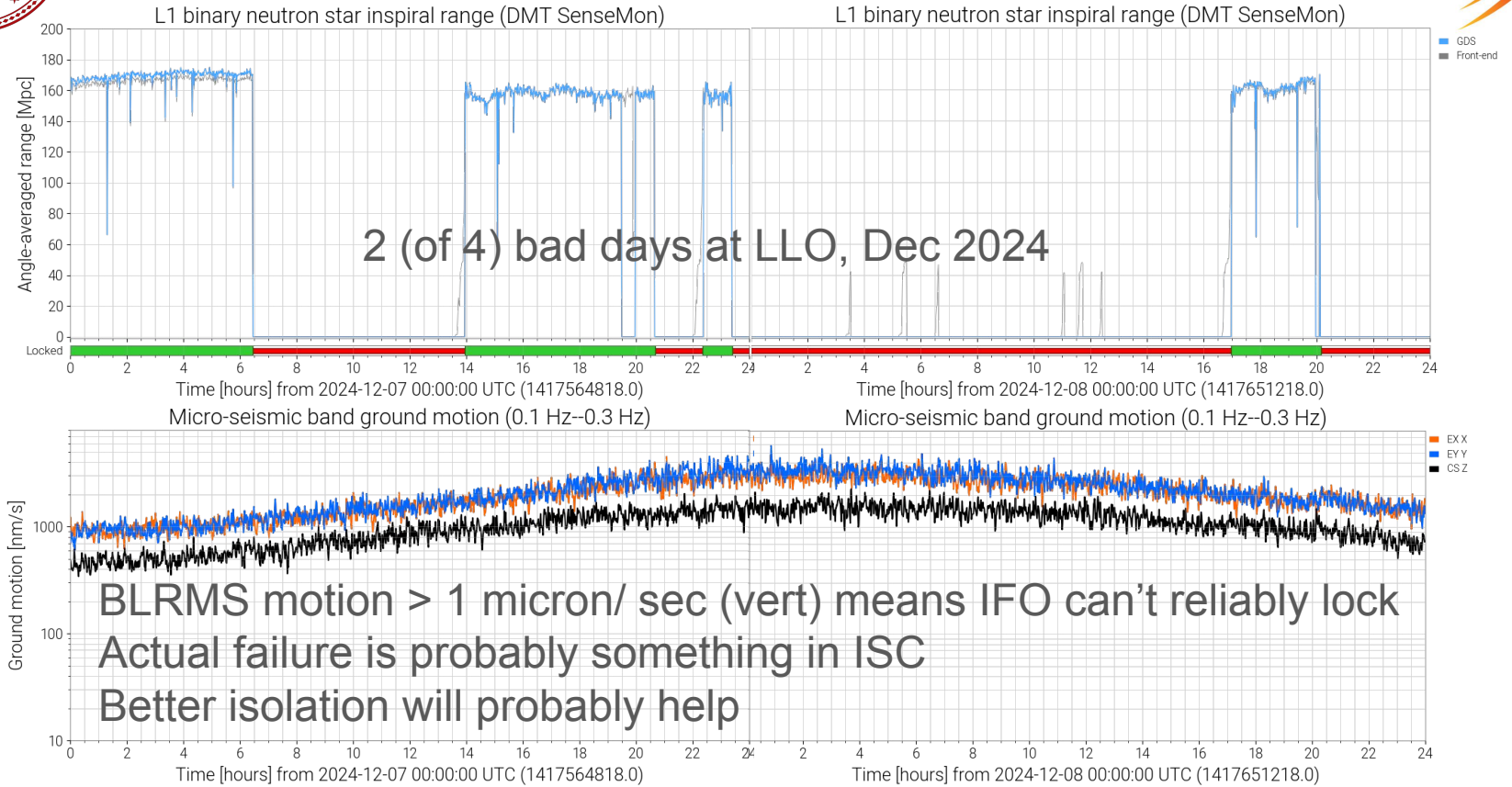
Excess motion of the ISIs: Degrading microseismic performance & Motivating the SPI, CRS, ML4Seismic, and sensors with excellent calibration

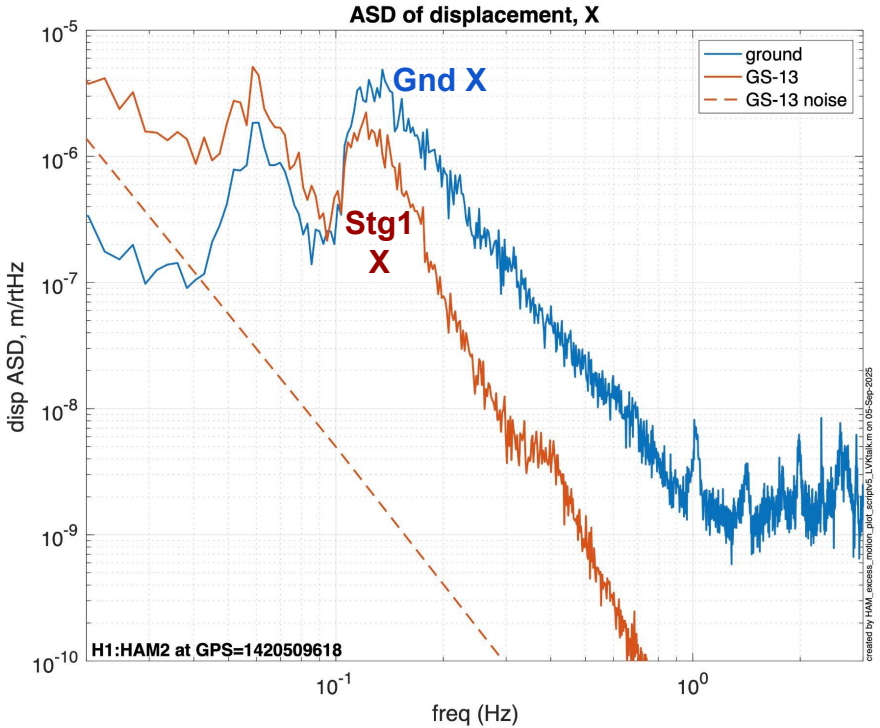
Brian Lantz, Sept 8, 2025, G2501853-v2

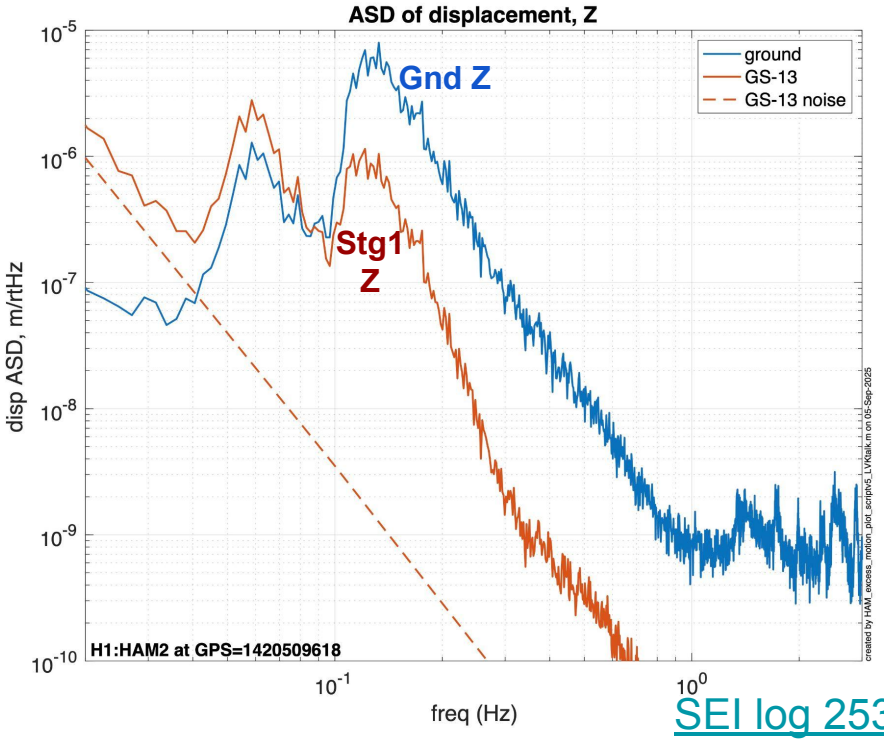
Large Microseism Means Trouble



Horizontal Isolation is good, but not as good as we would like - why?

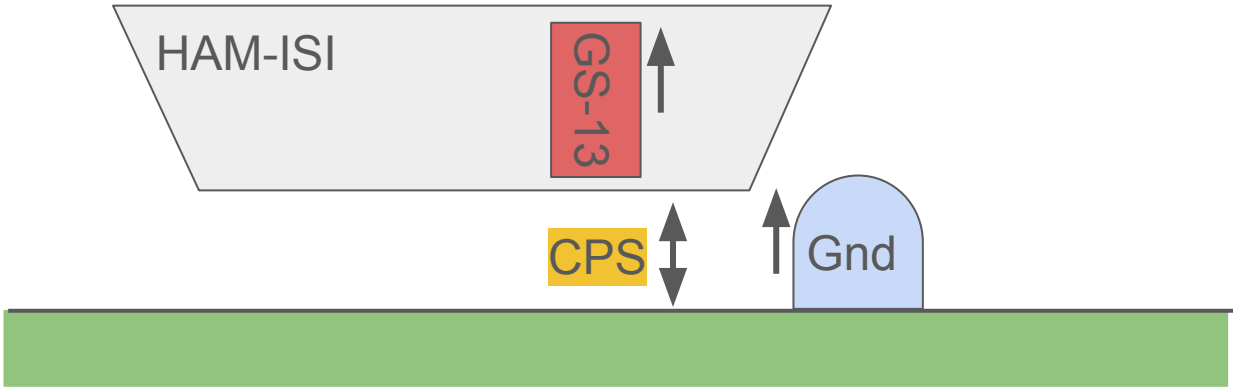
Horz isolation here is only 3x (chosen to be poor)
we see differential motion between tables (Brian says …)





SEI log 2538

Define a Residual

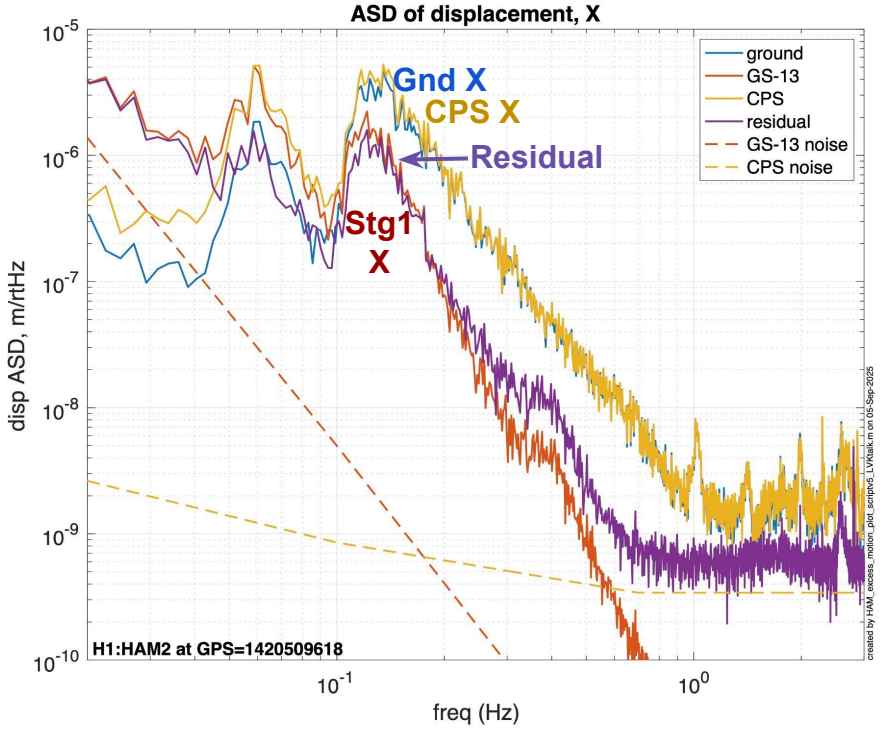


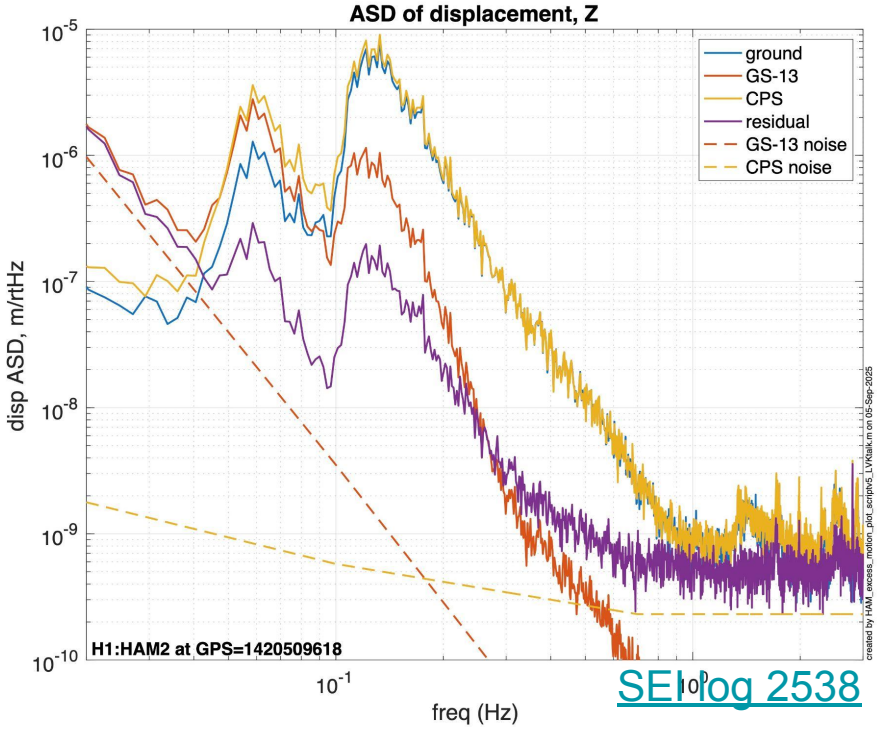
Ideally, CPS = (GS-13 - Ground),
i.e. GS-13 = Ground + CPS

Ideally, GS-13 - (Ground + CPS) = 0
Actually, GS-13 - (Ground + CPS) = residual

Compare the residuals

Z is good, but
The horizontal residual is about the same as the horizontal motion!

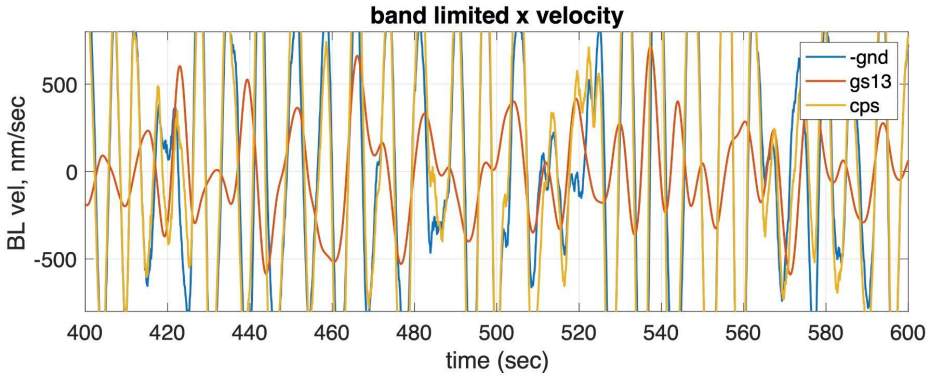


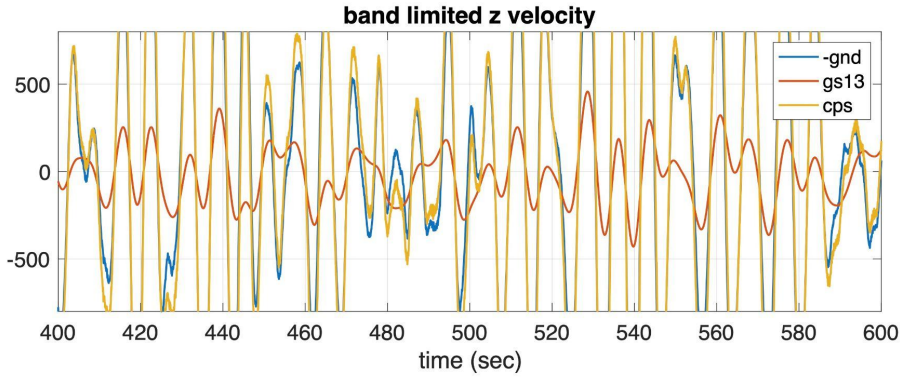


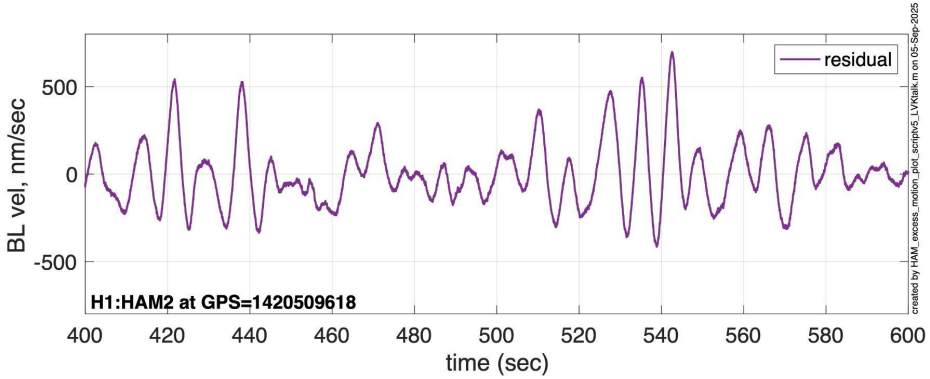
SEIlog 2538

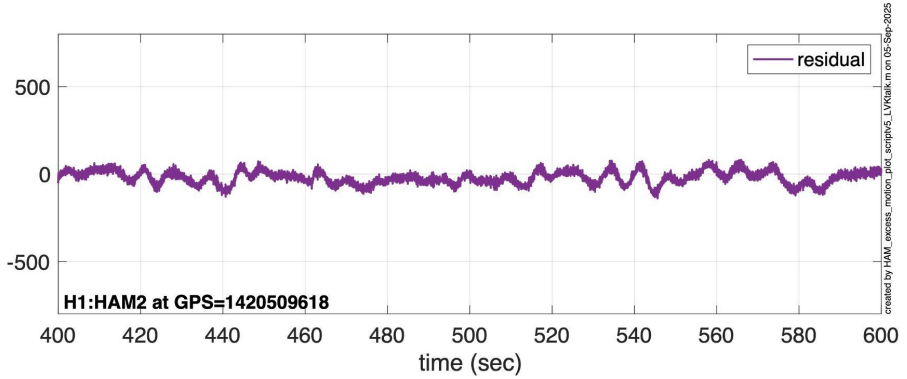
Residuals in the time series

Note - This is velocity around the microseism



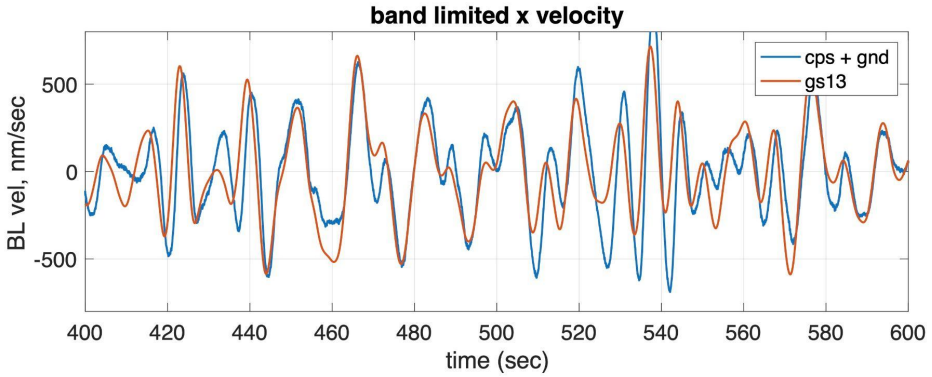


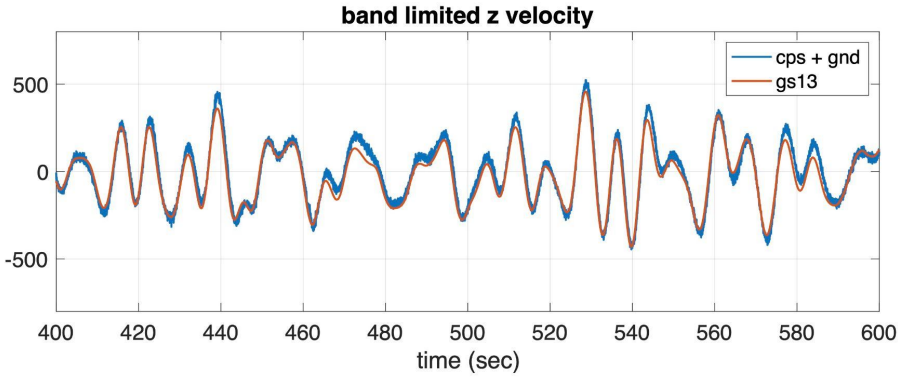


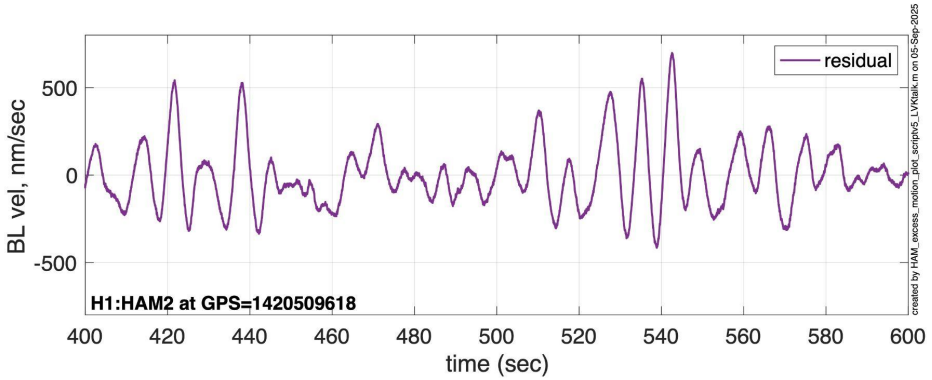


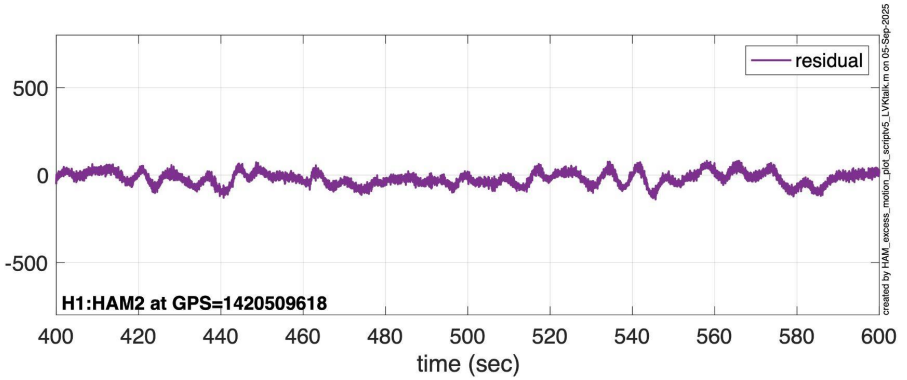
Residuals in the time series

Note - This is velocity around the microseism





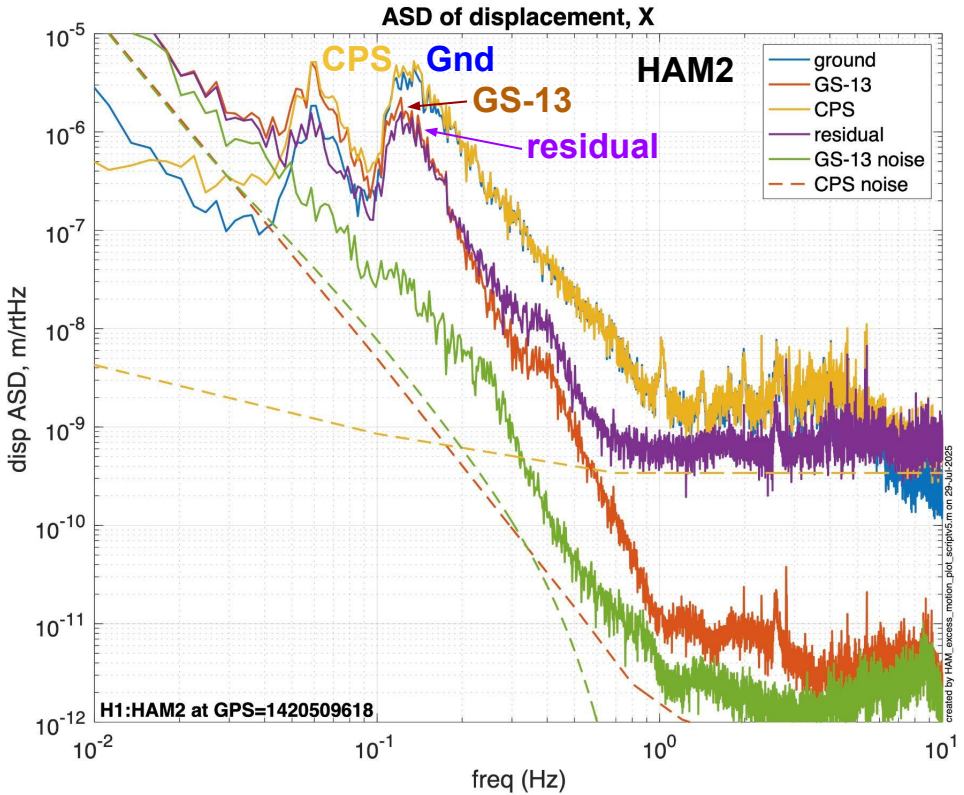




X motion data from high microseism

Should be GS-13 = (CPS - Ground), ie GS-13 - (CPS - Ground) = 0

Actually, GS-13 - (CPS - Ground) = residual



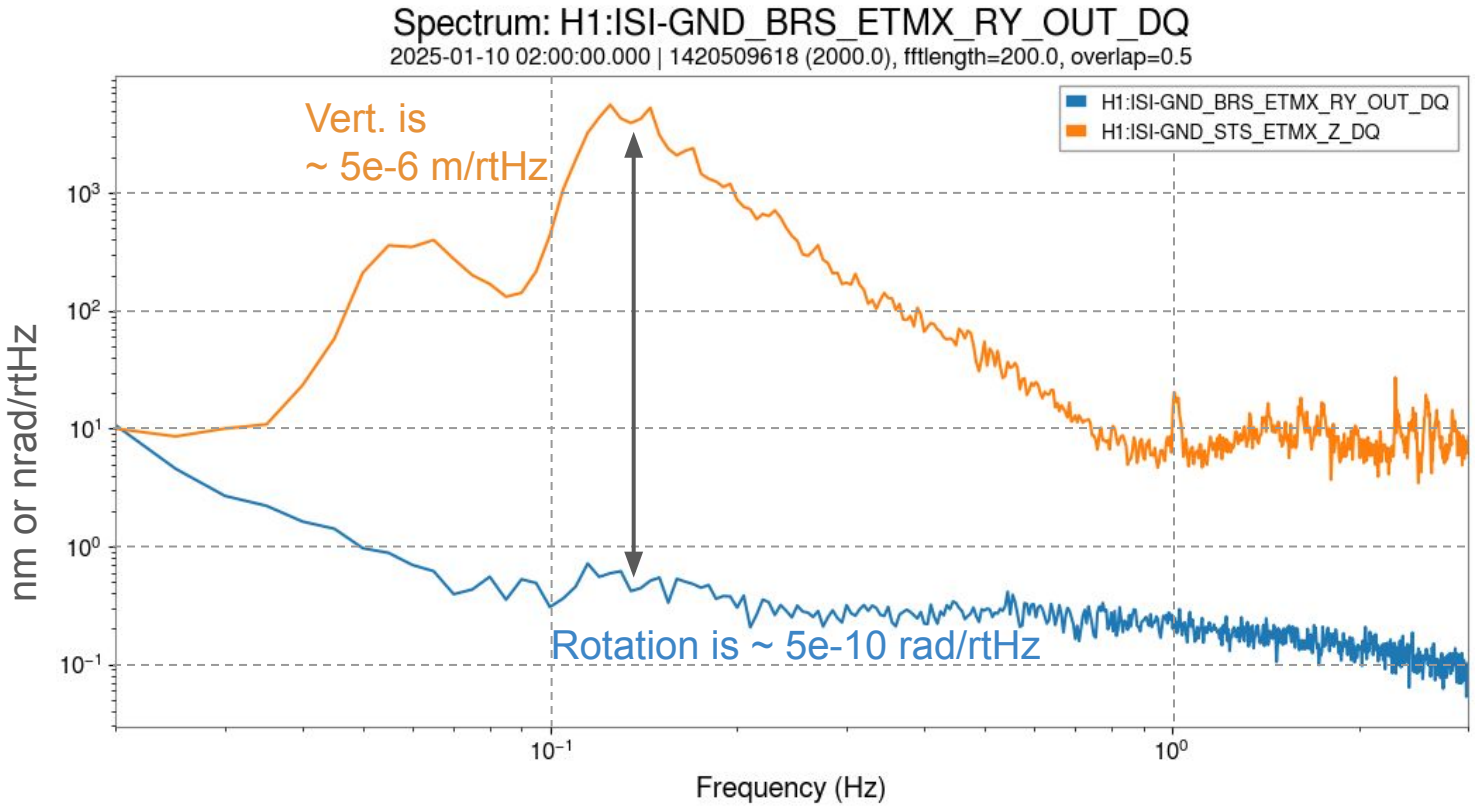
Likely from tilt in RY, looks like ‘noise’ on the GS-13.

Here the residual peaks at ~1e-6 m/rtHz
And is comparable to GS-13 signal

This is NOISE in the sensor (output which is not the thing we want to measure)

It’s very likely from tilt-horz. coupling (coherence is high, & all problems at low frequency come from tilt-horz. coupling)

Gnd Tilt vs. Vertical motion at the microseism



Gnd Tilt vs. Vertical motion at the microseism

Vert. is ~ 5e-6 m/rtHz

Rotation is ~ 5e-10 rad/rtHz

ISIs measure tilt (rx, ry) as difference of vertical sensors (CPS & GS-13)

Sensors are ~ 1 meter apart
- so if your calibration is off by ~ 1e-4,
  you might convert common-mode z into differential mode z - i.e. tilt.

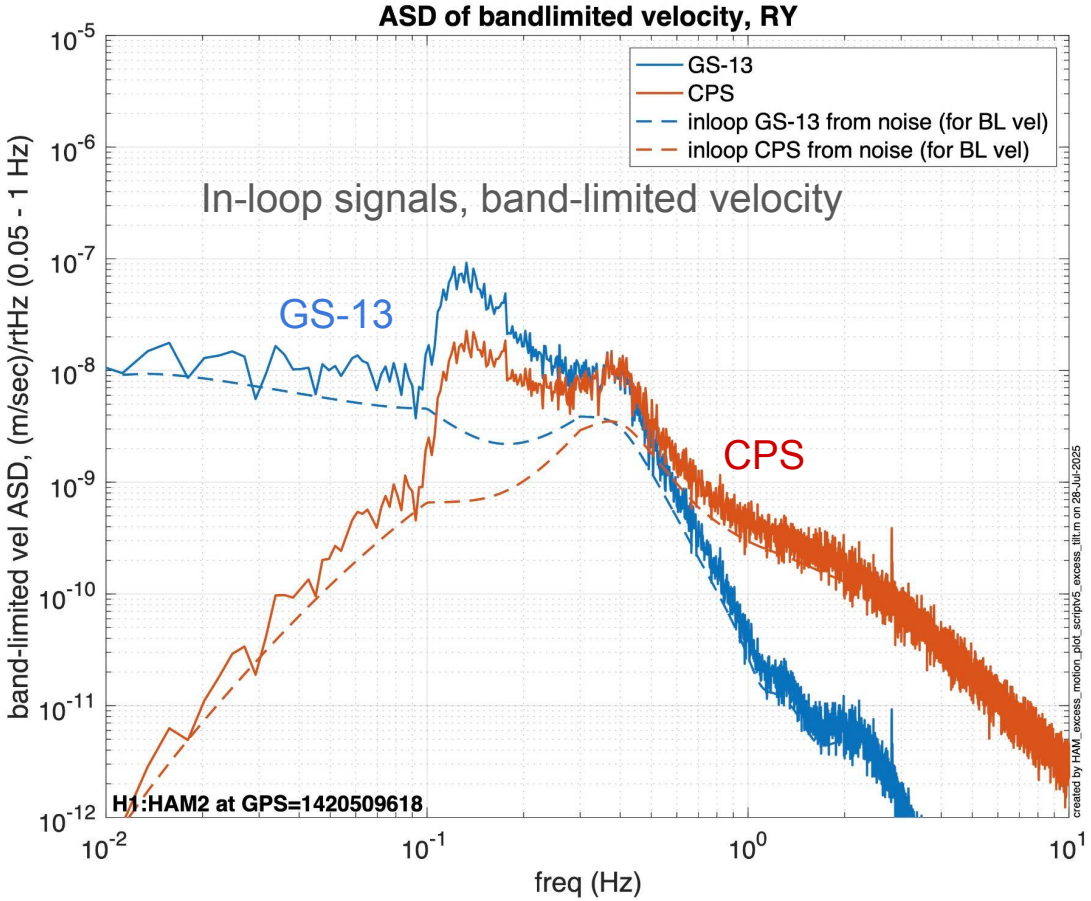
g/w^2 ~ 10 at the microseism,

ISI spec is 2e-7 m/rtHz at microseism, implies 2e-8 rad/rtHz max tilt.

Or, to get 10x reduction in translation (matches vert at LHO, 2x vert at LLO)

Need about < 10% calibration error in GS-13s, 1% for CPS (at microseism)
- lots of details omitted, e.g. blend design, 10x isolation vs. 2e-7 m/rtHz, freq of the microseism, what about earthquakes at 50 mHz,

Excess tilt is clearly present (inloop)



Signals are clearly coherent
coherence is ~1
Details match,

Overall shape difference is expected from blend-filters (see e.g. T2500279)

Obvious source of trouble,
>> ground tilt

SEI log 2540

Excess Noise, Equivalent Out-of-Loop

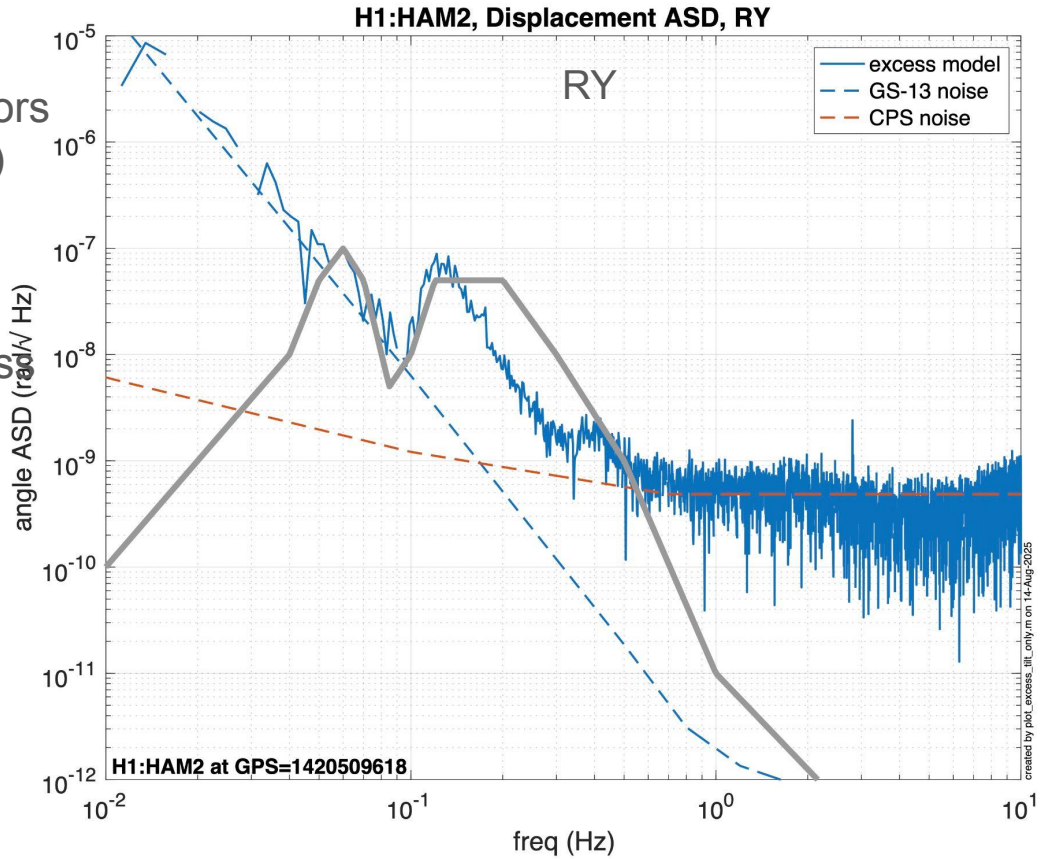
Equivalent Out-of-Loop noise from the sensors (with loops on, you can't distinguish source)

~6e-8 rad/rtHz (100x ground rotation)

If it becomes table tilt, it could become excess translation of ~ 6e-7 m/rtHz (3x the motion target)

20-50x the GS-13 electronics noise

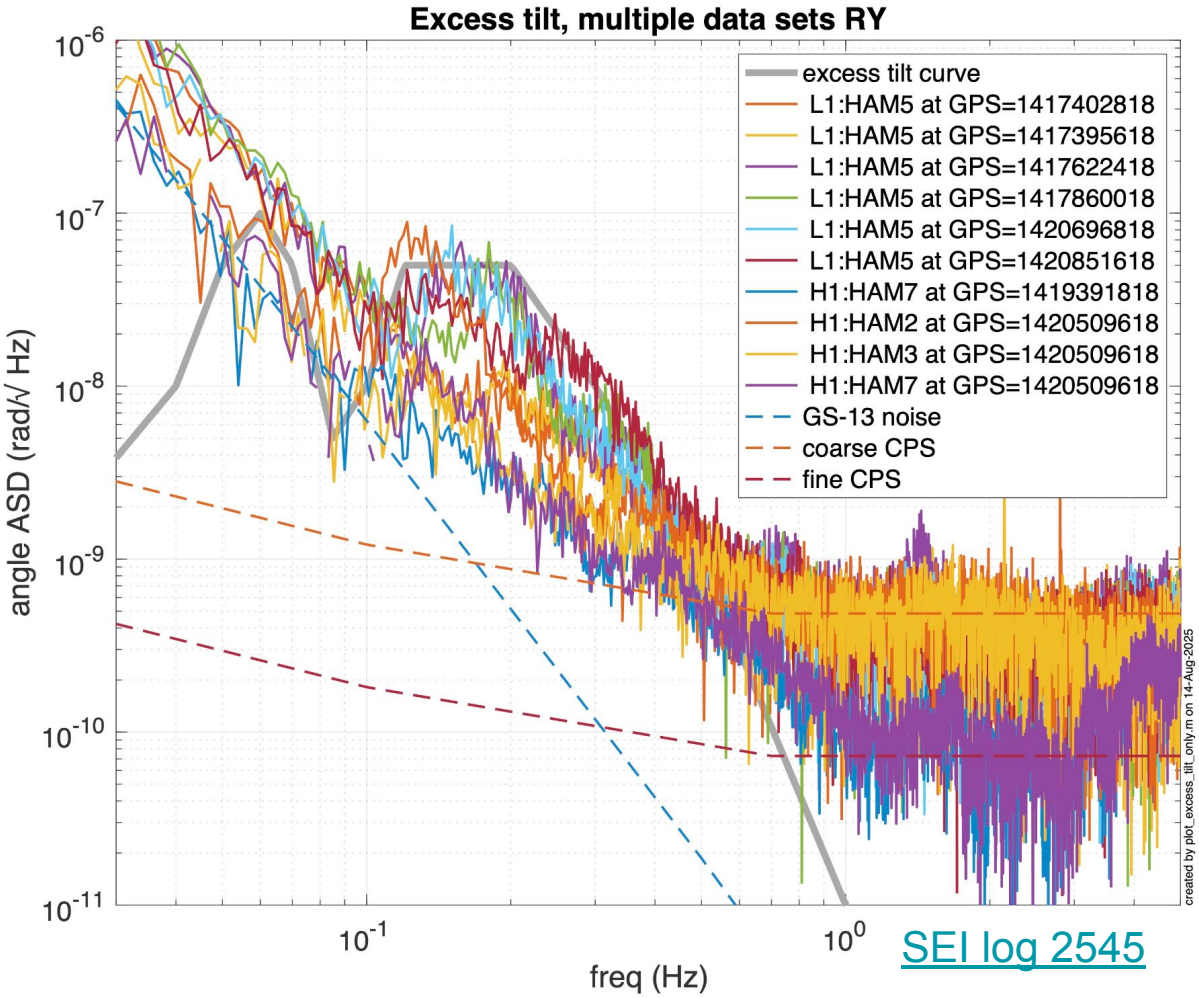
Make a grey envelope curve (SEI log 2545)



Try to make a reasonable “Excess GS-13 tilt noise for high microseism” curve for design work.

5e-8 rad/rtHz at the microseism
Probably follows ground motion
Every table is different

SEI log 2545



SEI log 2545

So what does it mean?

ISI platforms are good, but could be better
- they show clear “residuals”,
  ie excess tilt and excess horizontal translation

Platforms not limited by electronics sensor noise at the microseism.

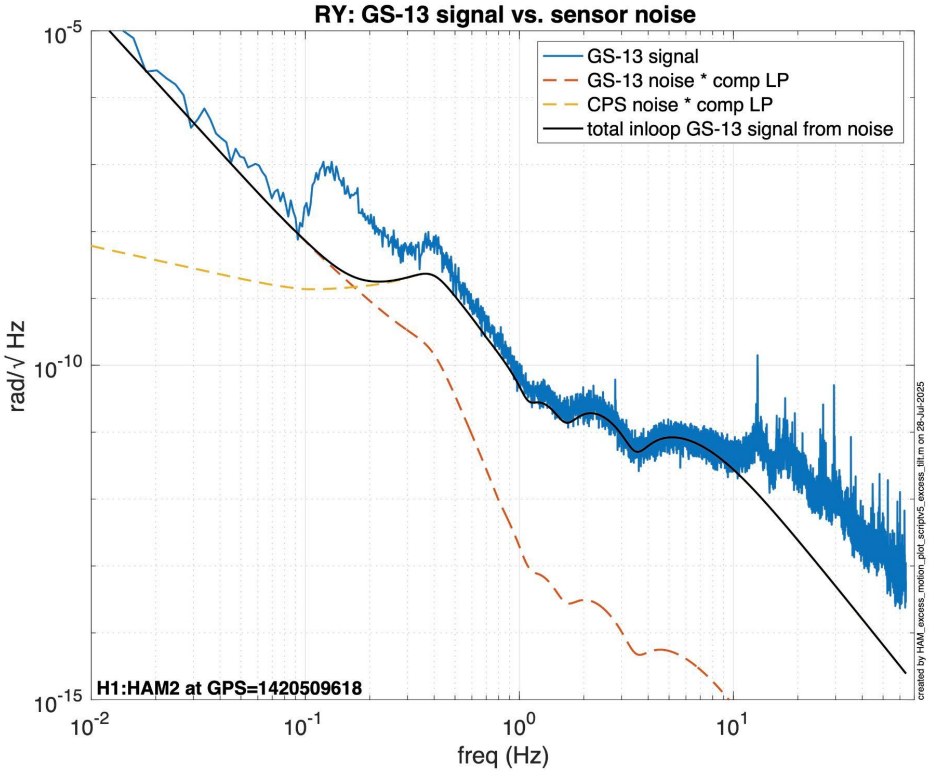
Not sure what the limit is - probably sensor calibrations

ML4seismic is using big-data techniques to (try and) identify correlations (see talks by Christina and Shivanshu) - maybe fix the calibrations? Maybe tune out the residuals

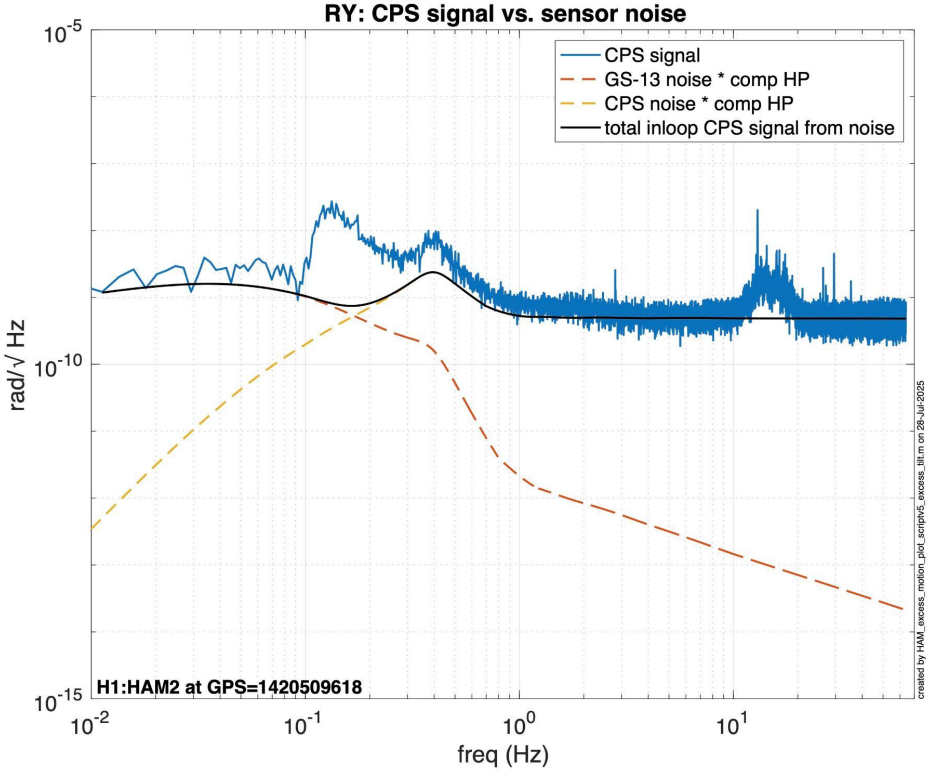
UWash is developing direct rotation sensors - independent witnesses which sidestep the “small difference of big numbers” problem

SPI directly measures relative positions so we can control that, measures horizontal motion and relative angles. (CPS-diff was early example of this)

GS-13 in-loop noise contibutions



CPS In-loop Noise Contributions

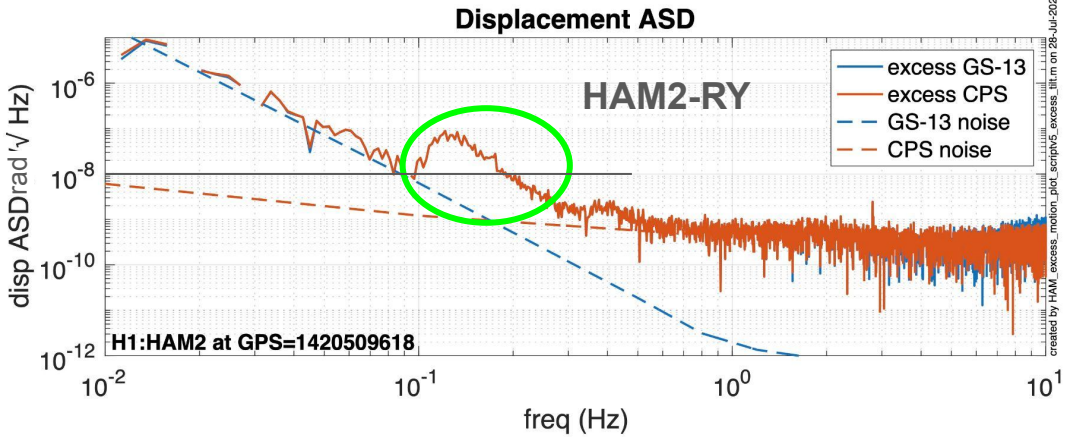


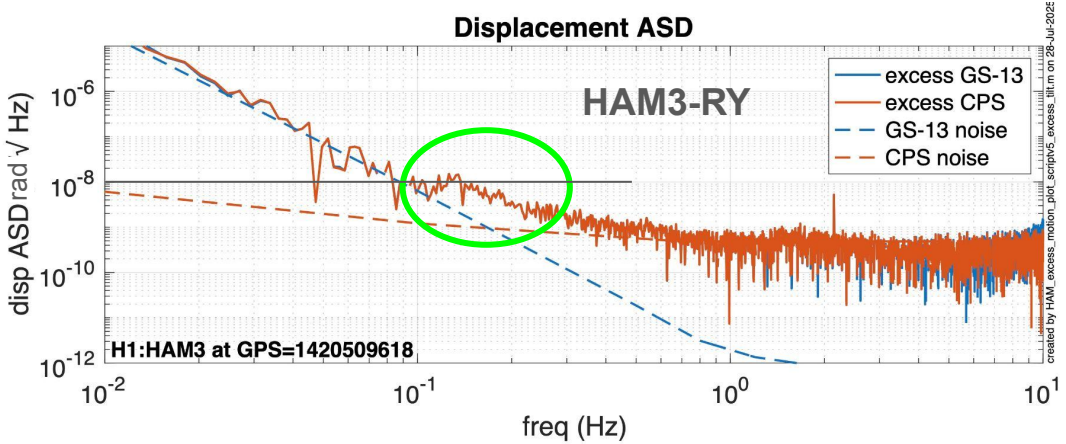
ISI Equivalent Open loop “sensor noise” for RY Microseism large (BLRMS 0.9 microns/ sec)

This is my guess at the “sensor noise” for HAM2 & 3 during a large microseismic time.

Cause is related to microseism, but not understood.

Level is 2-8e-8 rad/rtHz





[Brian L, SEI log 2538]

Yaw data from high microseism

HAM2 & HAM3 show similar excess Y,
equivalent to 2-3e-8 rad/rtHz of Yaw (at this moment of time)
The Yaw (RZ) motion of the tables was also 2-3e-8 rad/rtHz at this time
So it will probably be hard to show improvements