on viewports.**

**Nozzle baffles installed**

OPELV IN VP4



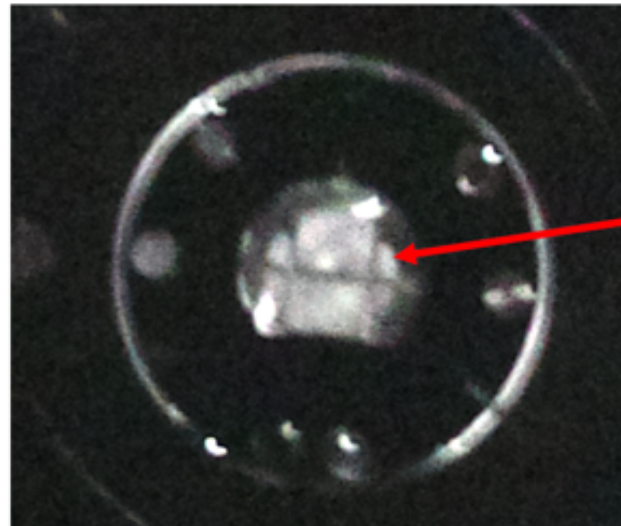
GIGE VP3



# Nozzle baffles for PCal ports, ports with beams and other ports opportunistically, even when not dominant source of light reflected to TM

940 nm IR photos taken from near the beam spot on ITMX

Before nozzle baffles



closed gate valve

After nozzle baffles



remaining annulus of light around the cryo-baffle

this optical lever laser was blocked for the. before image



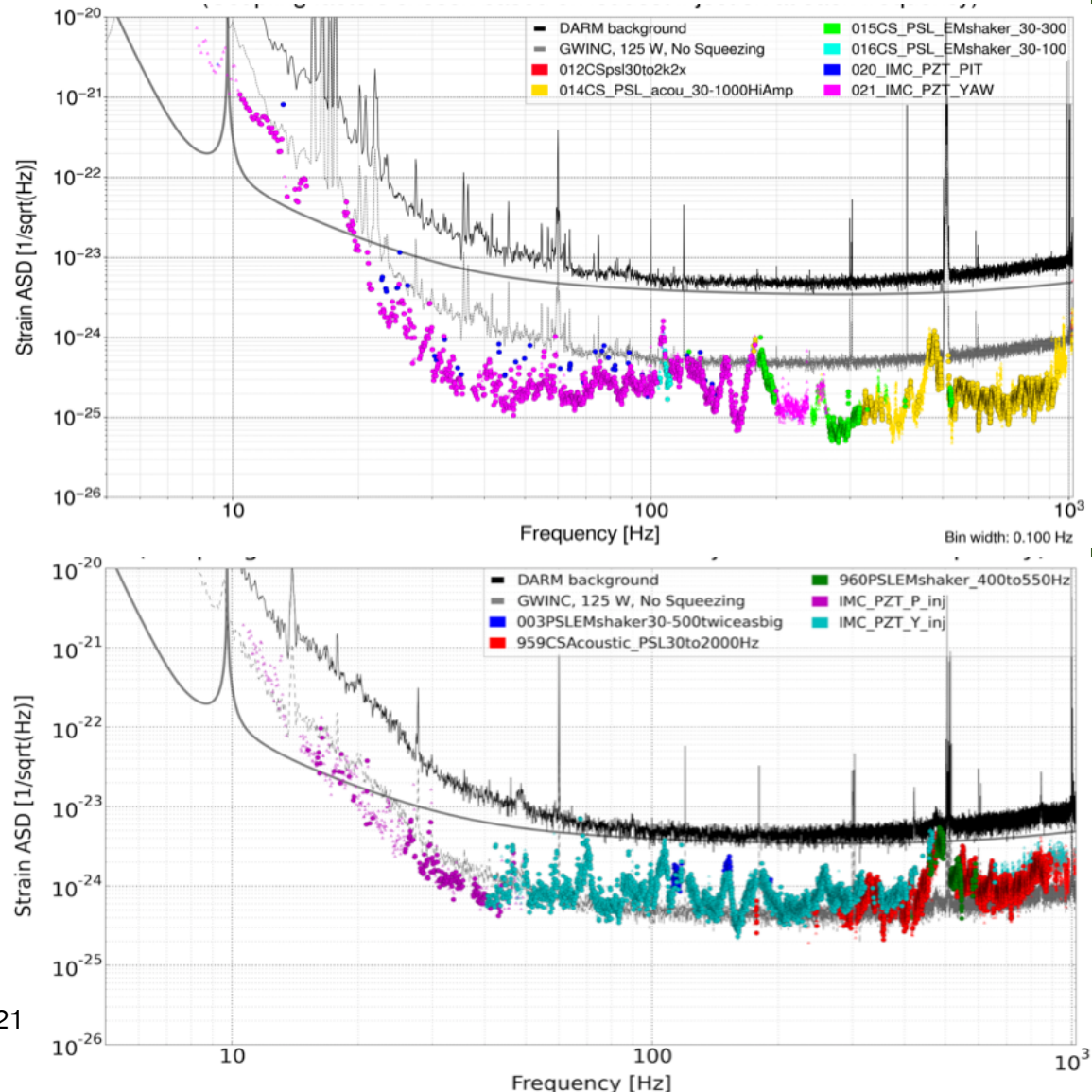
# Jitter coupling: ITMY replacement at LHO reduced coupling ~10X !

Now, after ITMY replacement

Worst jitter peak at about 500 Hz no longer appears in ambient DARM spectrum and is down by about ten

Before, May, 2019

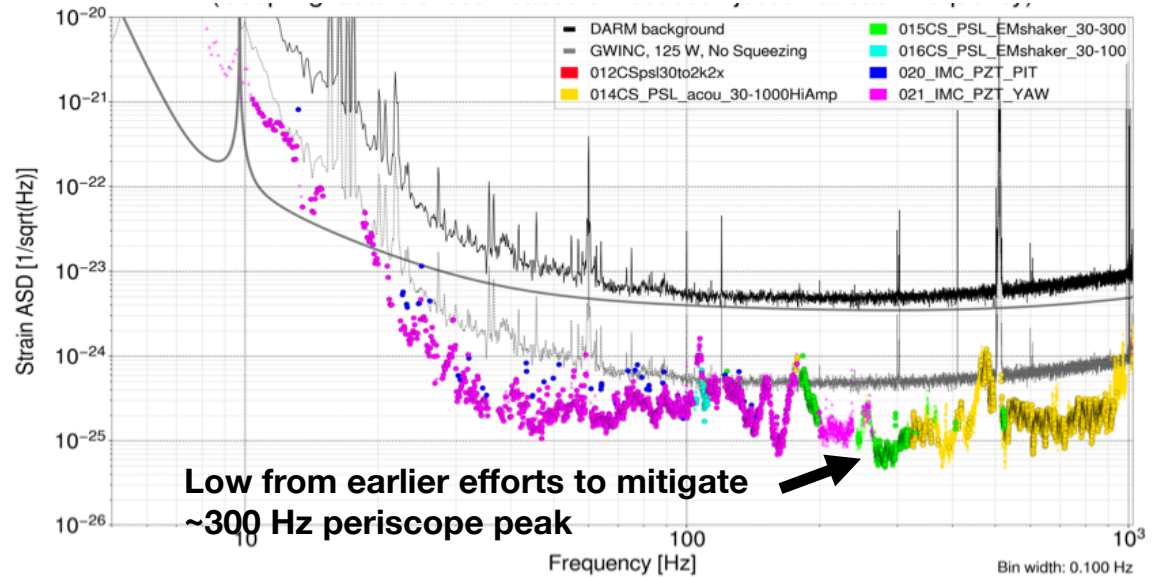
<https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=49521>



Ambient estimates are made by multiplying coupling factors by injection-free sensor levels. CIRCLES indicate estimates from measured coupling factors, i.e. where the injection signal was seen in the sensor and in DARM. TRIANGLES represent upper limit coupling factors, i.e. where a signal was not seen in DARM.

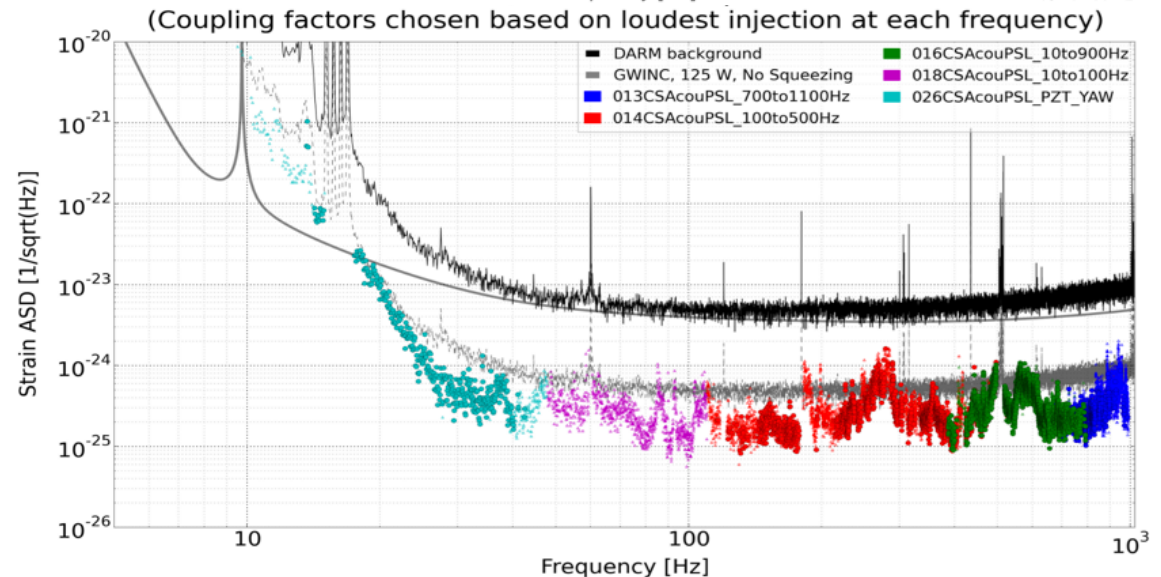
# Compared to LLO

LHO now



LLO, May 2019

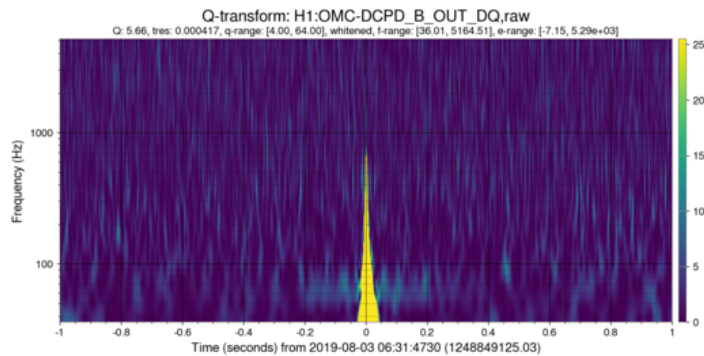
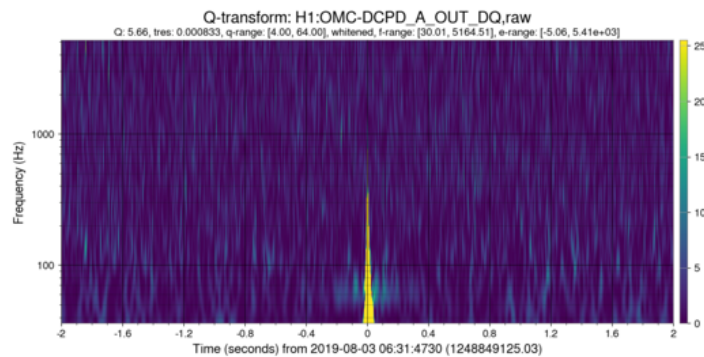
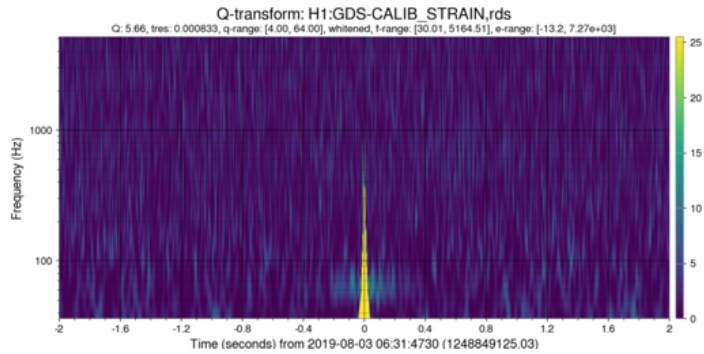
<https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=49521>



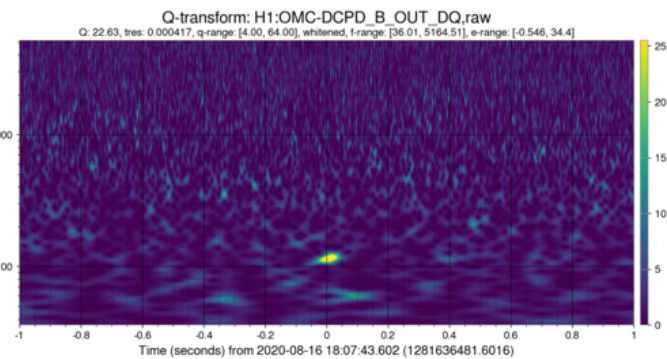
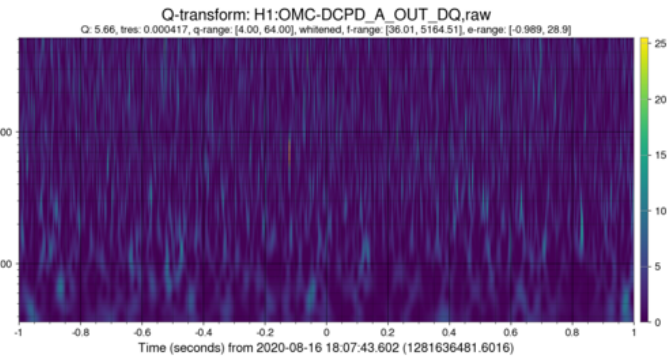
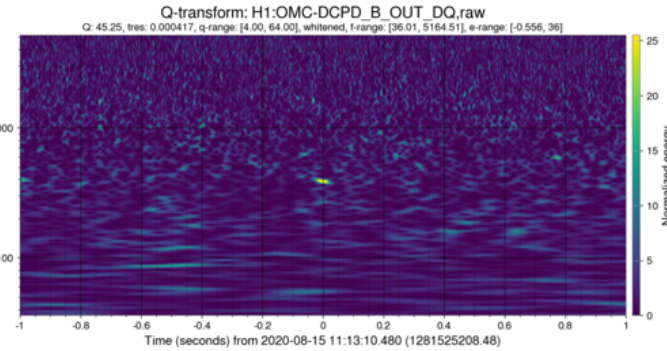
Ambient estimates are made by multiplying coupling factors by injection-free sensor levels. CIRCLES indicate estimates from measured coupling factors, i.e. where the injection signal was seen in the sensor and in DARM. TRIANGLES represent upper limit coupling factors, i.e. where a signal was not seen in DARM.

# Does the O3 DAQ make blip glitches without light ?

## DARM blip glitches



## Glitches with no light



**4-day period  
with IMC off,  
looked for  
glitches  
similar to blips  
in length and  
frequency and  
with SNR >6**

H1 AOS

adrian.helmling-cornell@LIGO.ORG - posted 11:47, Tuesday 13 October 2020 - last comment - 11:14, Monday 19 October 2020(57011)

Blip glitches not seen when DCPDs dark



# Does the O4 DAQ system produce blip glitches?

**EE shop test stand with mainly O4 electronics**

***Similar study did not find blip glitches even when mock DARM signal injected: see Adrian's poster***



# 04 DAQ test stand eliminates many 03 problems, still a couple of problems

a) Much reduced fan and power supply coupling, and no flashing LED lines in channels (<https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=57983>)

b) In-band drifting lines from beating 50 MHz ADC board clocks

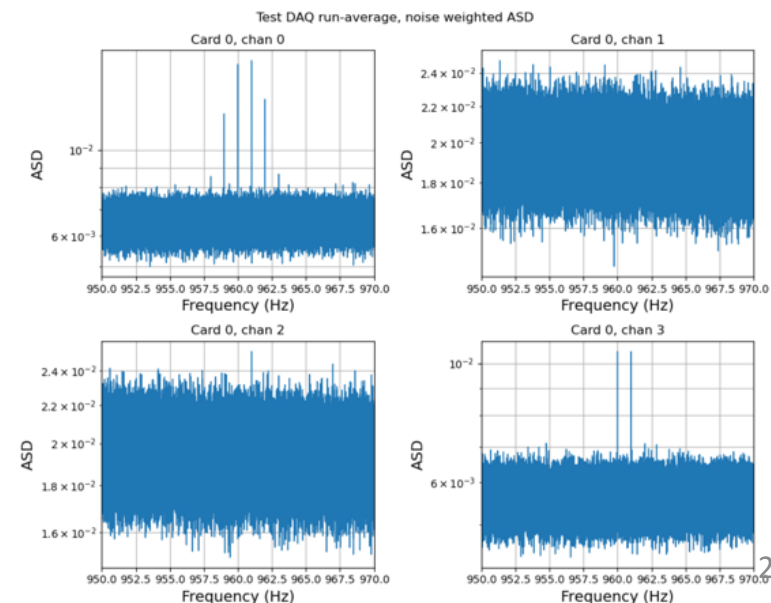
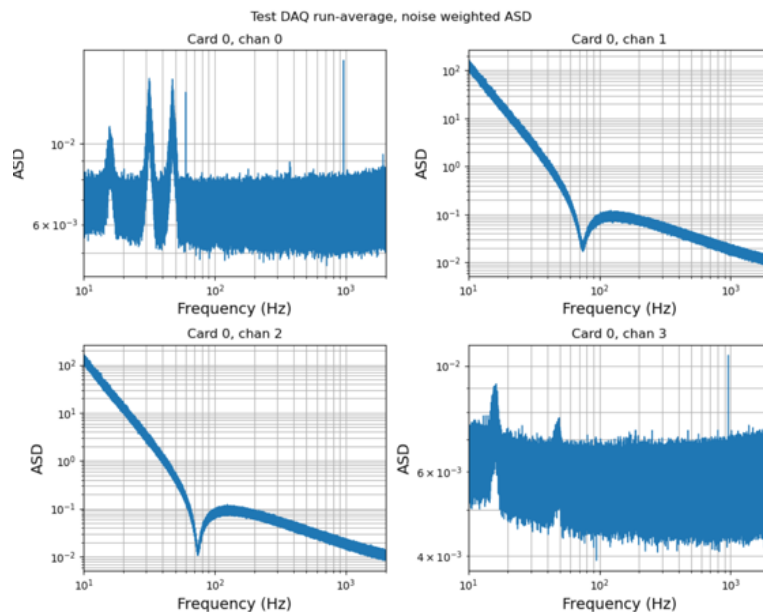
(<https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=58313>)

Mitigation of clock lines possible by replacing with set-able clocks

(<https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=58635>)

c) Evan: a couple of line features, including DuoTone, but mostly clean

(<https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=58786>)





Photographed while at full sensitivity, lit by scattered infrared beam.

cryo-baffle

P-cal periscope

arm cavity baffle  
(ACB)

ETMY test  
mass

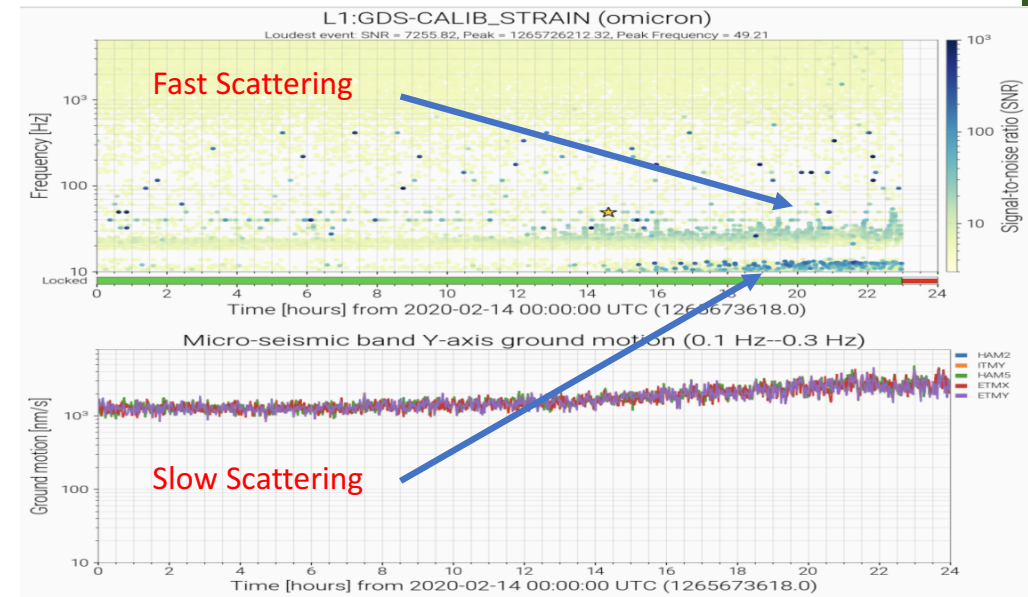
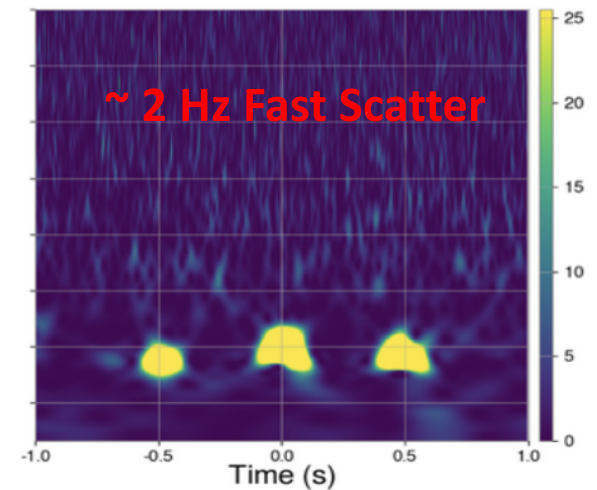
annular reaction mass  
with electrostatic drive  
traces (concentric lines)

transmission monitor  
(TMS)

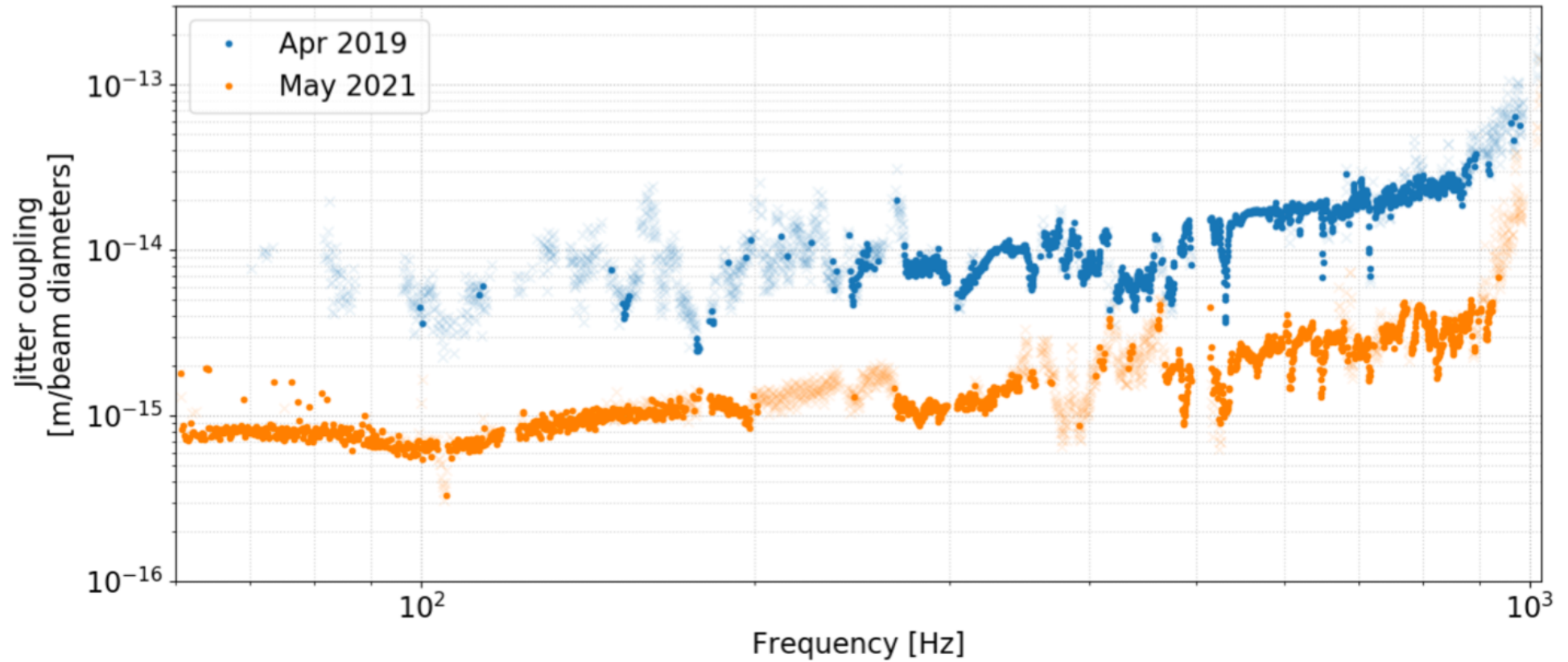


# 2Hz scattering also, but may be cryo-baffle excited by 2 Hz shaking at end station

- Correlates with ground motion in the microseism band
- Dominant type of scatter on Feb 6, Feb 14, Feb 21 at LLO
- [Hveto](#) correlations with L1:SUS-ITMX\_L3\_OPLVEV channels
- On some days with very high microseism both 2 Hz Fast Scatter and Slow Scattering noise appears in h(t)
- Noise observed in Post O3 data as well
- See also [G2001639](#)



# ITMY replacement reduced LHO jitter coupling ~10X !



Philippe's analysis