Fast scattering noise at LIGO and DetChar Noise sprint

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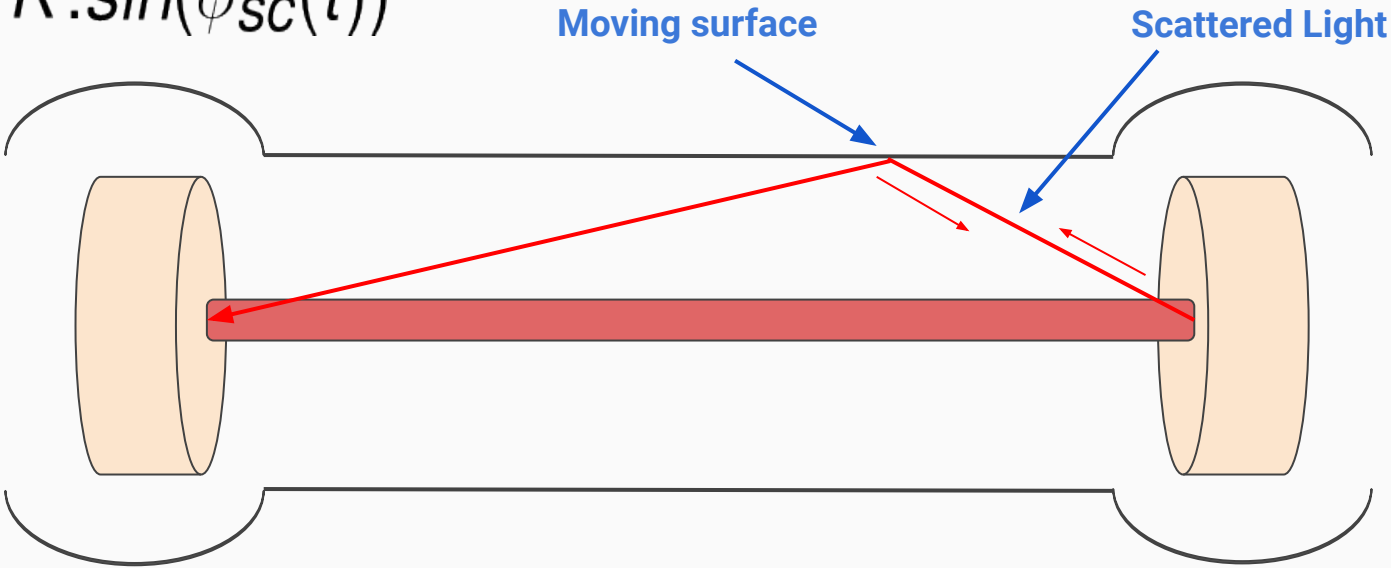
LVK Meeting Sept 2020

Light scattering

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

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

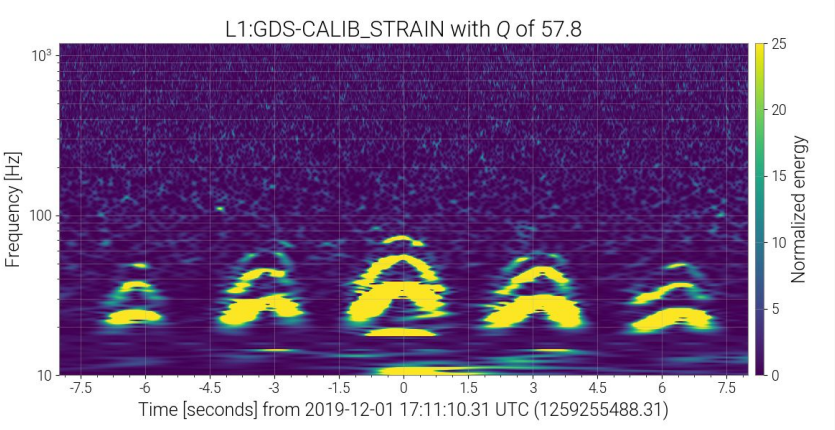
$$h_{sc} = K.sin(\phi_{sc}(t))$$

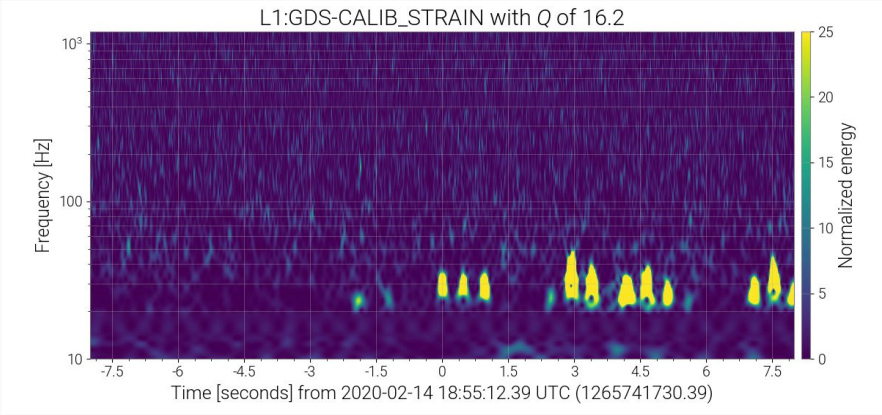


David J Ottaway, Peter Fritschel, and Samuel J. Waldman

T Accadia et al

Slow scattering and Fast Scattering in O3.





Slow scattering (~0.2 Hz)

- Two different couplings of Slow scattering
- ETM-AERM relative motion and ETM-TMS relative motion
- RC tracking in Jan 2020 reduced the rate considerably

Scattering paper [arXiv]

Fast scattering (~ 1 - 4 Hz)

- Multiple couplings is a possibility
- Different frequency and glitch morphology than slow scattering
- Lot more frequent at LLO than at LHO

Most frequent disturbances in O3b

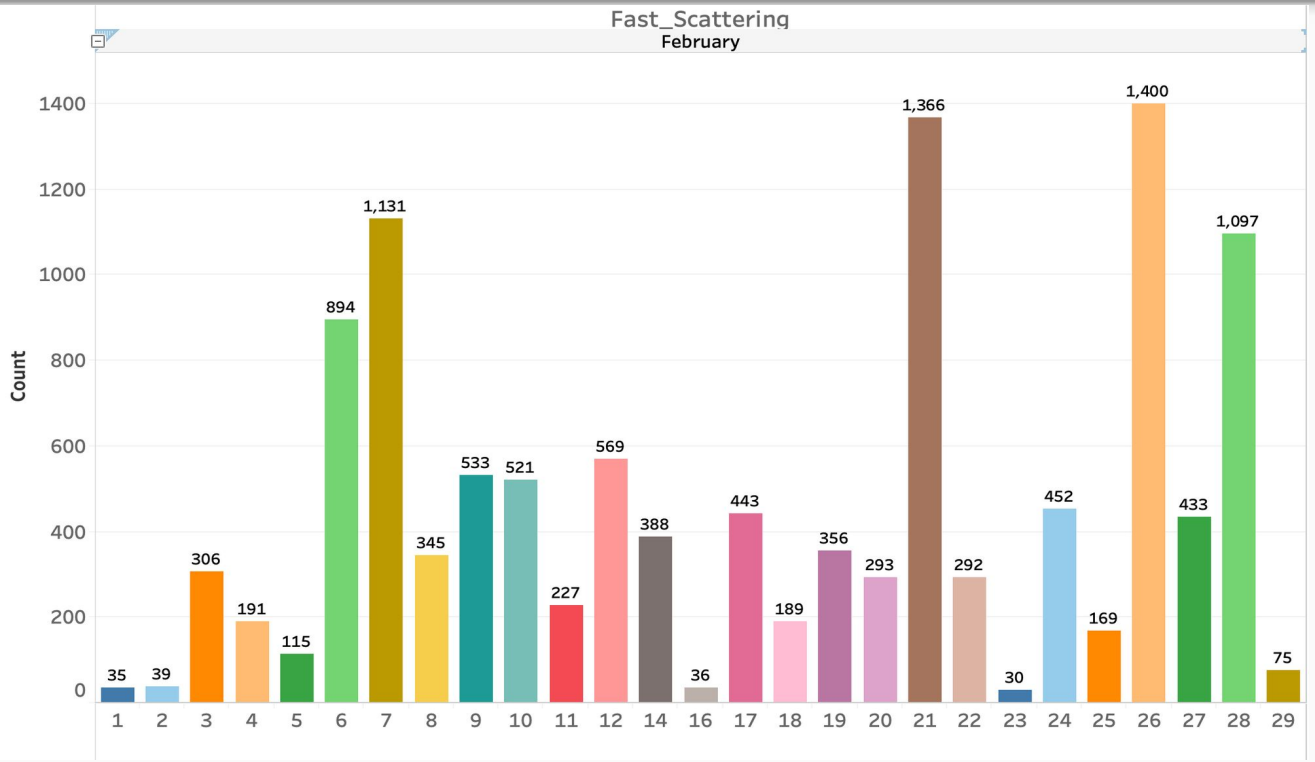
Glitch	Count	Percent
Scattered_Light	44682	32.4%
Fast_Scattering	36918	26.8%
Tomte	22361	16.2%
Blip_Low_Frequency	8728	6.3%
Whistle	5381	3.9%
Extremely_Loud	3461	2.5%
Low_Frequency_Lines	3190	2.3%
Koi_Fish	3010	2.2%
Low_Frequency_Burst	2918	2.1%
Blip	2564	1.9%

LLO O3b

Glitch	Count	Percent
Scattered_Light	58739	71.4%
Extremely_Loud	5604	6.8%
Koi_Fish	3710	4.5%
Blip	3410	4.1%
Blip_Low_Frequency	1928	2.3%
Low_Frequency_Burst	1885	2.3%
Tomte	1357	1.6%
Fast_Scattering	1304	1.6%
Whistle	1258	1.5%
Low_Frequency_Lines	1018	1.2%

LHO O3b

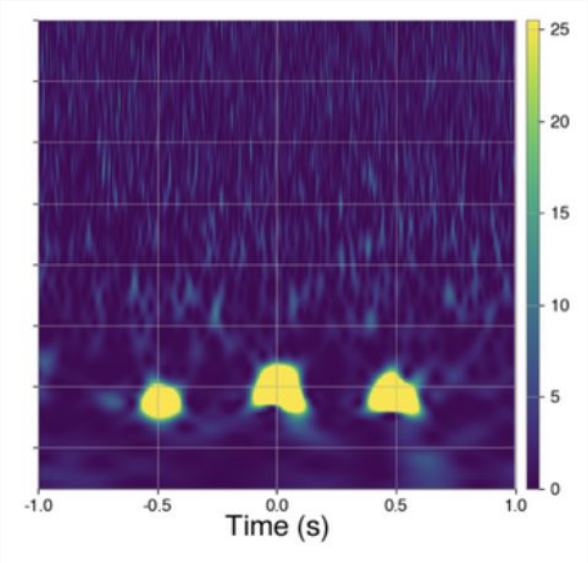
Identifying Fast scattering

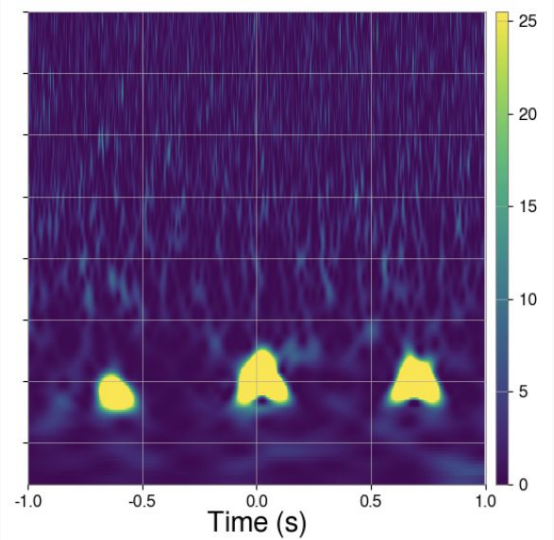


- GravitySpy ML algorithm for noise classification
- Re-trained GravitySpy to recognize Fast_Scattering
- In O3 at LLO, Feb 2020 has highest number (~12000) of Fast scattering triggers

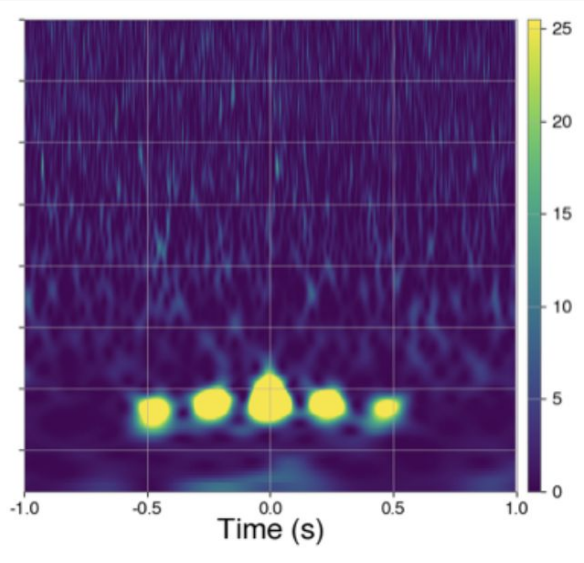
Fast scattering triggers in Feb 2020 at LLO, identified by GravitySpy with confidence above 0.9

Types of Fast scatter





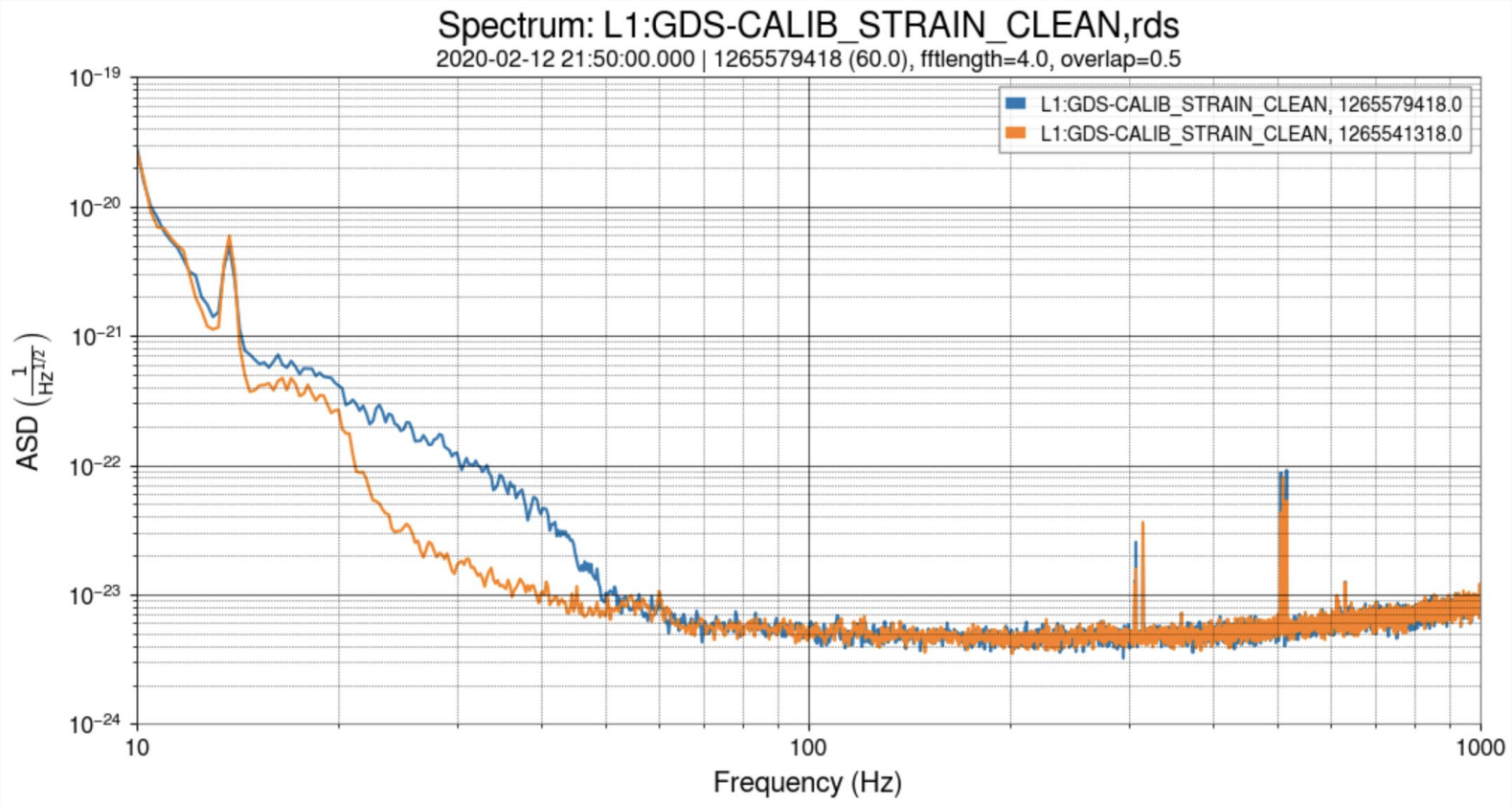
Non 4 Hz fast scatter



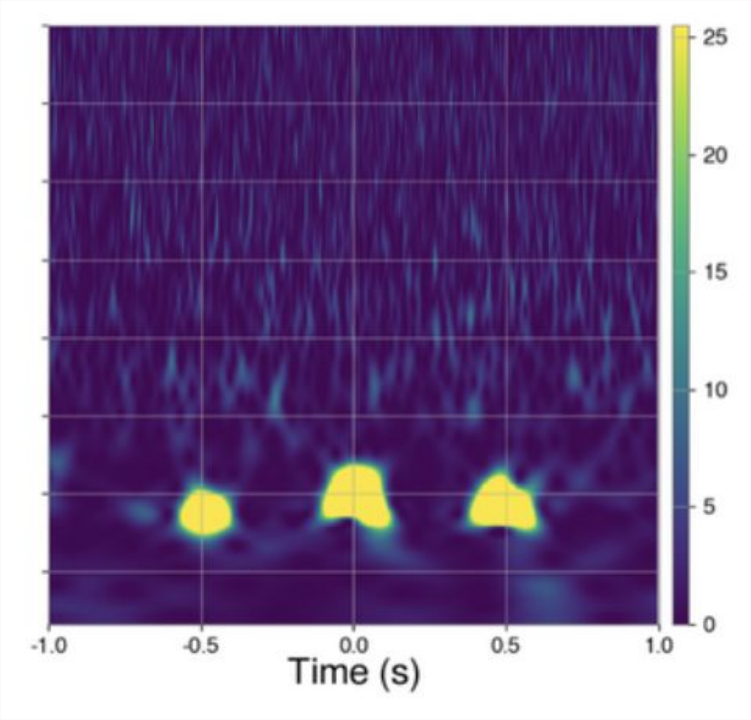
4 Hz fast scatter

alog 53263

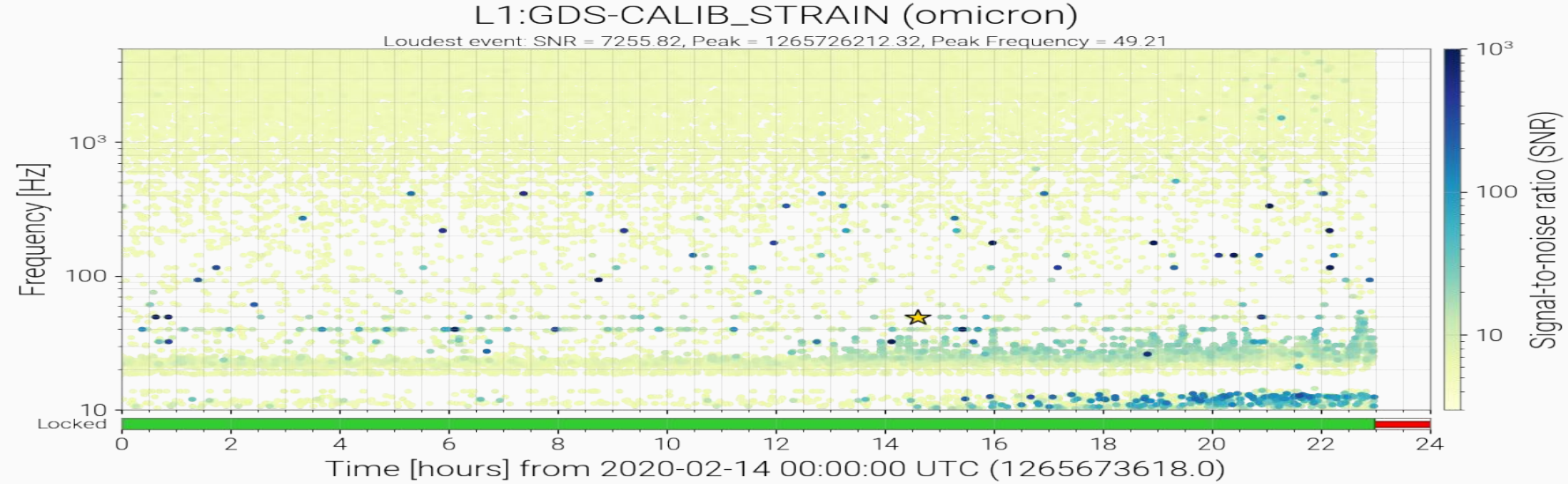
Scatter shelf

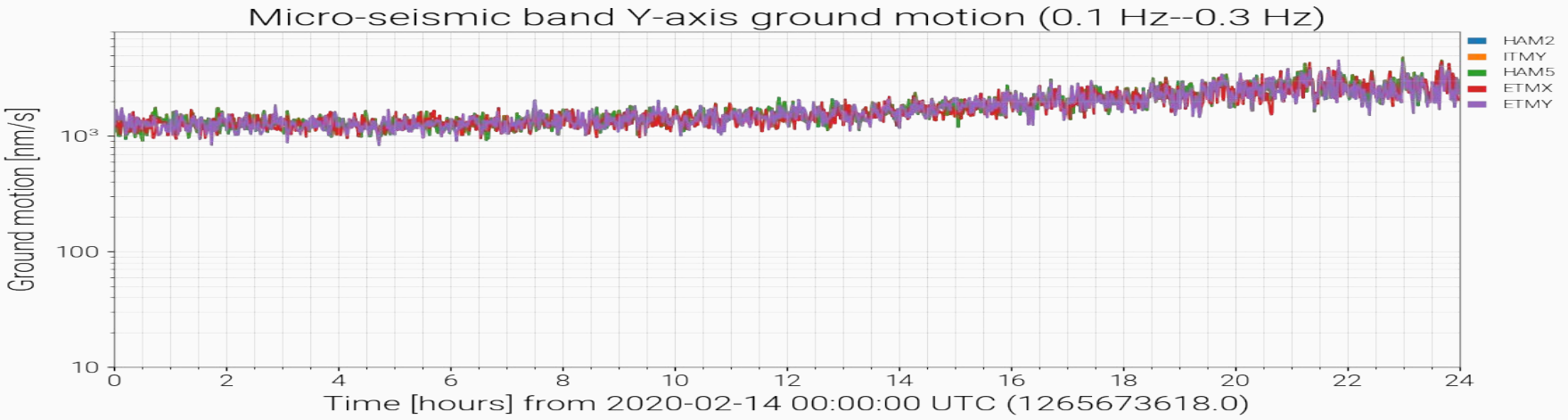


Non 4 Hz fast scatter

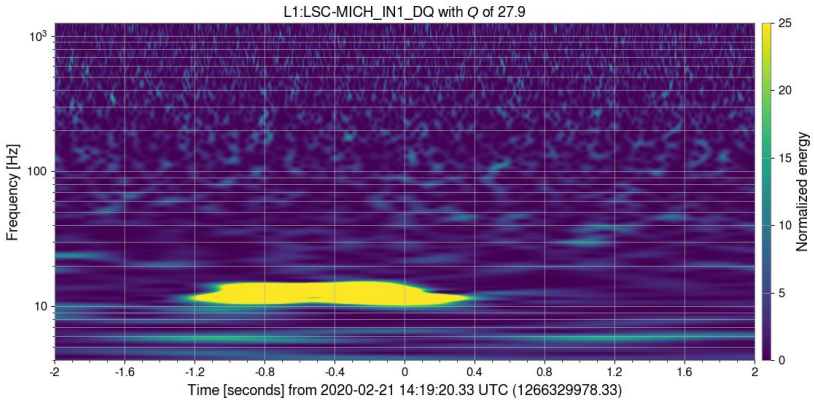


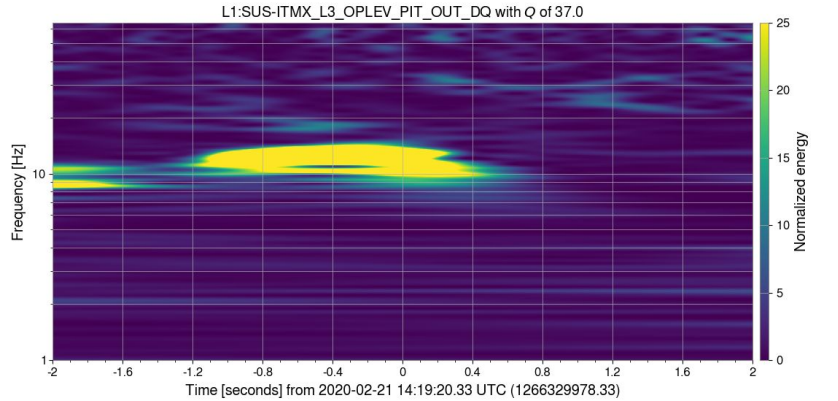
- Correlates with ground motion in the microseism band
- Dominant type of scatter on Feb 6, Feb 14, Feb 21 at LLO
- Corner station coupling?
- Hveto correlations with L1:SUS-ITMX_L3_OPLVEV channels


L1:GDS-CALIB_STRAIN (omicron)
Loudest event: SNR = 7255.82, Peak = 1265726212.32, Peak Frequency = 49.21
Frequency [Hz]
Signal-to-noise ratio (SNR)
Locked
Time [hours] from 2020-02-14 00:00:00 UTC (1265673618.0)

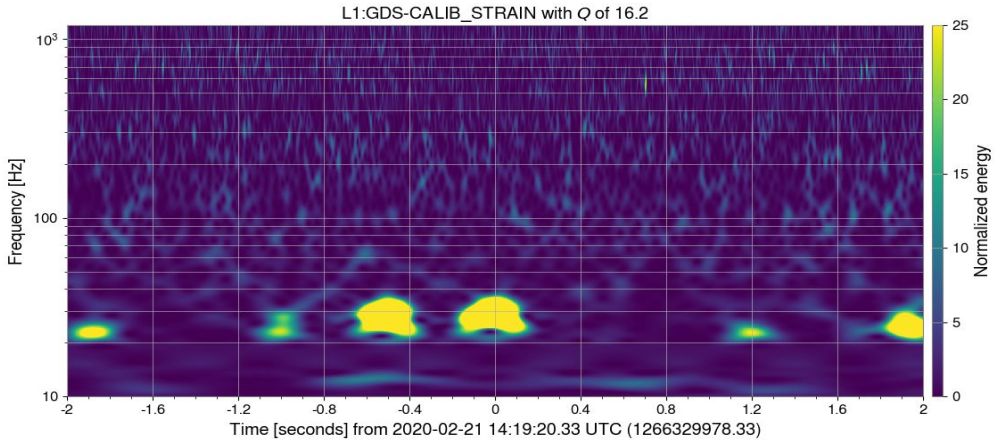

Micro-seismic band Y-axis ground motion (0.1 Hz--0.3 Hz)
Ground motion [nm/s]
HAM2
ITMY
HAM5
ETMX
ETMY
Time [hours] from 2020-02-14 00:00:00 UTC (1265673618.0)

Long duration arches in auxiliary channels



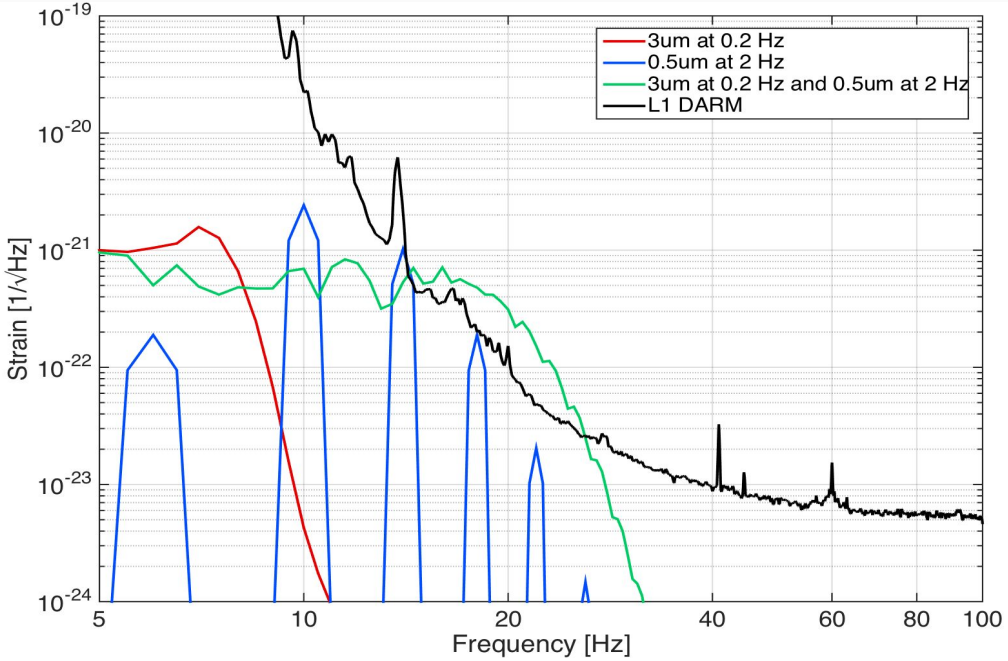


[Omega scans]

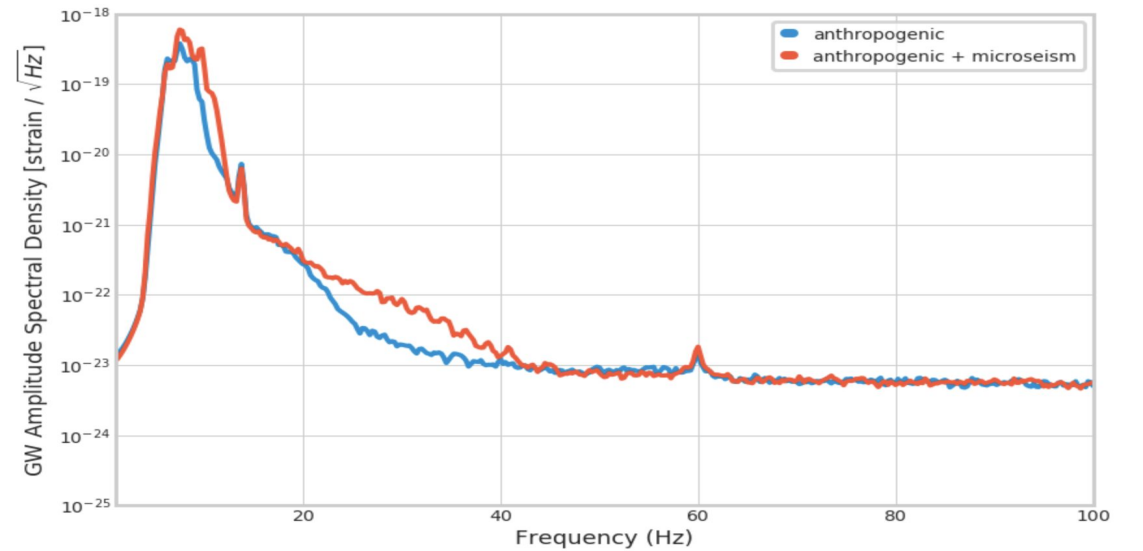


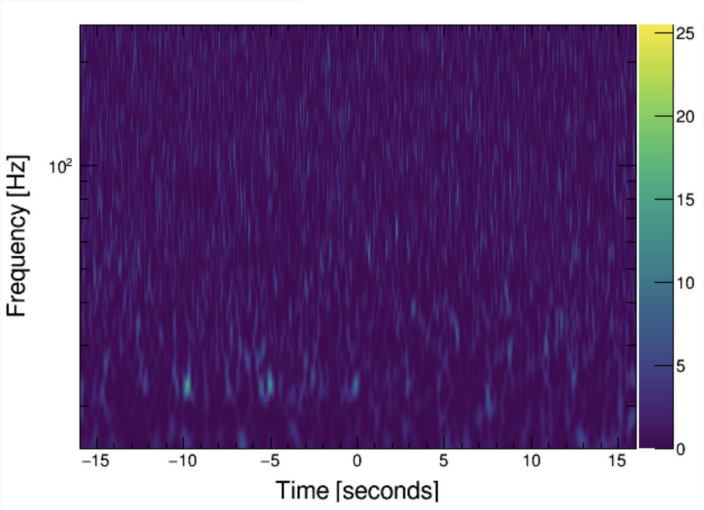
We observe long duration arches in some LSC and ITMX channels with fast scatter in DARM around the same time. More investigation required to understand the possible connection.

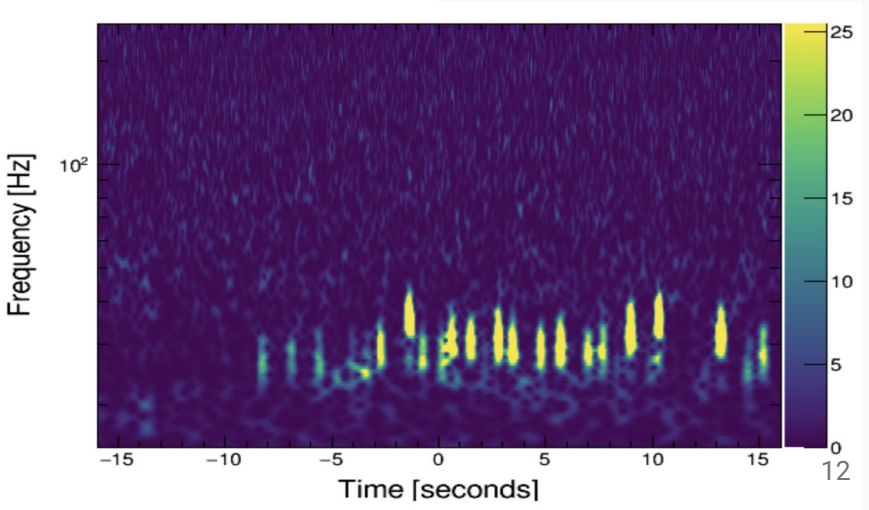
Microseism + anthropogenic for non 4 Hz



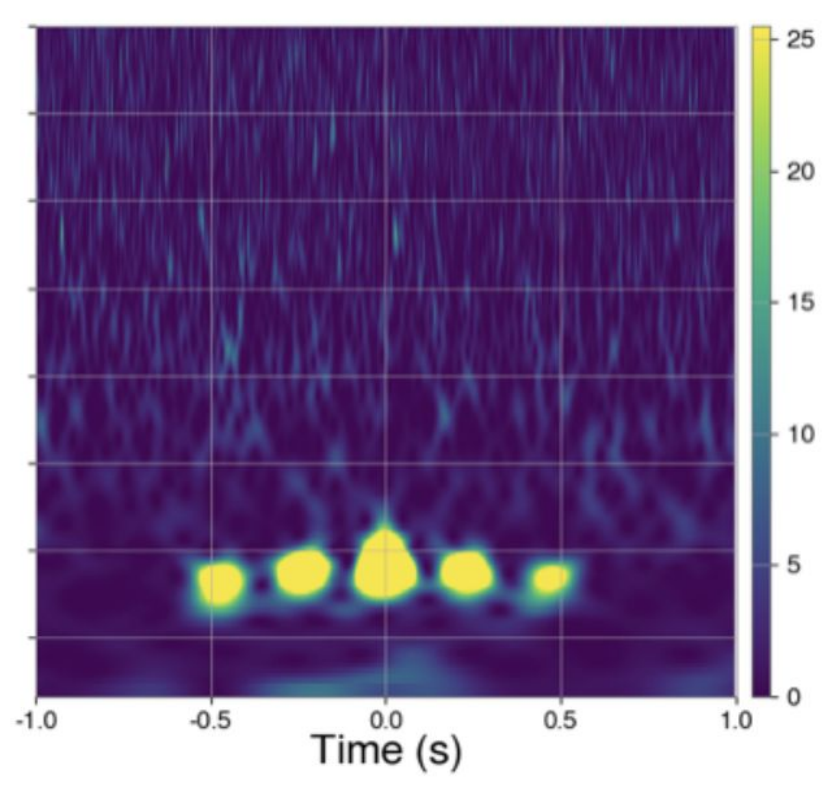
- 2 Hz Q low (needs useism)
- 4 Hz Q high (fringes with or without useism)
- Normal motion is ~10nm at 2 Hz but can be amplified by anthropogenic and resonances


anthropogenic
anthropogenic + microseism
GW Amplitude Spectral Density [strain / √Hz]
Frequency (Hz)


Frequency [Hz]
Time [seconds]

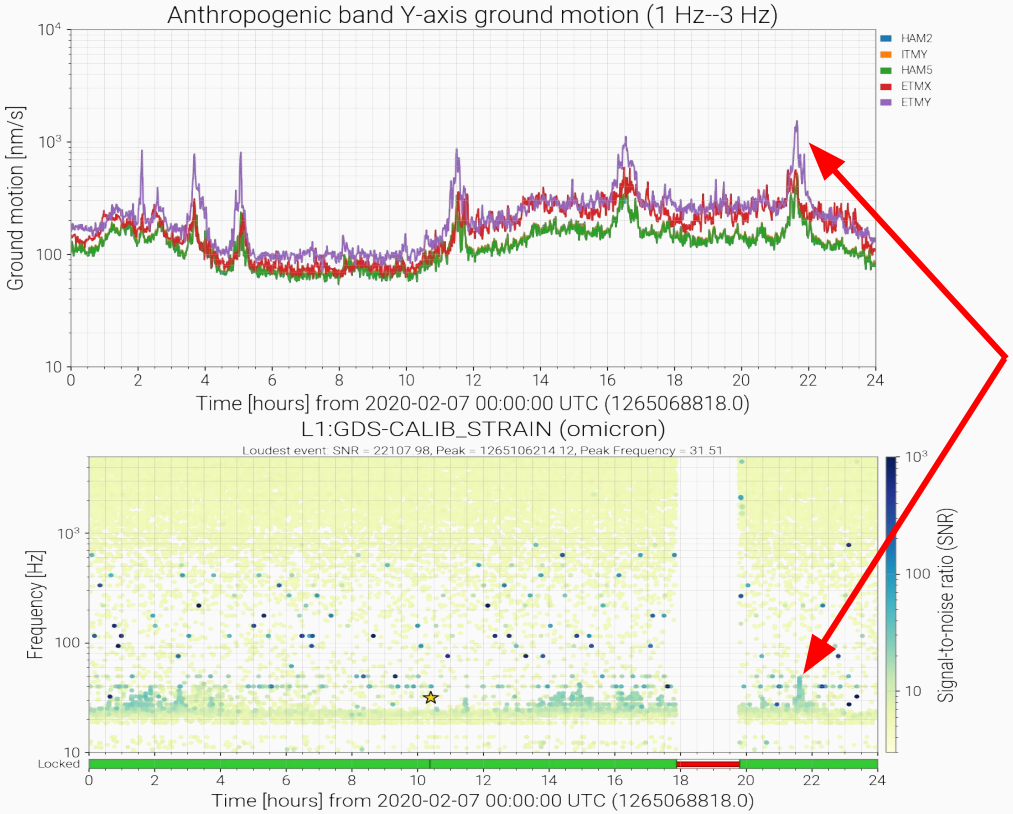

Frequency [Hz]
Time [seconds]

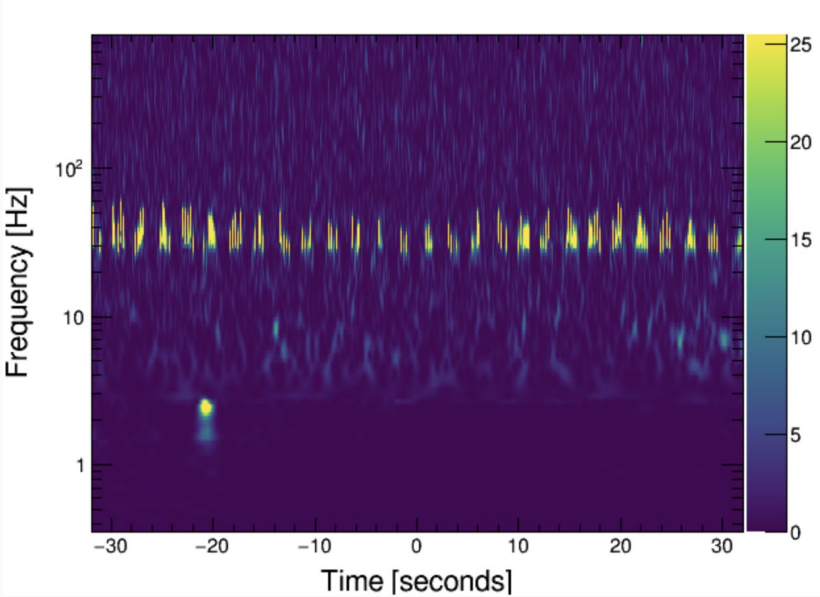
4 Hz fast scatter



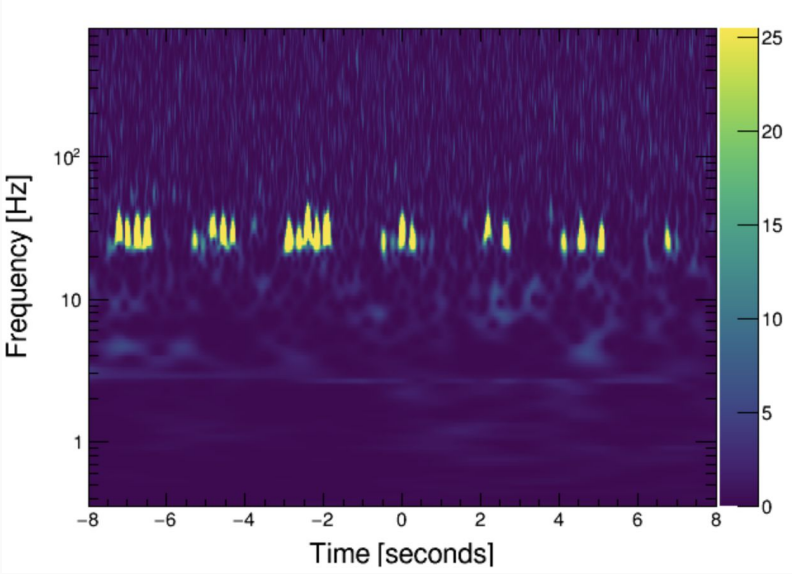
- Correlates with motion in anthropogenic band (1 - 3 Hz) and 3 - 10 Hz band
- Does not require high microseism
- Trains near the Y end at LLO, thunderstorms near the site, delivery trucks shake the ground
- Higher shelf frequency than non 4 Hz scatter
- Possible couplings from corner and end stations

Trains

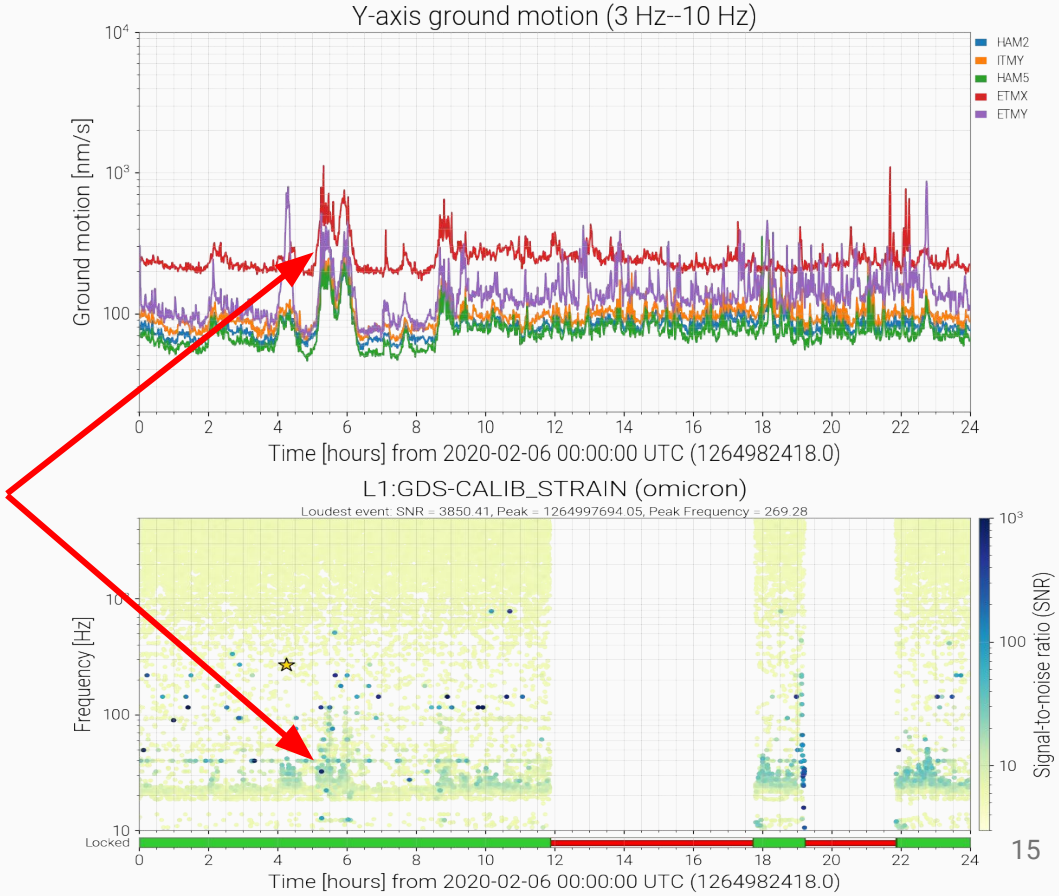

Anthropogenic band Y-axis ground motion (1 Hz--3 Hz)
Ground motion [nm/s]
HAM2
ITMY
HAM5
ETMX
ETMY
Time [hours] from 2020-02-07 00:00:00 UTC (1265068818.0)
L1:GDS-CALIB_STRAIN (omicron)
Loudest event: SNR = 22107.98, Peak = 1265106214.12, Peak Frequency = 31.51
Frequency [Hz]
Signal-to-noise ratio (SNR)
Locked
Time [hours] from 2020-02-07 00:00:00 UTC (1265068818.0)


Frequency [Hz]
Time [seconds]

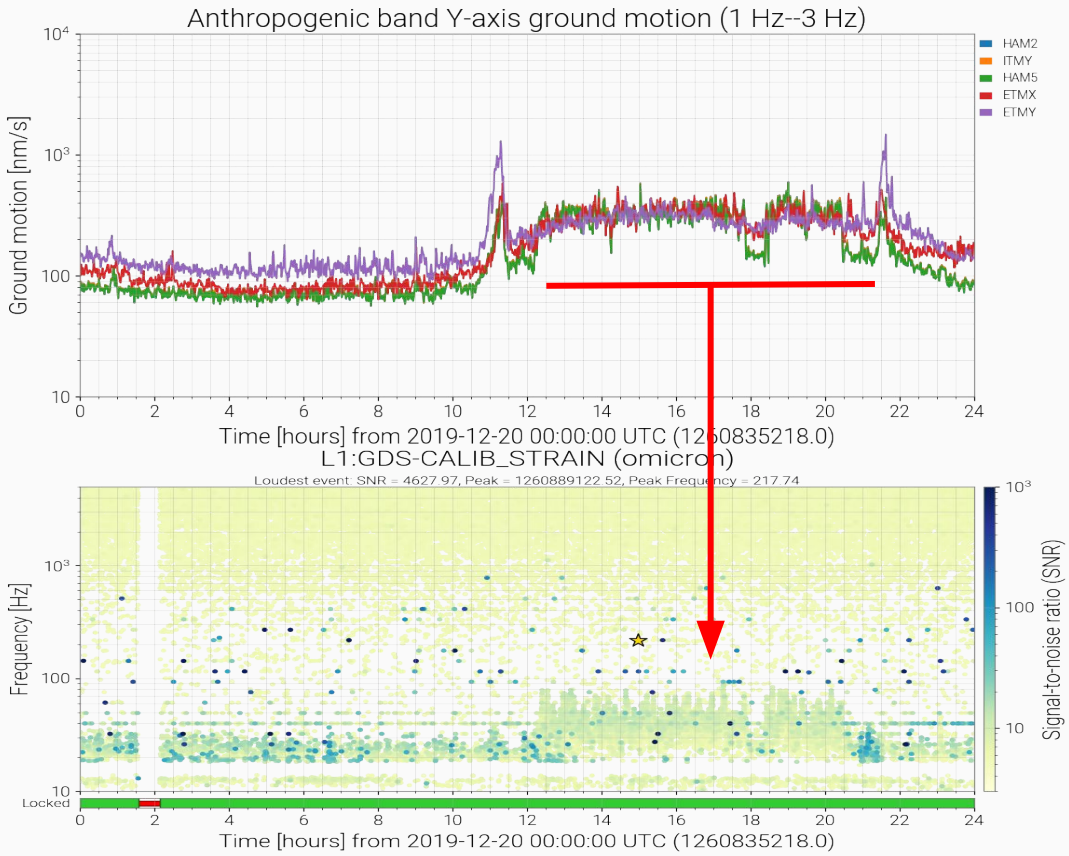
Thunderstorms



Very heavy rain and thunderstorms alog 51489

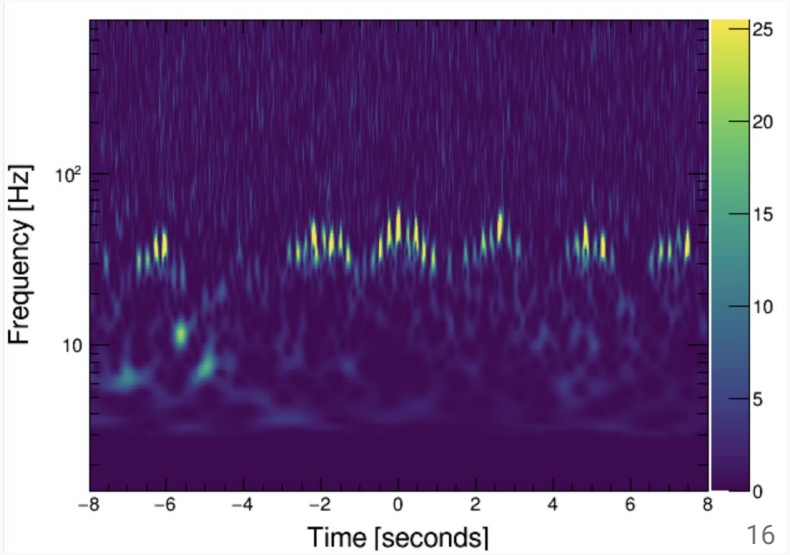


Or just really high anthropogenic



GravitySpy identified 1386 fast scattering triggers between 12:00 and 21:00 UTC!

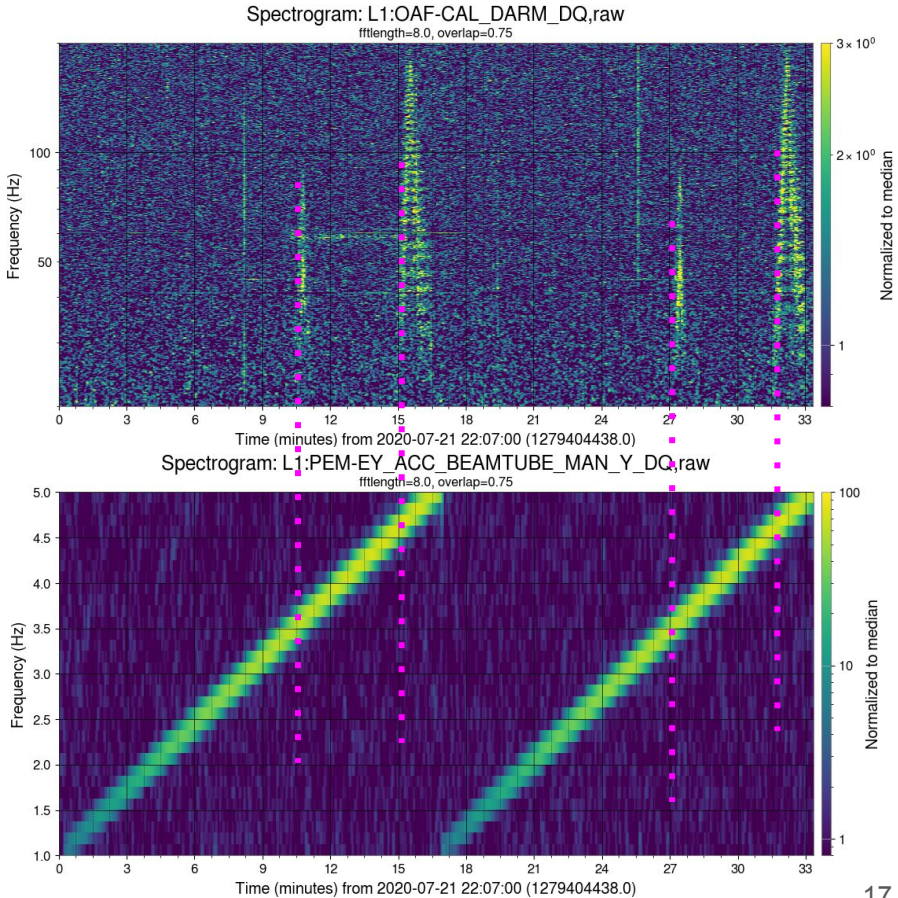
Logging near X end alog [50583]



Cryo Baffle Resonances

EY has 3.49 and 4.62 Hz, Q~140, 440

EX has 4.10 Hz, Q~2000
Corner (ITMY) has 3.825 and 4.191, Q~ 70, 2000



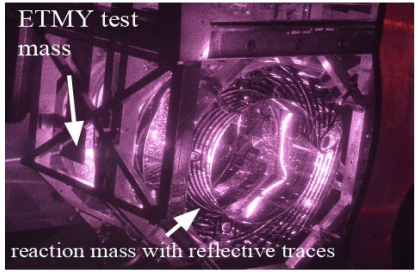
During the EY vent at L1, we plan to damp the cryo baffle, and retest.
If successful, propagate to all stations including H1

alogs: 53364, 53025, 53057, 53062, 53077, 53131, 53166, 53185, 53191, 53257, 53271, 53327, 53309

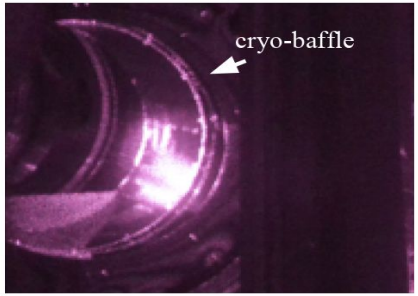
Preparing for O4

Mitigating O3b scattering noise for O4

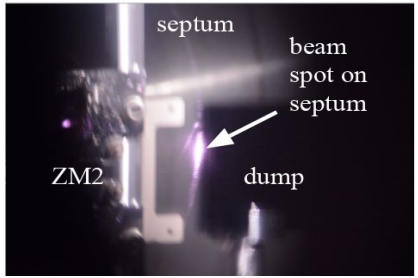
1) Noise mainly associated with microseismic peak motion: ***greatly mitigated during O3b by moving reaction mass with test mass (R0 tracking).***



2) Noise mainly associated with >1 Hz motion at Y-ends, anthropogenic and wind: ***cryo-baffle damping being tested.***



3) Noise mainly associated with >1 Hz motion in HAM5,6 region: ***HAM5-6 septum baffling planned. This may be the least certain mitigation.***



alogs 56508, 55927, 54556

Noise Sprint
Aug 2020

Siddharth Soni
Guillermo Valdes
Brennan Hughey
Derek Davis
Jess McIver
Laura Nuttall
and many others

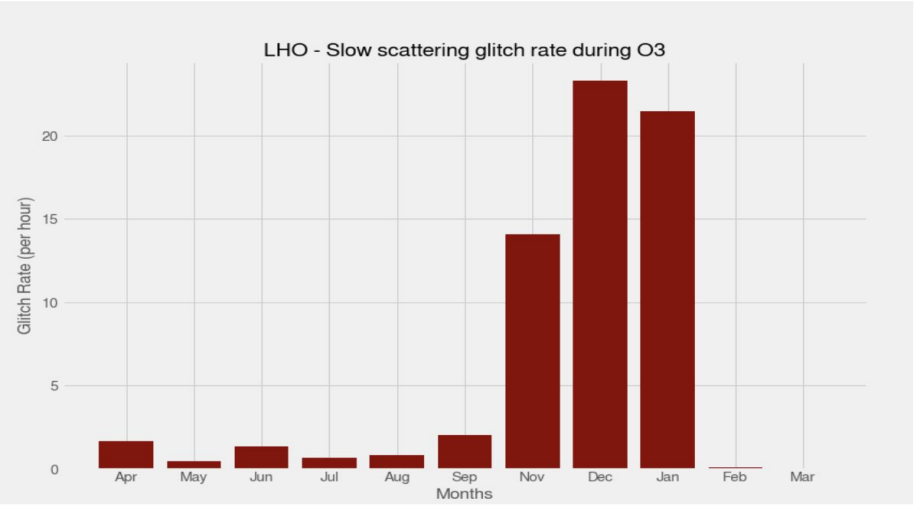
Detchar Noise sprint

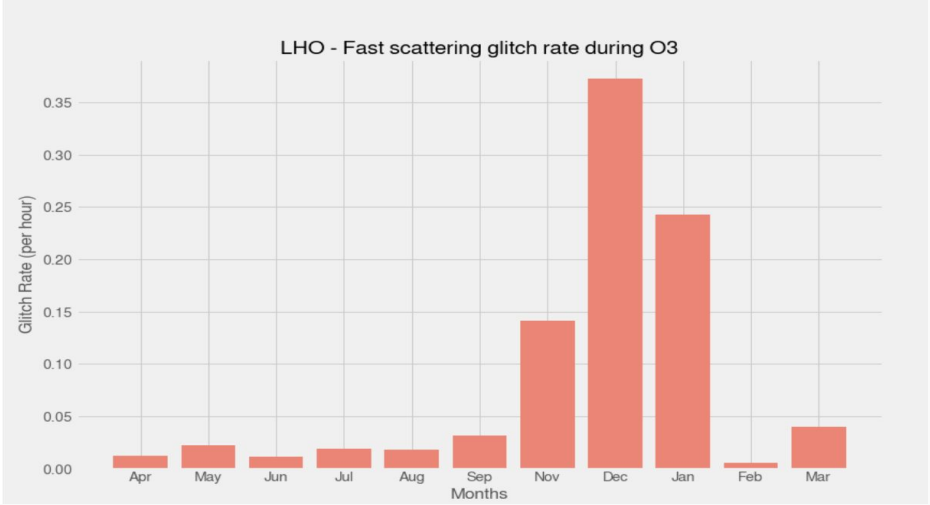
- 3 day event at the end of Detchar f2f meeting
- Current issues in the detector, talk to commissioners
- Junior and Senior LIGO scientist get together for noise hunting
- Participants are divided into multiple teams
- Present the work in Detchar telecons, alog, continue the project
- A great learning experience for the new members

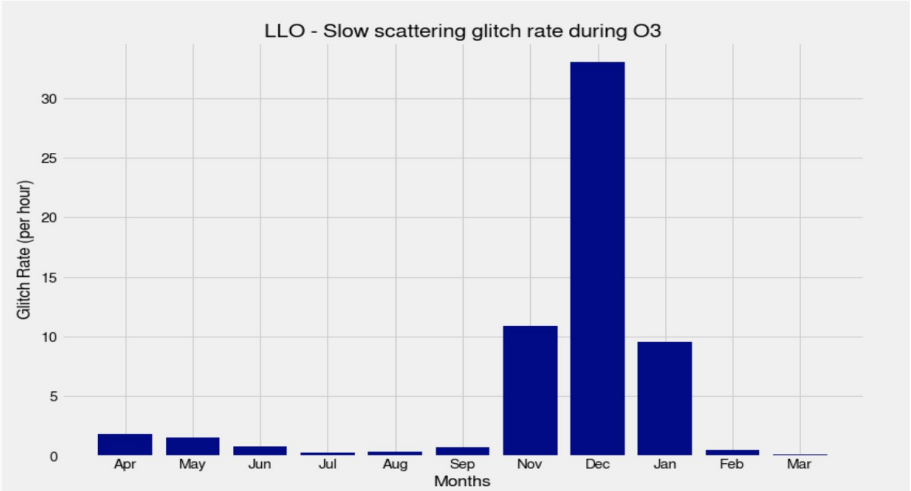
Slow and fast scattering trigger rate in O3 ~ Katie, Ashley, Sidd

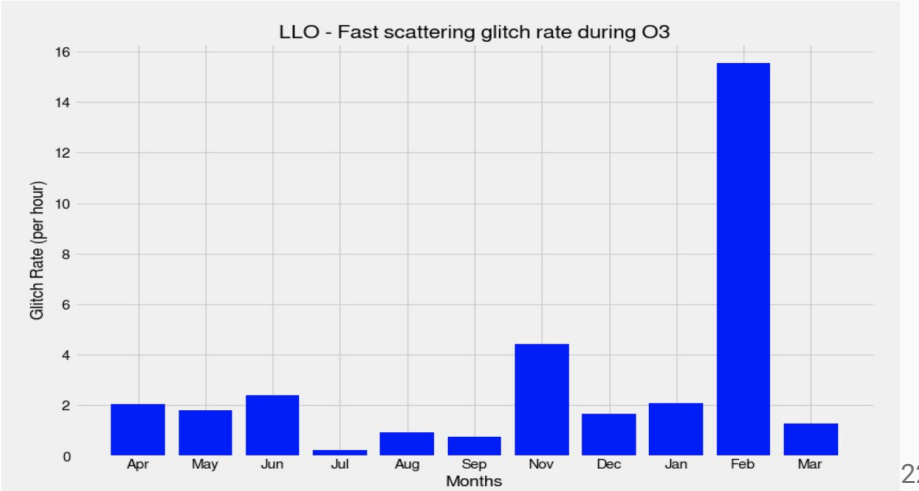
- How do the rates of slow and fast scattering compare with each other?
- How different are these rates for LLO and LHO?
- alog 53678

- Data : GravitySpy with SNR > 10 and confidence > 0.9
- Observing duration for each month
- Plot the per hour rate for each month in O3 at LLO and LHO

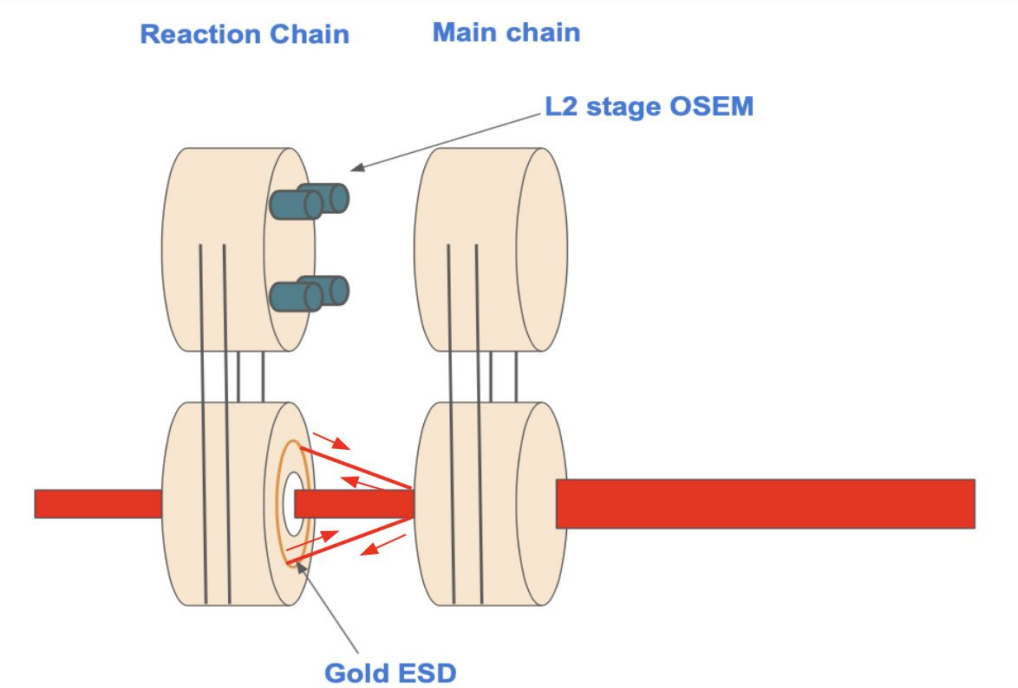

LHO - Slow scattering glitch rate during O3
Glitch Rate (per hour)
0
5
10
15
20
Apr
May
Jun
Jul
Aug
Sep
Nov
Dec
Jan
Feb
Mar
Months


LHO - Fast scattering glitch rate during O3
Glitch Rate (per hour)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Apr
May
Jun
Jul
Aug
Sep
Nov
Dec
Jan
Feb
Mar
Months


LLO - Slow scattering glitch rate during O3
Glitch Rate (per hour)
0
5
10
15
20
25
30
Apr
May
Jun
Jul
Aug
Sep
Nov
Dec
Jan
Feb
Mar
Months


LLO - Fast scattering glitch rate during O3
Glitch Rate (per hour)
0
2
4
6
8
10
12
14
16
Apr
May
Jun
Jul
Aug
Sep
Nov
Dec
Jan
Feb
Mar
Months

ETM-AERM scattering and RC tracking



- DARM control drive applied in between the chains creates relative motion between them
- A fraction of light hits the Gold ESD, reflects back and joins the main beam after ETM transmission
- Scattering arches in h(t)
- Take the motion from L2 stage and feed it to R0 stage. This way the relative motion between the test mass chain and reaction mass chain is reduced.

Reducing scattered light in LIGO's third observing run arXiv

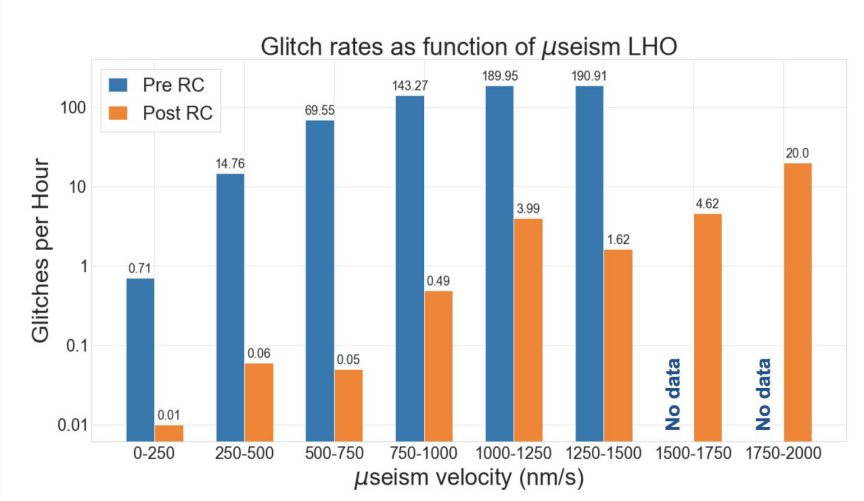
alogs 54298, 50851

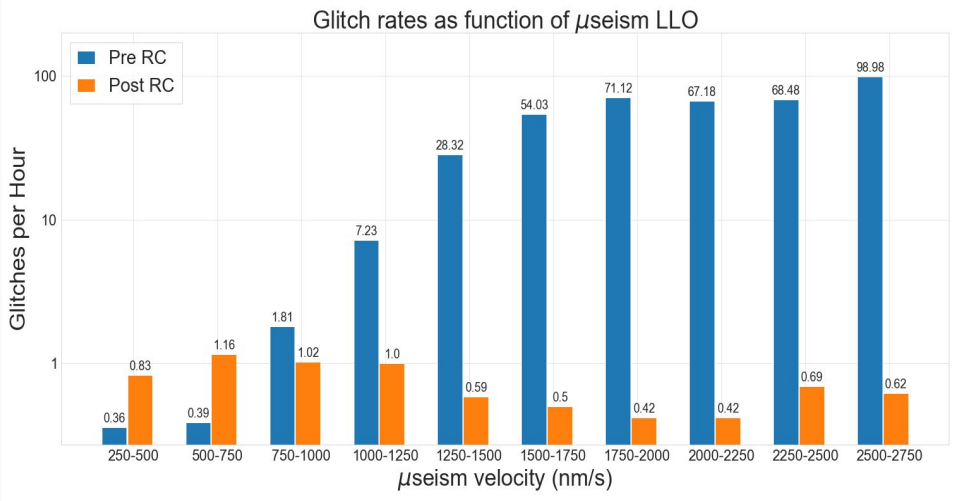
Pre and Post RC tracking slow scattering ~ Jane, Shania, Sidd

- Measure the impact of RC tracking on the rate of slow scattering
- We did this in Feb, 2020 (alog 51613) but now we have more data
- Rate of slow scattering triggers normalized by ground motion in microseismic band (0.1-0.3 Hz)
- Measure the impact at LLO and LHO

- Used Corey Austin's code to calculate the normalized rate
- Split the data between Pre and Post RC tracking
- Data : GravitySpy with SNR > 10 and confidence > 0.9

Pre and Post RC tracking slow scattering ~ Jane, Shania, Sidd





Clear reduction in the rate of Slow scatter at both the sites following RC tracking alog 53499

Intermittent narrow-band noise investigations

Beverly B. (Stanford), Guillermo V. (LSU), Mouza A. (UMN), Sumeet K. (Mississippi). Shreejit J. (IUCAA), Sang Hoon O. (NIMS), Oli P. (CSUF).

- Noise sprint project.
- Motivation:
  - 38Hz noise generated by an AC unit detached from the ground.
  - 75Hz noise generated by a broken vacuum system equipment.
- alogs:
  - https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=53090
  - https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=51745
  - https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=51361

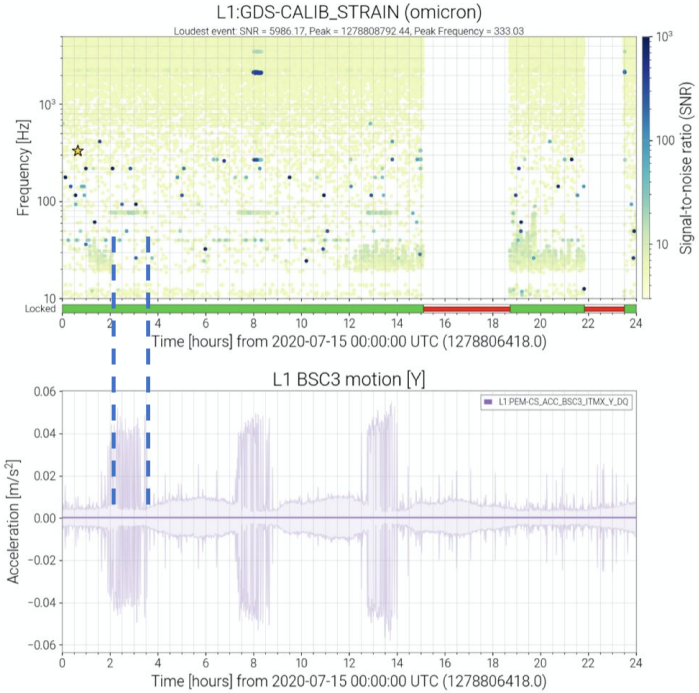
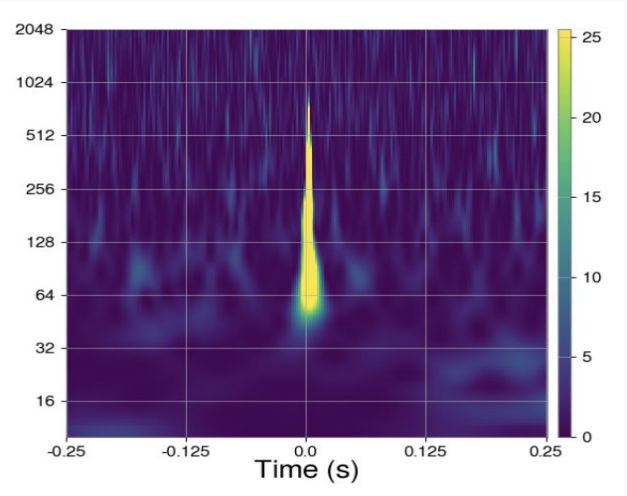


Fig 4. Intermittent narrow-band noise in the GW channel is coincident with periodic elevated ground motion recorded by the accelerometers.

Noise sprint - Burst Breakout Sessions

- Blip glitch investigations (led by Marissa and Brennan)
  - Resurrecting O2 work by Miriam Cabero correlating blips and FEC errors
  - Focused on outlier blips in burst analyses
  - Failed to establish statistically significant correlation between any type of FEC errors and blip-dominated burst backgrounds, but scripting now exist for further follow-up
- Veto evaluation (led by Amber Stuver)
  - Tutorial on VET software used to evaluate effectiveness of offline vetoes
  - Working on automating VET runs on Hveto and other trigger generators

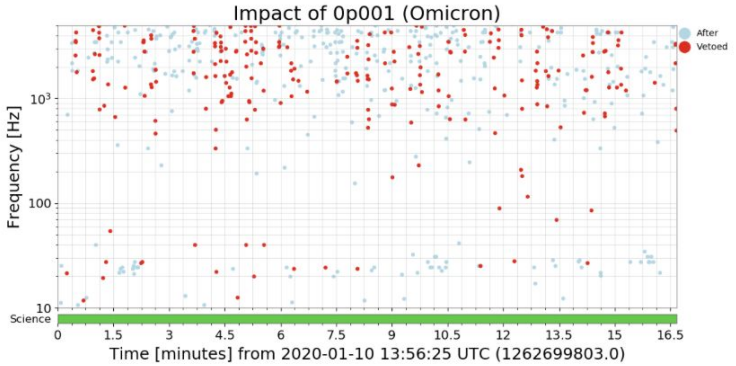


Blip

Noise Sprint - iDQ+PyCBC Breakout Session

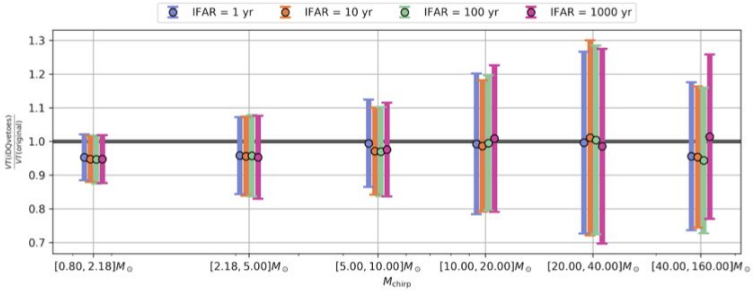
Comparison of CAT2 vetoes and iDQ (Patrick, Derek)

- Compared efficiency and false alarm probability of CAT2 vetoes and iDQ during time with high rate of Whistle glitches
- Found comparable efficiency and deadtime between the two methods



Effect of iDQ veto on PyCBC sensitivity (Max, Tito)

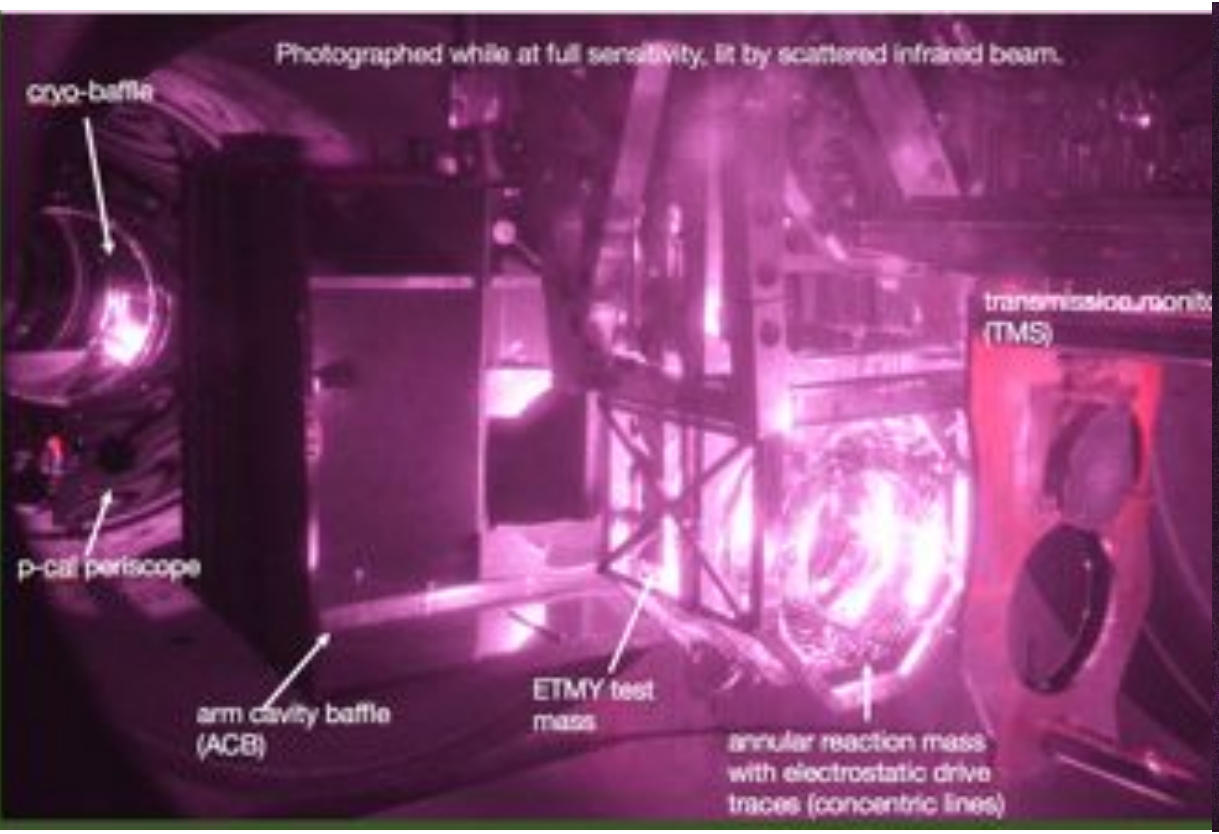
- Created vetoes using segments of low iDQ false alarm probability
- Found that using iDQ as a veto did not significantly increase search sensitivity during periods of whistle glitches



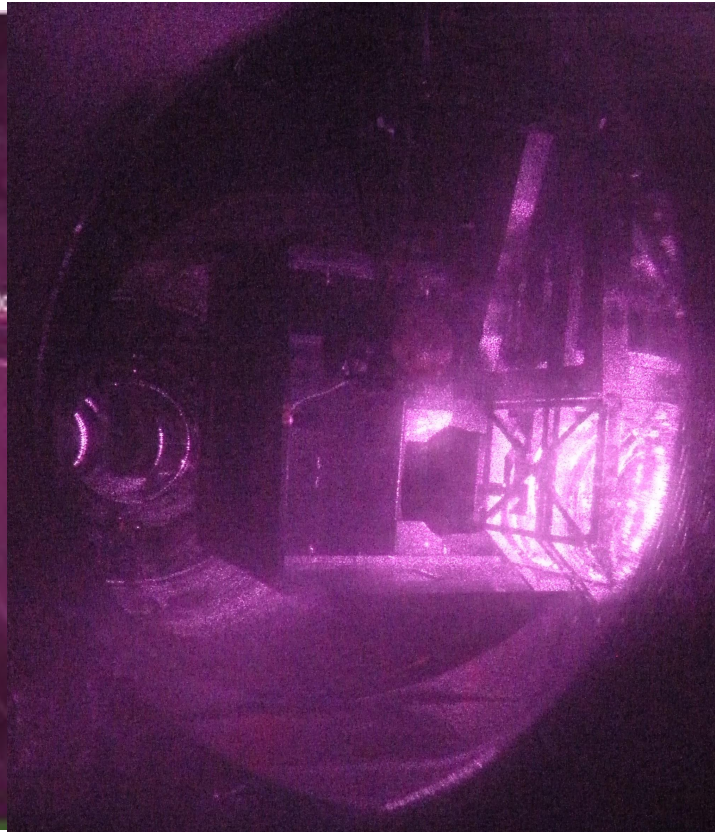
Thank You!
Questions and comments.

Extra slides

H1 EY photo



L1 EY photo



View from beam tube,
showing manifold/cryo baffle aperture

Arm Cavity Baffle, ITM

D1200580, ITMX; D1200578, ITMY

Catches small angle scatter from ETM & wide angle scatter from ITM

Oxidized SS
Aperture: D = 343.9 mm
Mounted on ISI Stage 0

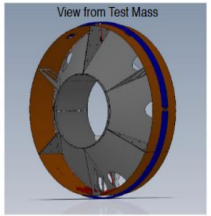
Manifold/Cryopump Baffle, ITM

D0902617

Shields cryopumps from test mass scattered light

Oxidized SS
Center aperture: D = 769 mm

View from Test Mass



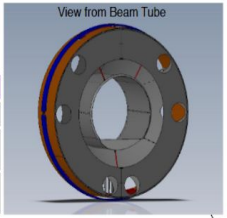
Manifold/Cryopump Baffle, ETM

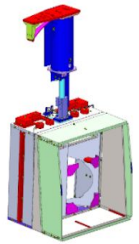
D1003181, ETMX; D1003228, ETMY

Shields cryopumps from test mass scattered light

Oxidized SS
Center aperture: D = 769 mm

View from Beam Tube



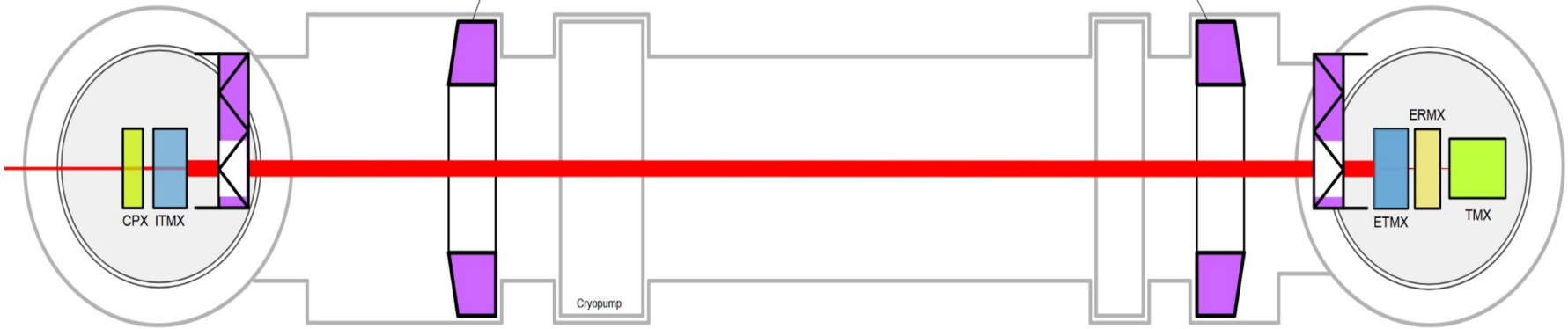


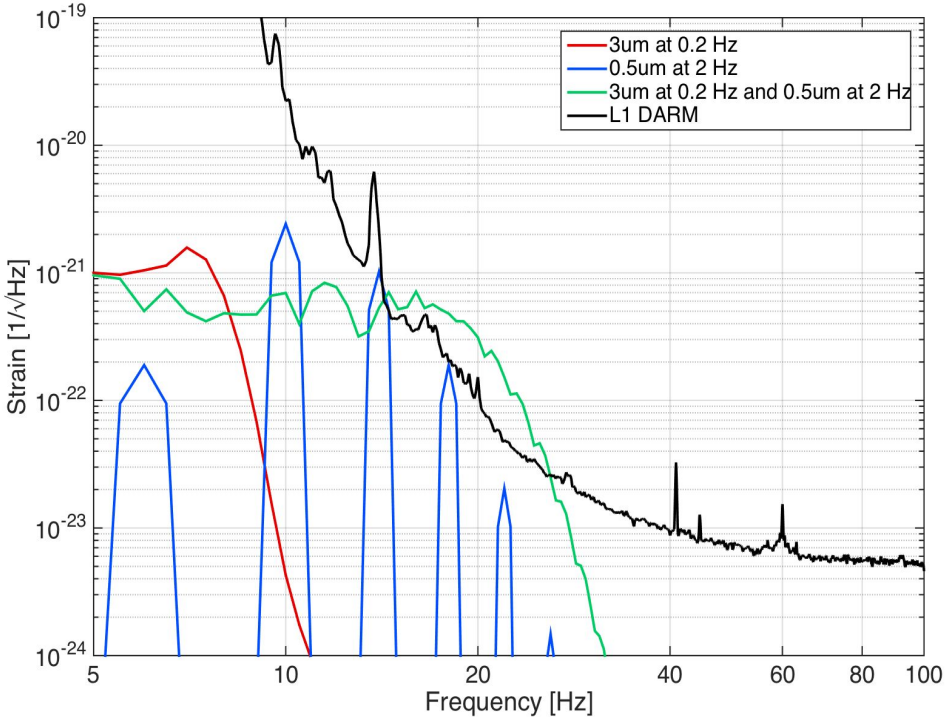
Arm Cavity Baffle, ETM

D1200656, ETMX; D1200653, ETMY

Catches small angle scatter from ITM & wide angle scatter from ETM

Oxidized SS
Aperture: D = 343.9 mm
Mounted on ISI Stage 0





- 2 Hz Q low (needs useism)
- 4 Hz Q high (fringes with or without useism)

Generally: if lots of motion, it can show up by itself in DARM (orange) but if lower, then useism by itself (red) or 2 Hz motion by itself (blue) dont show up but the combination (green) does

Graph is just A * lambda/8*pi*sin(4pi/lambda * motion)

A is chosen to showcase our point, but same for all curves

Frequency of few Hz can be whatever, conclusion is the same, just exact motion thresholds differ

Normal motion is ~10nm at 2 Hz but can be amplified by anthropogenic and resonances