Blend filter for stg2 rX rY

tilt_800 blend filters, T2100273, B. Lantz, Aug 2021

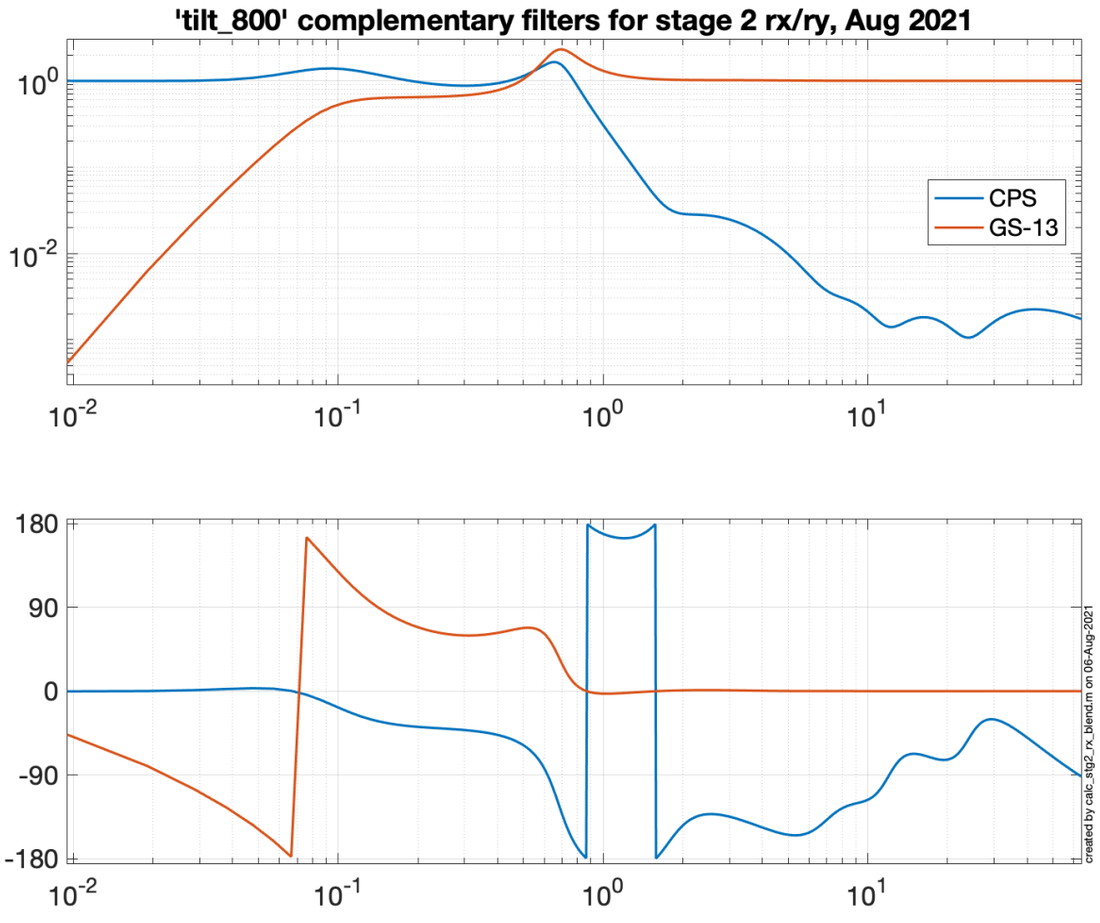
- Using data from 3 different times, I've designed a blend filter to be used for the rX and rY directions of stage 2 of the BSC-ISI.
- Data from ITMY at each site - this platform has good performance.
  1 at LHO to match other analysis, 2 at LLO - big/ small microseism.

- The filter is designed to control the noise of the GS-13 and to minimize gain peaking around the microseismic peak. The gain peaking for the filter happens 0.5-0.8 Hz, and a bit just around 0.1 Hz.
- This filter should allow the stage 2 rX and rY loops to be run with no noticeable increase of angular motion below 1/2 Hz, and with significant improvement to the angular motion above 1 Hz.
- This should improve the SUSpoint motion around 1-5 Hz.

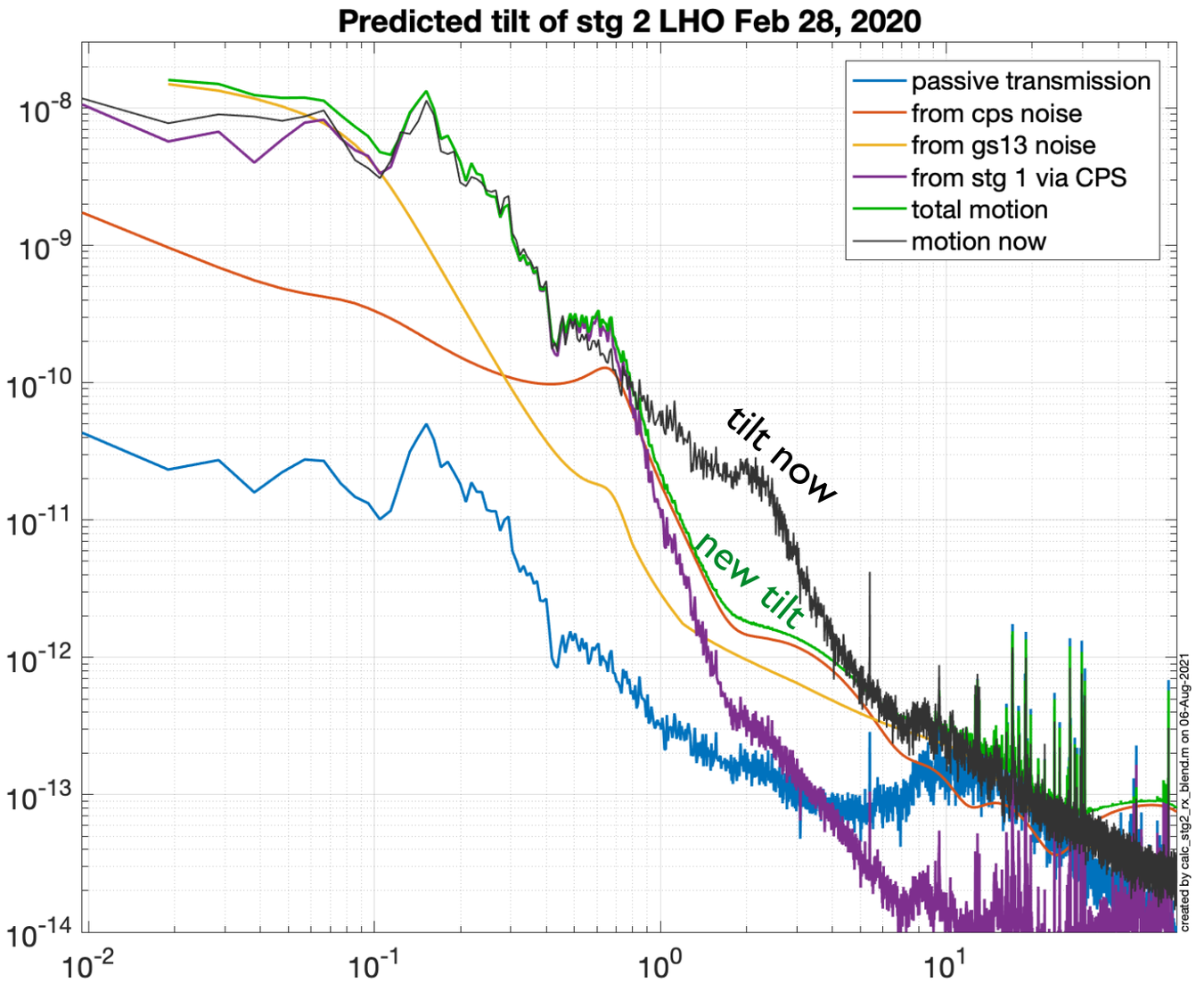
- This might help the ~1.25 Hz oscillation at LLO-ETMY (if we're lucky, but - Arnaud tried something similar in 2016 and it didn't help, alog 28499)
- This should enable Stg 2 -> SUS feedforward.
- This enables rX sensor correction stage 1 to stage 2, which might be helpful.
- Better CPS sensors will improve stage 2 tilt motion, SUSpoint motion, and maybe the stg1-> stg2 sensor correction.

Summary - filter and tilt change

This new ‘Tilt_800’ rx/ry blend filter



Let us turn on stage 2 rx and ry loops, Changes stage 2 tilt from the black ‘motion now’ curve to the green ‘total motion’ curve.



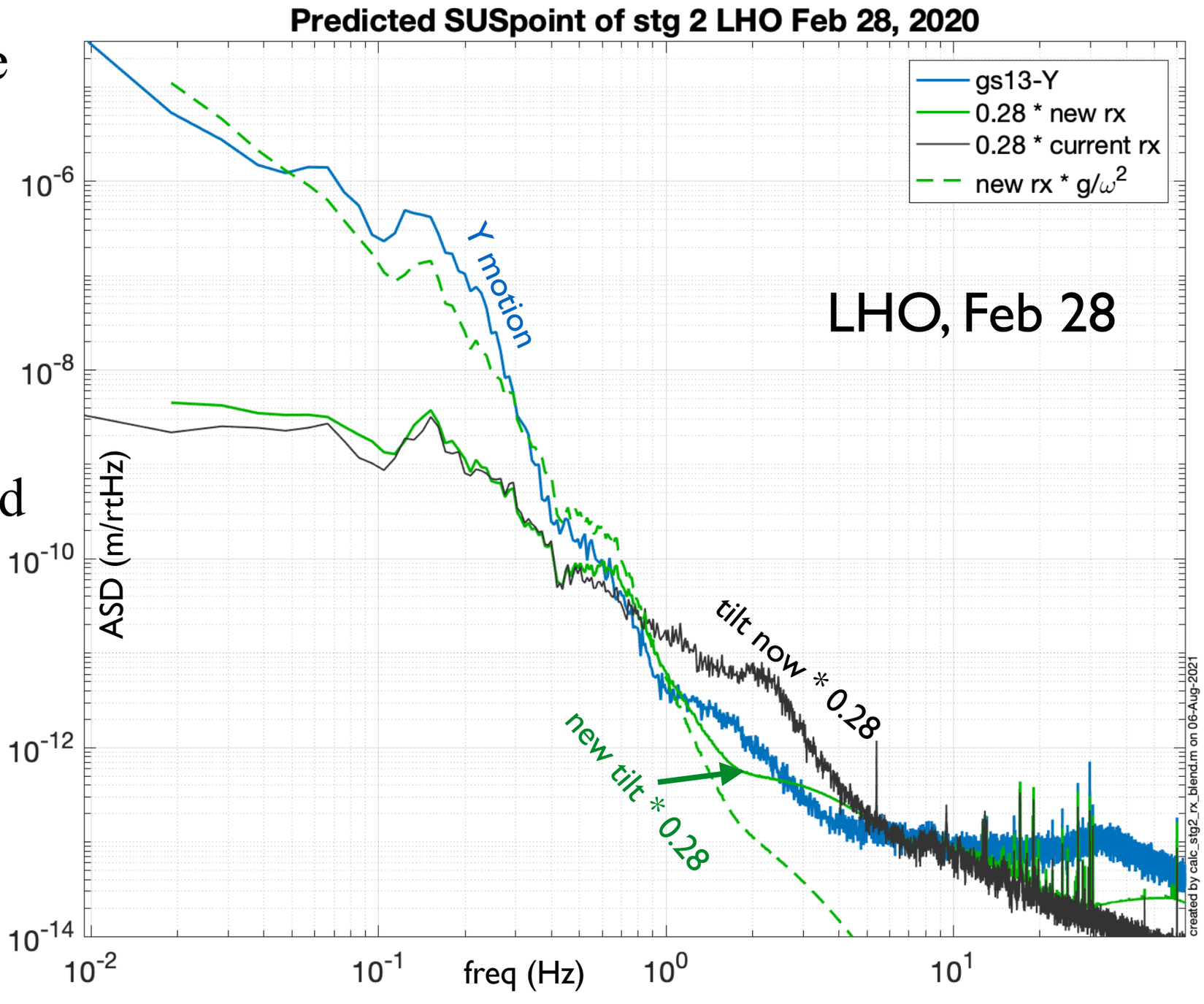
Summary - SUSpoint

SUSpoint motion (blue) is now dominated by tilt around
0.8 - 5 Hz @ LHO, 1-10 Hz @ LLO
new filter & running control loops helps across this band.

Suspoint motion should be improved at a few Hz.

Changes to tilt around μseism should not impact SUSpoint.

Extra tilt at 0.5 - 0.8 should be comparable to existing SUSpoint.



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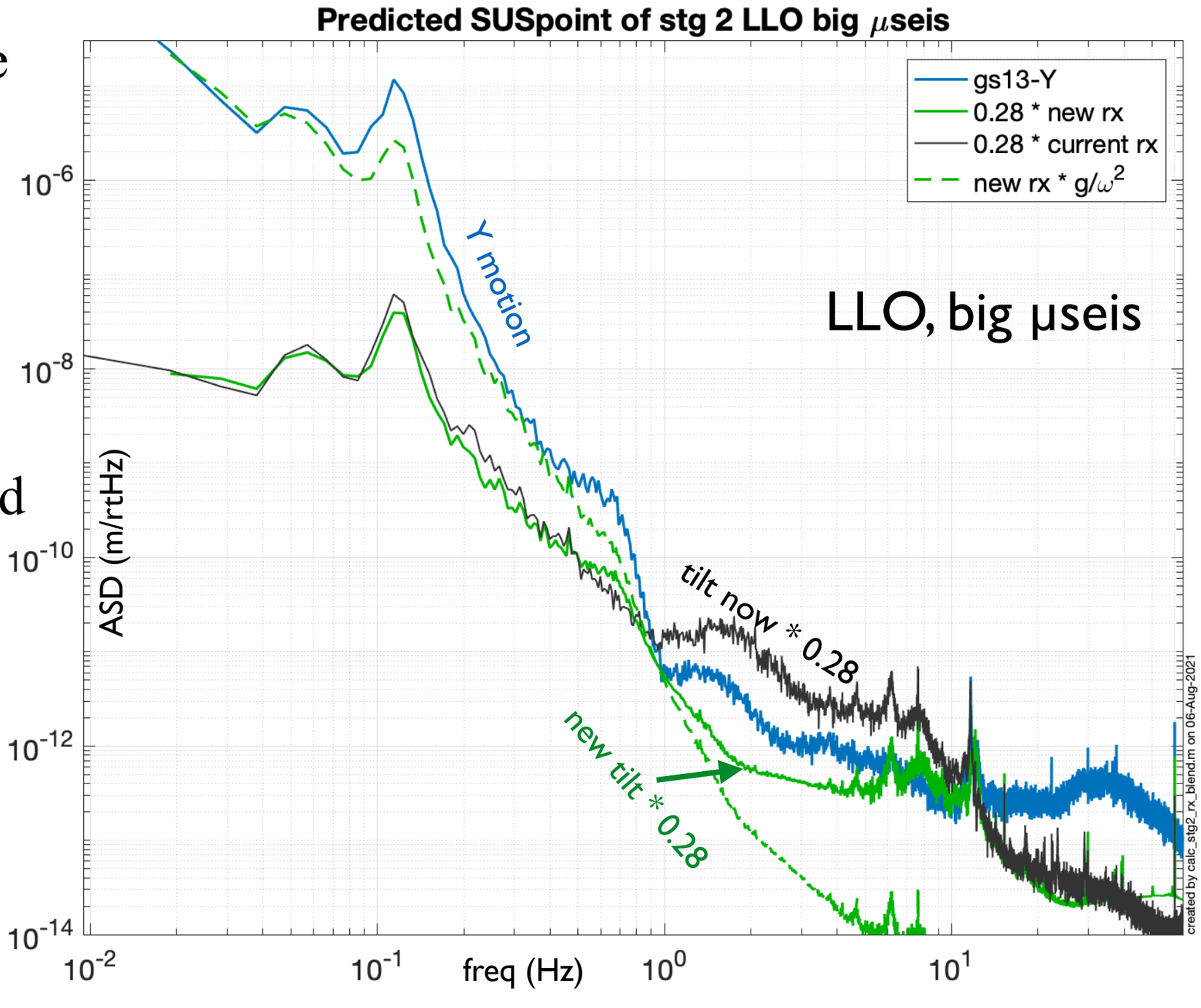


Summary - Installation

Install script for autoquack: (this should be all that you need)
{SeismicSNV}/Common/MatlabTools/Install_tilt_800.m
(you need to set the IFO, seisSVN directory, and chamber.
warning - Brian has not tested this updated script)

Matlab file with filters:
{SeismicSNV}/BSC-ISI/Common/Complementary_Filters_BSC_ISI/…
aLIGO/tilt_800_blend_filter_set.mat

Analysis script: (not a small directory, it has some data in it…)
{SeismicSNV}/Common/Documents/…
T2100273_reblend_stg2_rx/calc_stg2_rx_blend.m

```
% save tilt_800_blend_filter_set.mat rXY_tilt_filters note1 install_filter_DT install_filter_CT comp_filter
% comp_filter:         contains highpass and  lowpass complementary filters
% install_filter_CT:   continuous time version of filters to install, includes GS-13 calibration
% install_filter_DT:   install filter as discrete time for 4096 rate
% rXY_tilt_filters:    struct for autoquack - installs to bank 5.
%                      set for rX ad rY, cur and nxt, CPS and GS-13 (8 total)
```

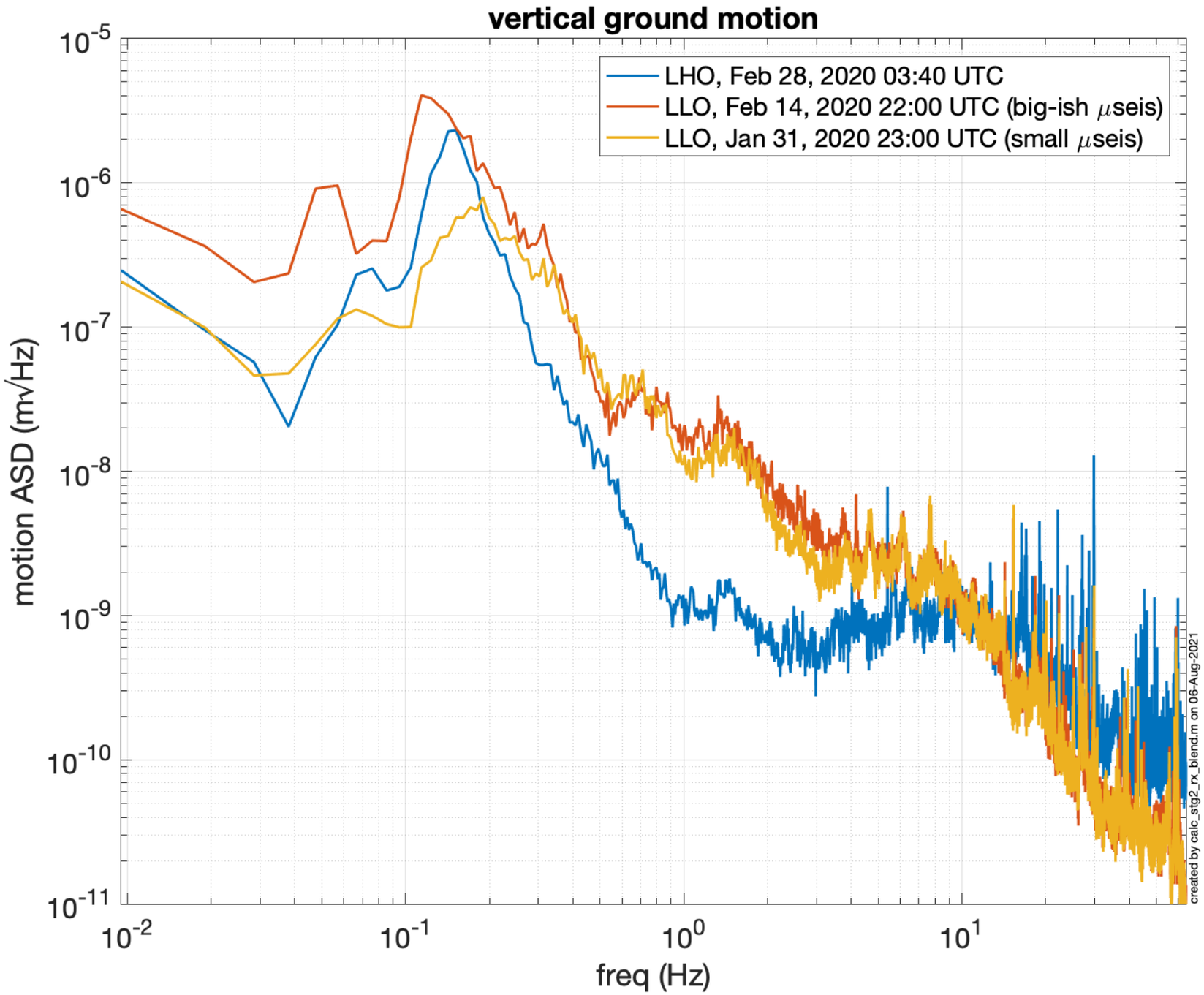
Analysis times

Three times were chosen for the analysis. Each is a 2000 second segment.
IFO is running, no earthquakes, LLO microseisms were large/ small for Feb 2020.
Data 1, LHO, Feb 28, 2020 3:40 UTC, gps = 1266896418

This is the same time used for SRCL analysis. z-BLRMS ~ 0.3 - 0.6 microns

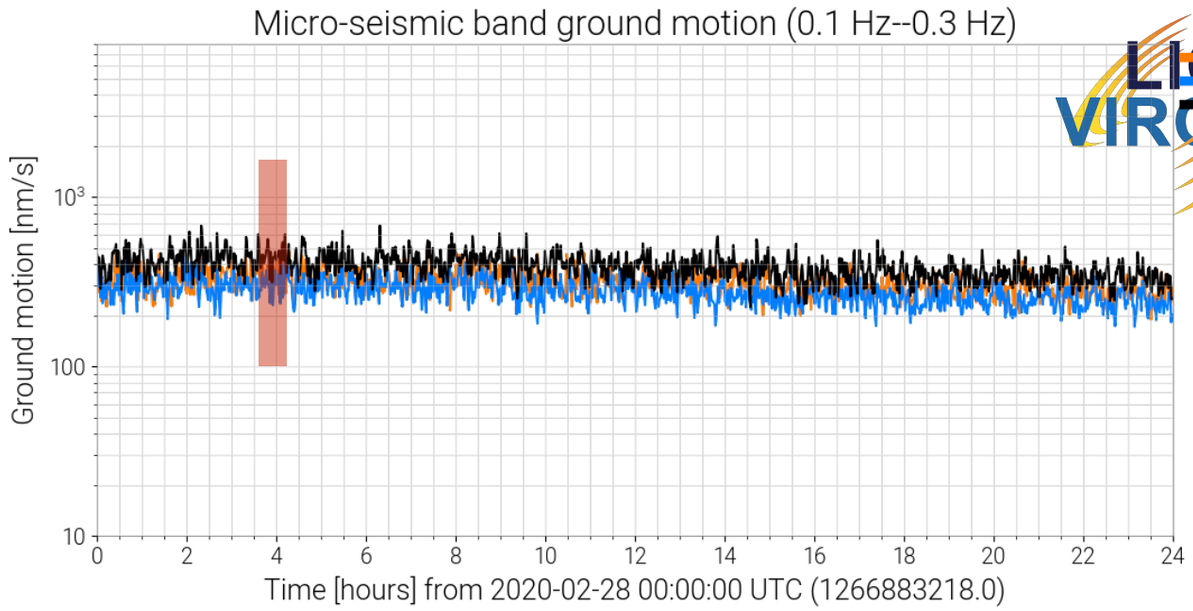
Data 2, LLO, Feb 14, 2020, 22:00 UTC,
GPS = 1265752818
Pretty large µseism,
z-BLRMS ~ 0.7-1.0 micron

Data 3, LLO, Jan 31, 2020, 23:00 23:00:00 UTC,
GPS Time = 1264546818
Relatively smaller µseism.
z-BLRMS ~ 0.2-0.3 microns

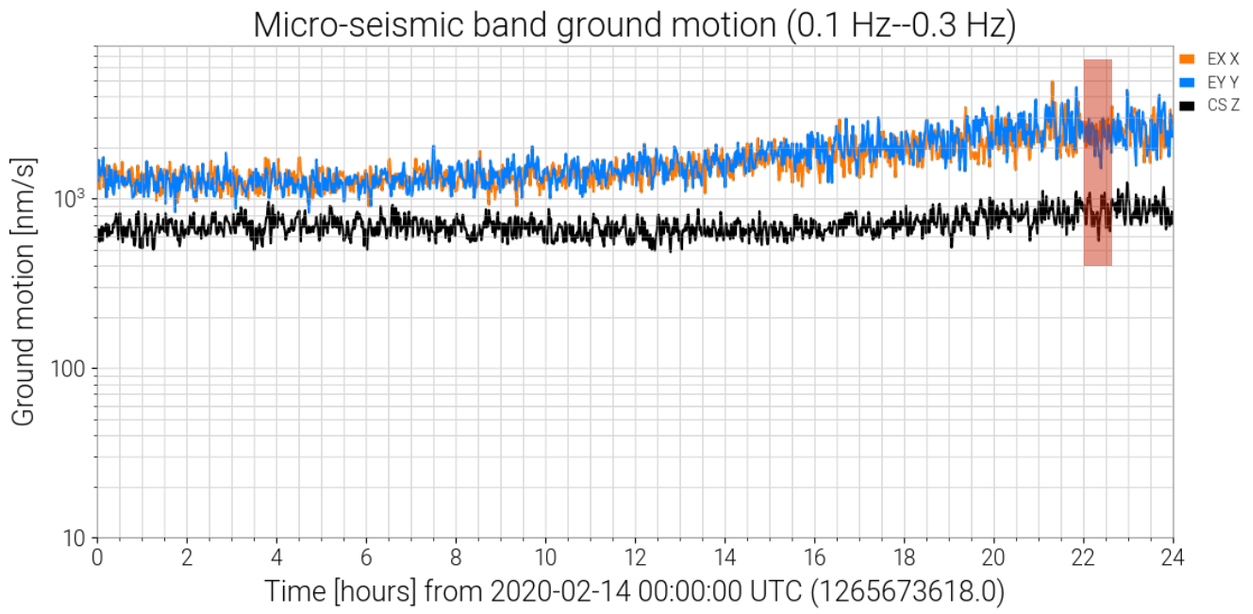


BLRMS

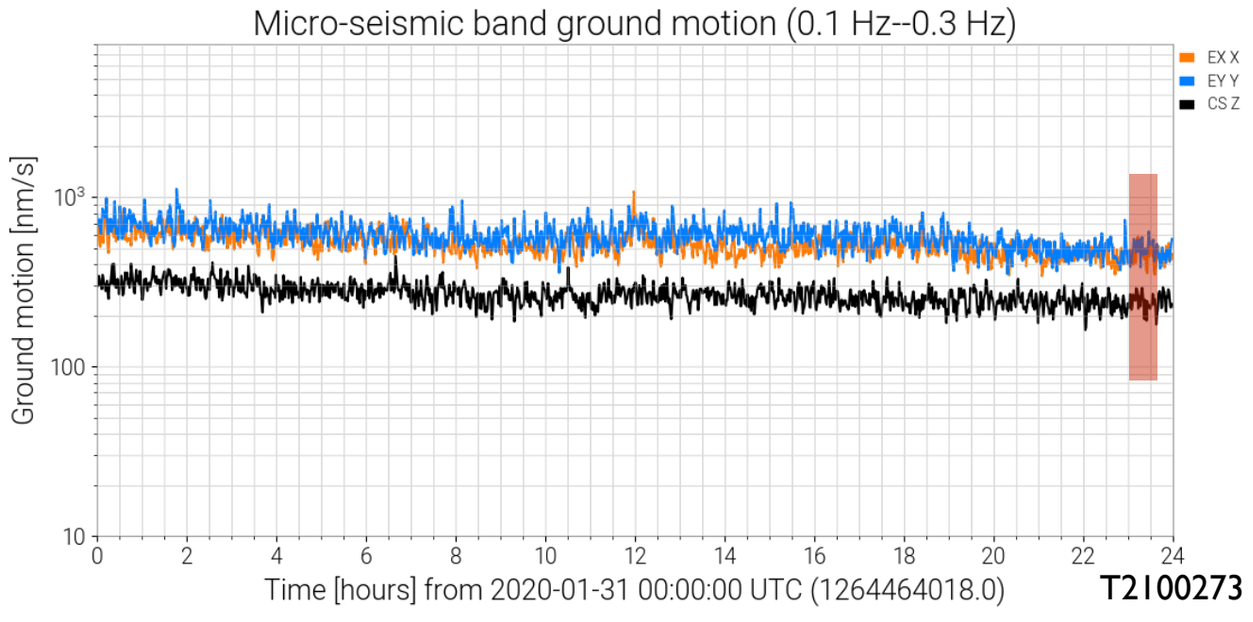
Data 1, LHO



Data 2, LLO, loud



Data 3, LLO, quiet



Estimate the current tilts

I used a variety of channels to estimate the tilt of stage 1 and stage 2. One important criteria is to not make the low frequency performance worse, but the direct tilt sensing for stage 2 is not good enough to show the actual tilt below 0.1 Hz - it's limited by the noise of the GS-13.

To measure stage 2, I used 3 sensor sets:

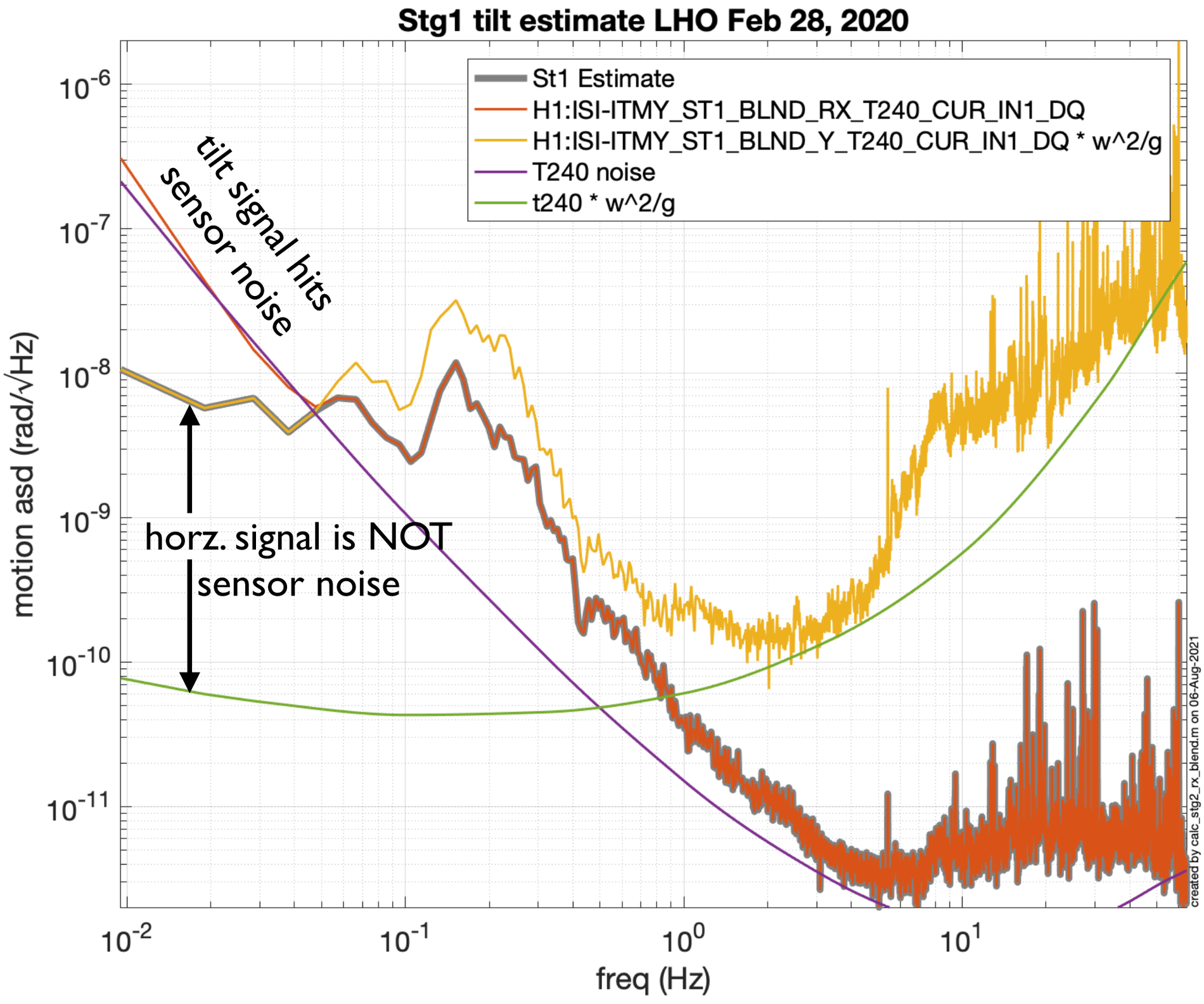
-The GS-13 rx signal is good above about 0.1 Hz

-The GS-13 Y signal is probably limited by tilt below about 50 mHz. At these frequencies, the signal is well above the sensor noise and not consistent with a real translation (too big). GS-13 Y * w^2/ g is an upper limit to the platform tilt.

- I constructed a synthetic stage 2 tilt by combining the stage 1 T240-rX and the stage 2 CPS-rX signals. This is about 50x lower noise that the stage 2 GS-13 rx signal below 0.1 Hz. (We should consider using this for Sensor correction. This blend filter has low enough GS-13 noise to support this, if we ever get to it)

- For stage 1, I did the same thing, but only used the T240 RX and the T240 Y signals.

Improved tilt estimates - stage 1

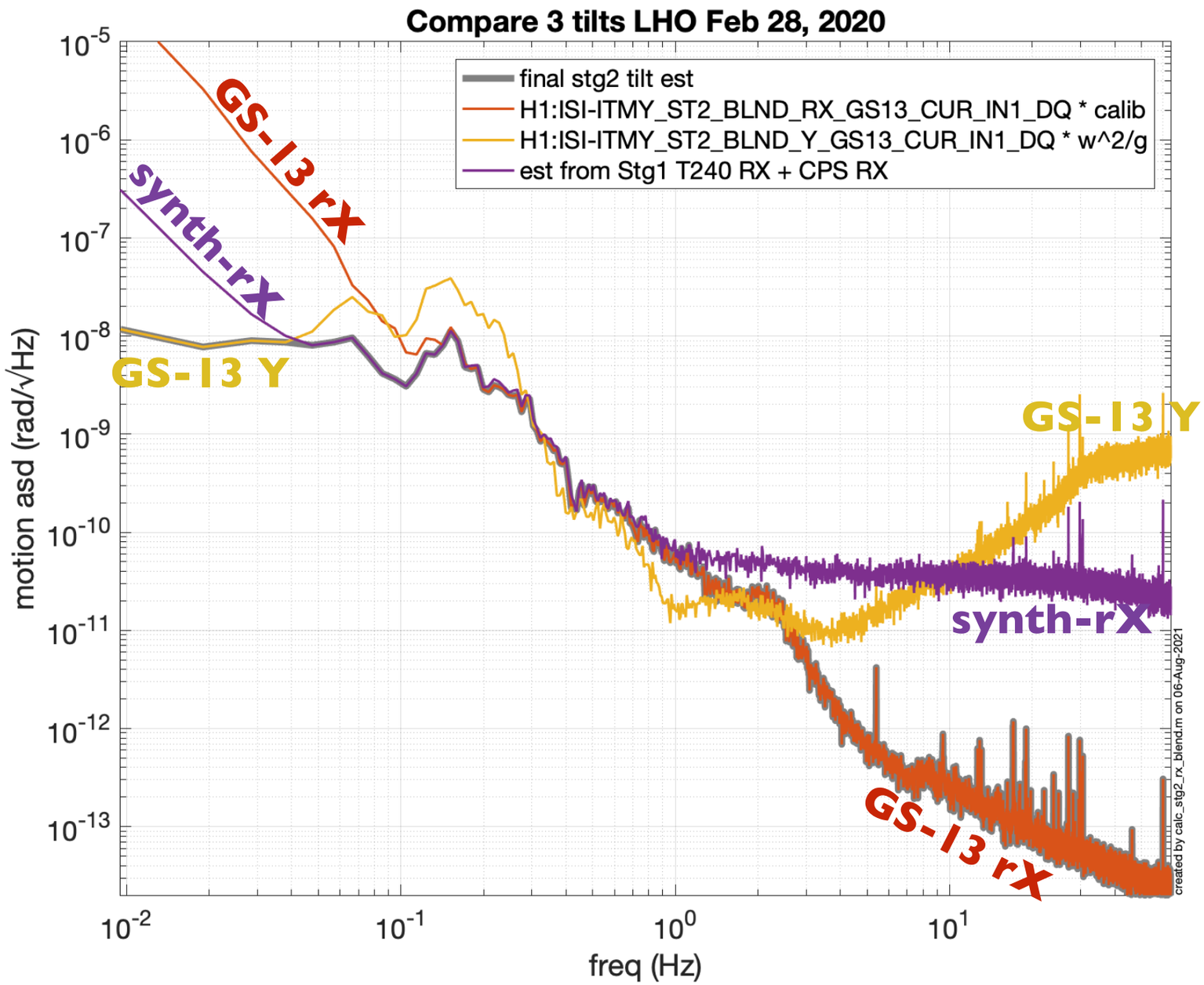


Improved tilt estimates - stage 2

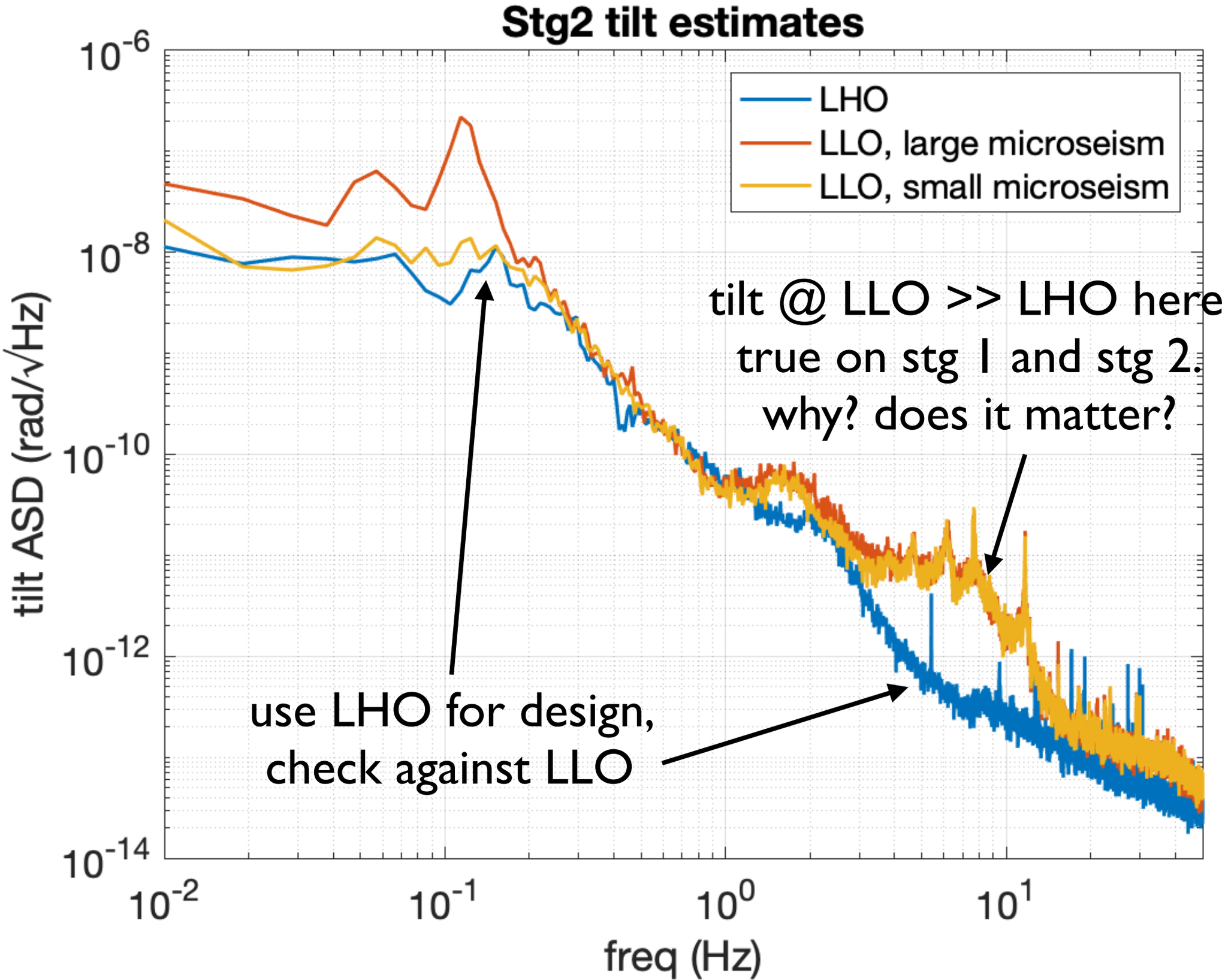
Observations:
The GS-13 rX signal is noise below the μseism.
The GS-13 Y signal is probably translation at the μseism, but suspicious at 0.3-0.5 Hz. It's driven by tilt below 0.1 Hz.

Synth-rX is good from
50 mHz ~ 1 Hz in this plot,
50 mHz - 600 mHz at LLO.

We should investigate rx sensor correction from T240s to stage 2.

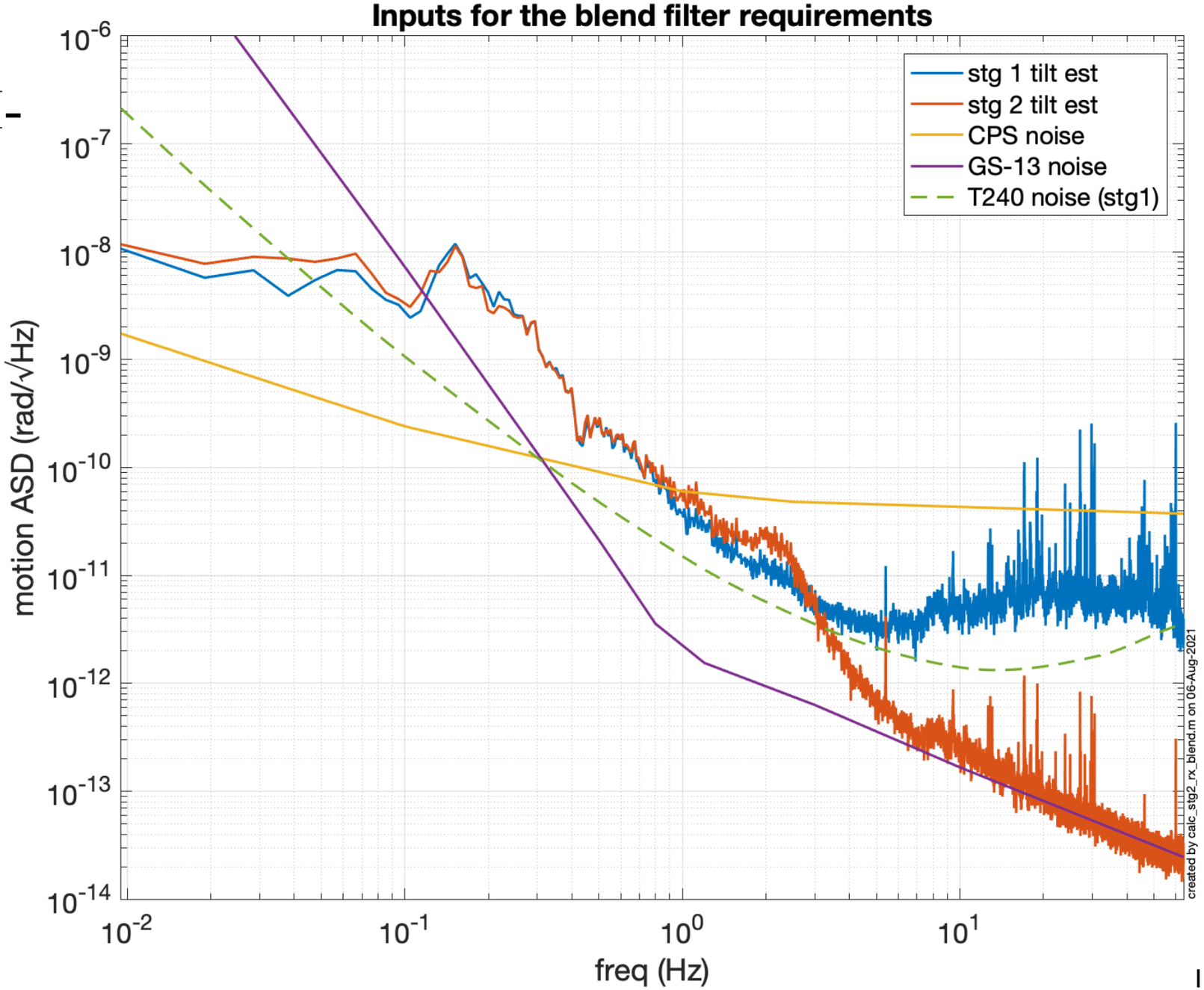


Estimate tilt for 3 times



tilt motion and sensor noise

- Sets limits for the blend filters (LHO data set)
- GS-13 noise diverges from tilt very quickly below 100 mHz
- Stg2 CPS noise well above current tilt by 5 Hz.
- Good SNR for GS-13 around 0.4 might allow SEI-SUS feed-forward
- Good SNR of T240 around µseis might allow sensor correction.



recast to show limits

(LHO data set)

If the blend filter (green/ purple) is above the target (yellow / red-or-blue) then the stage 2 motion will increase from current level (tells you how to not make it worse)

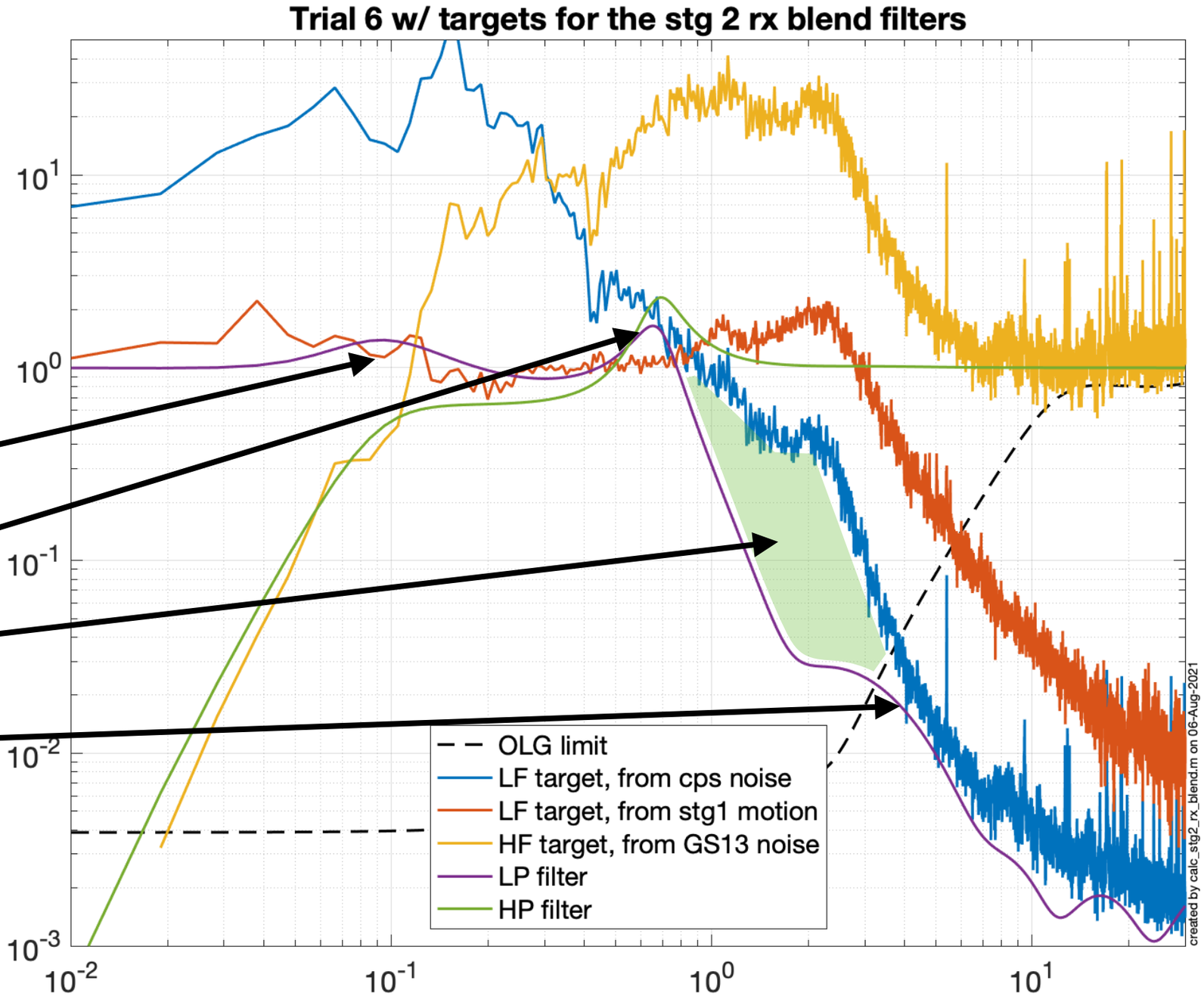
The dashed line is the Sensitivity function. You can't get more isolation than this (this limits how much better it can be)

LHO about the same below 0.2 Hz, limit is gain peaking.

Worse at 0.5-0.8 Hz

Better at 1-4 Hz,

More loop gain won't help LHO unless you add more notches to the CPS (purple) curve.



recast to show limits

(LLO data set, big microseis)

If the blend filter (green/ purple) is above the target (yellow / red-or-blue) then the stage 2 motion will increase from current level (tells you how to not make it worse)

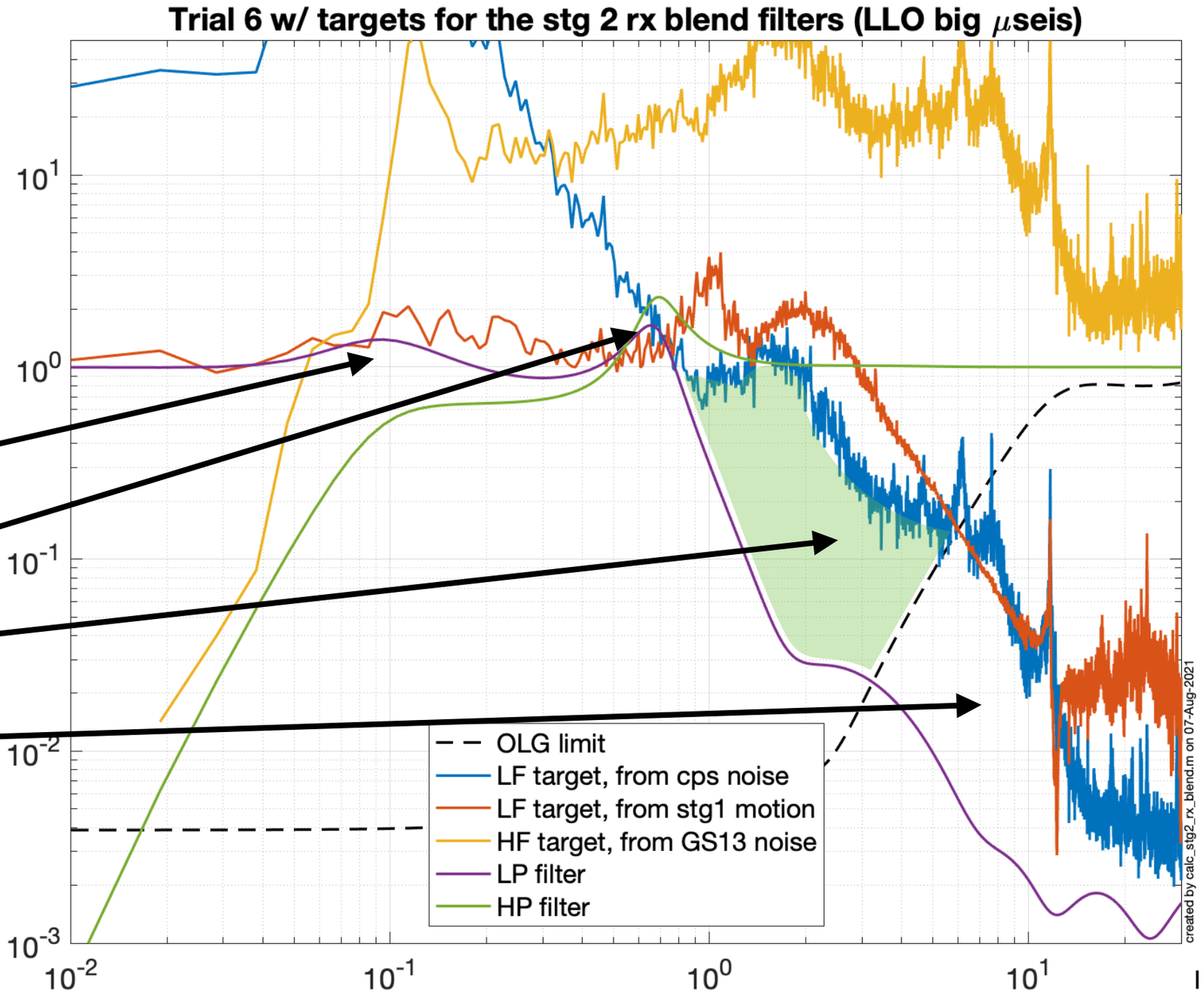
The dashed line is the Sensitivity function. You can't get more isolation than this (this limits how much better it can be)

LLO about the same below 0.2 Hz, limit is gain peaking.

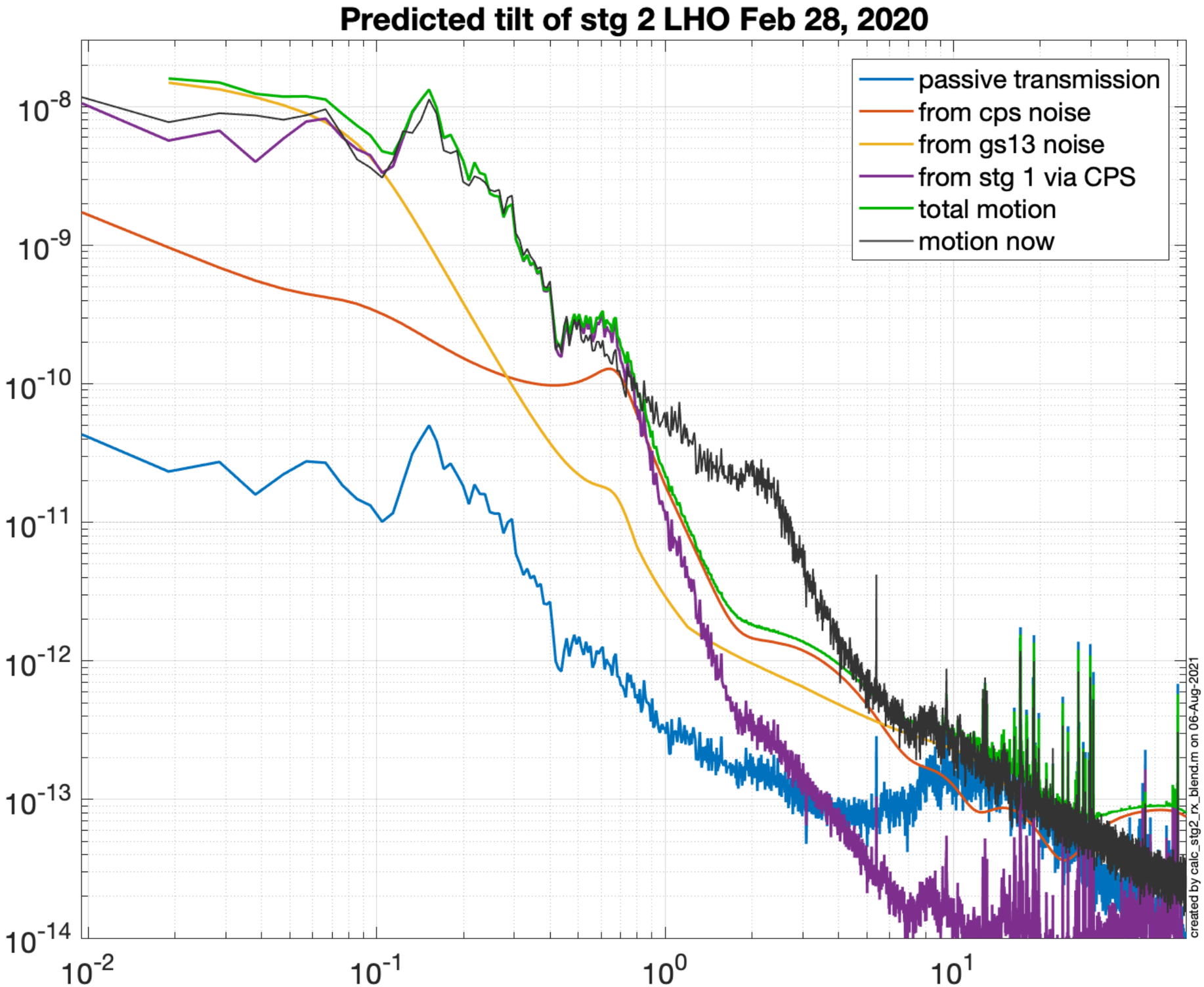
Worse at 0.5-0.8 Hz

Better at 1-6 Hz,

More loop gain will help at LLO



Tilt Performance



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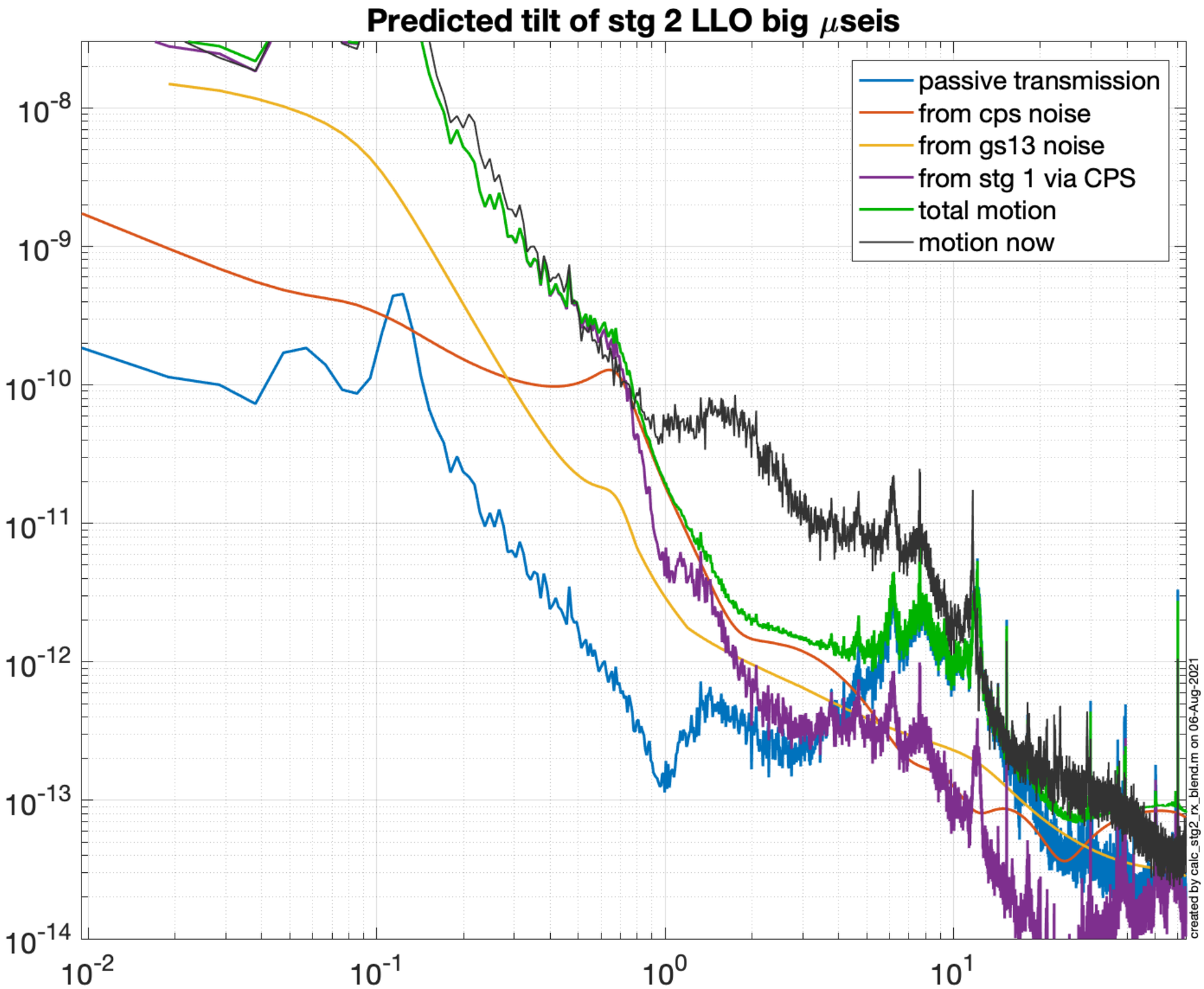
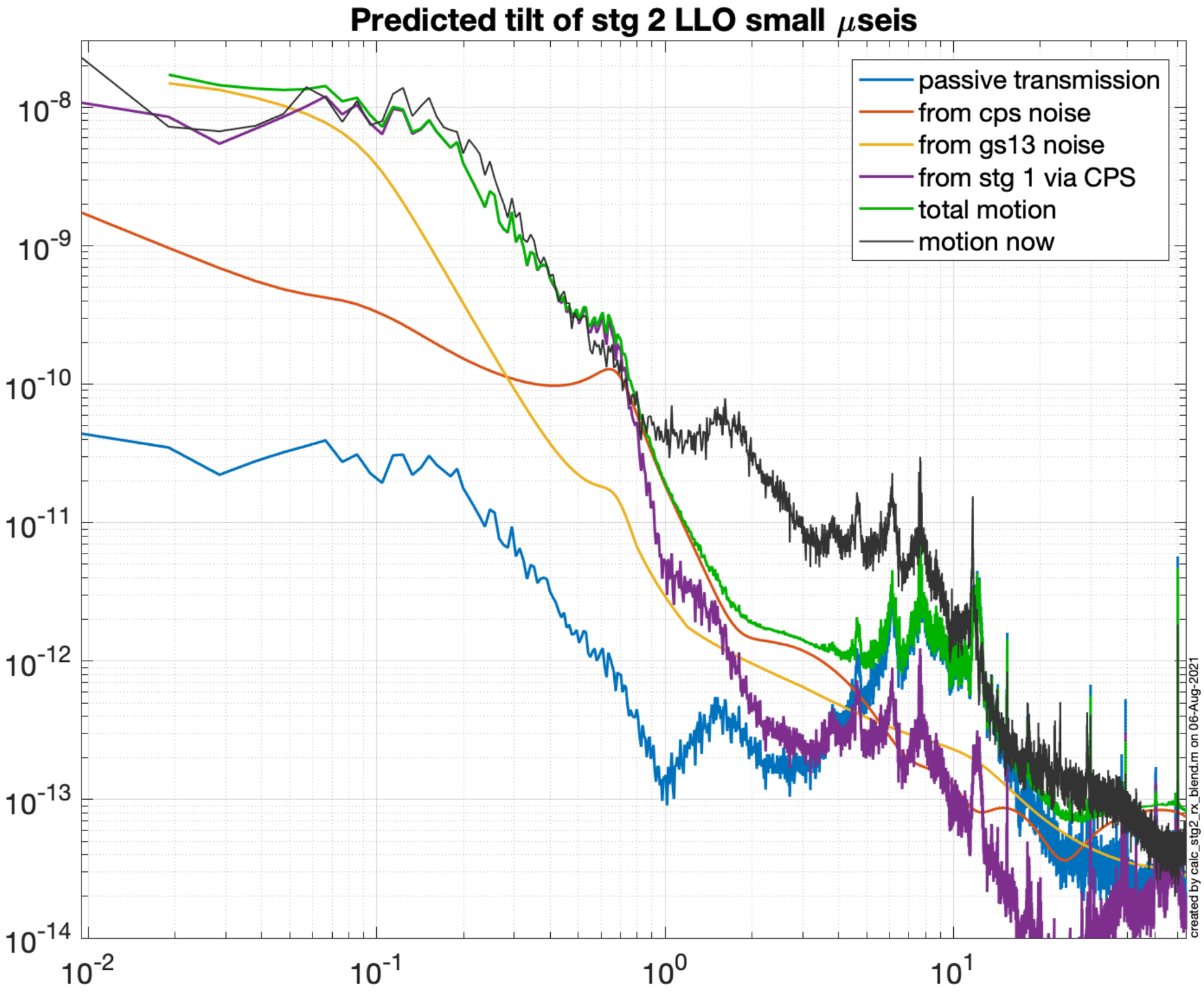
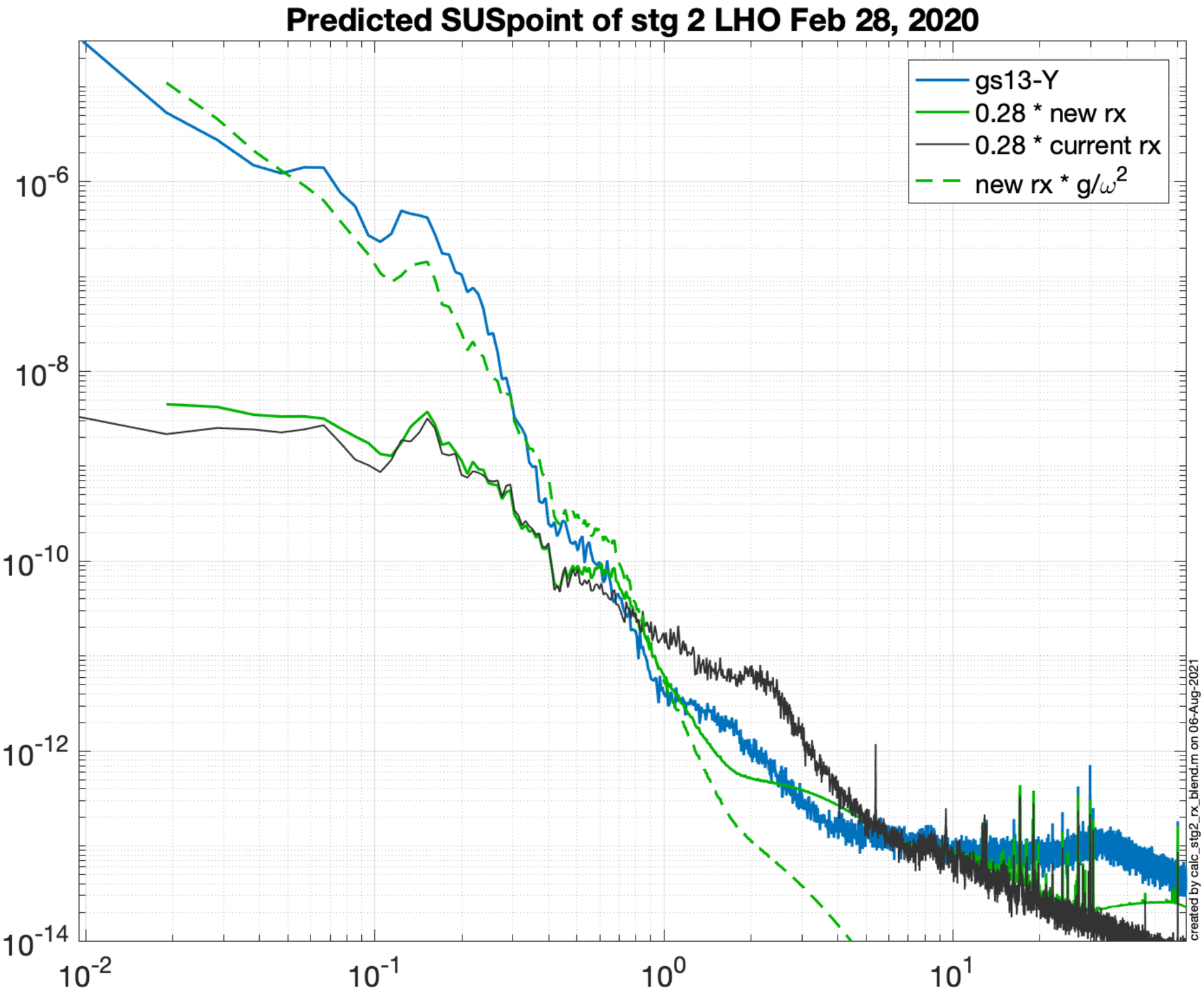


Tilt Performance



SUSpoint performance



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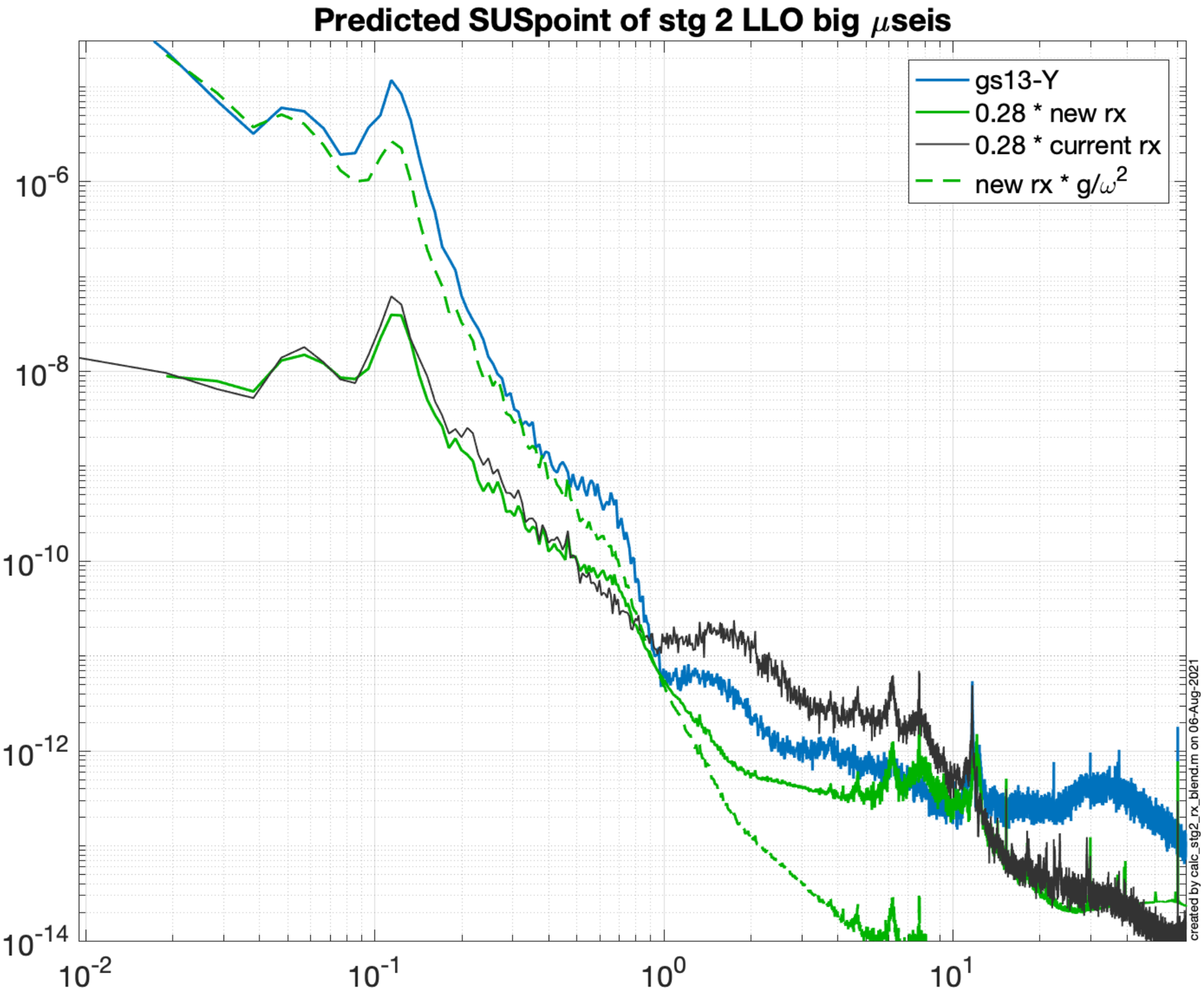

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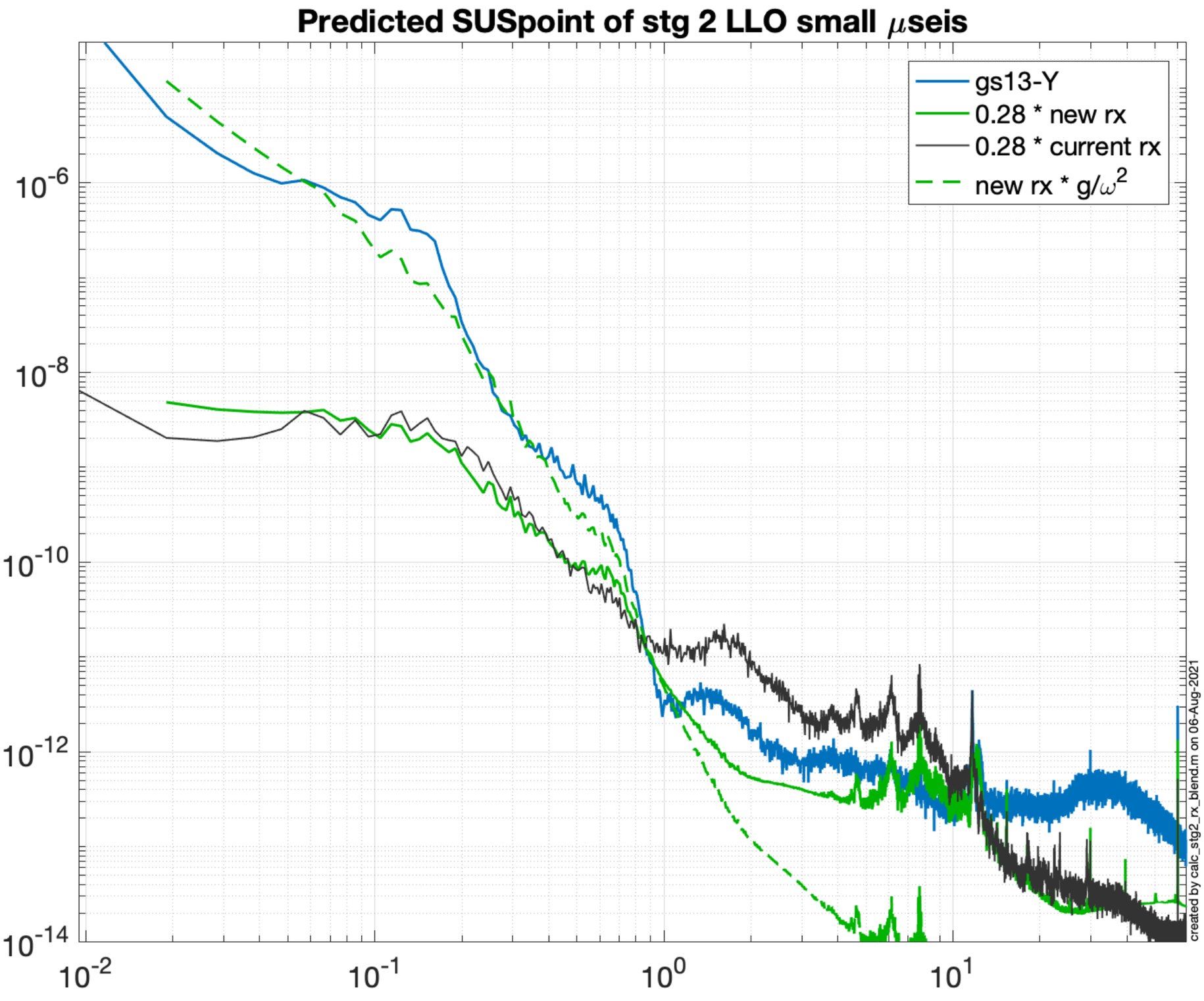


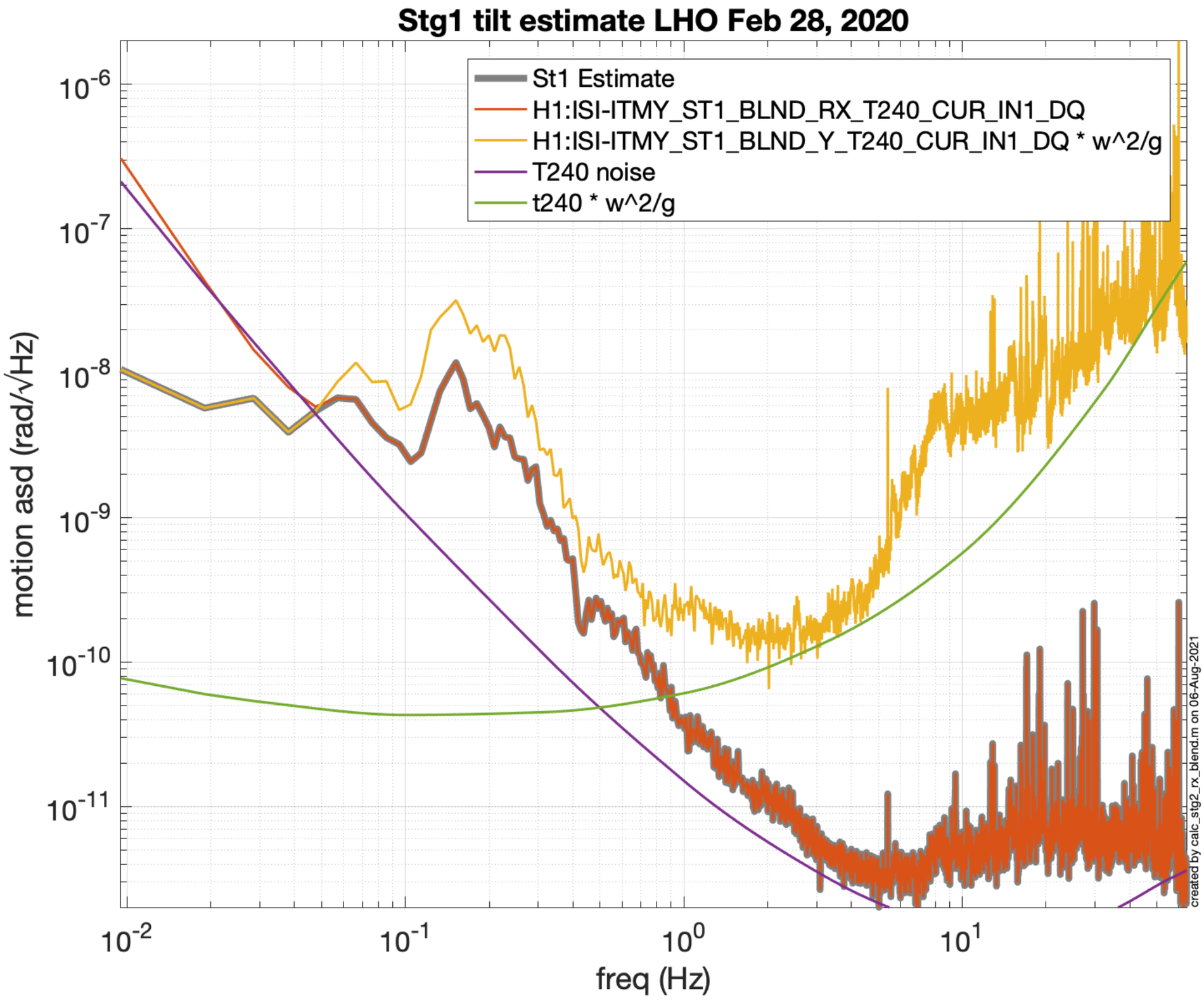
Conclusions

- We should try these filters and check the results
- Watch for change in tilt, and change in SUSpoint motion
- Watch for issues of “badness” which are rumored to have been a problem
- Someone should run the numbers on sensor correction from the T240
  - can this reduce the tilt?
  - Does that allow a different stg 2 blend for X&Y (probably not)
- New tilt estimate tool is pretty useful for analysis
- Someone should look again at the SEI->SUS feedforward

Tilt of stage 1

these are the 3 plots for the tilt estimates of stage 1

Improved tilt estimates - stage 1



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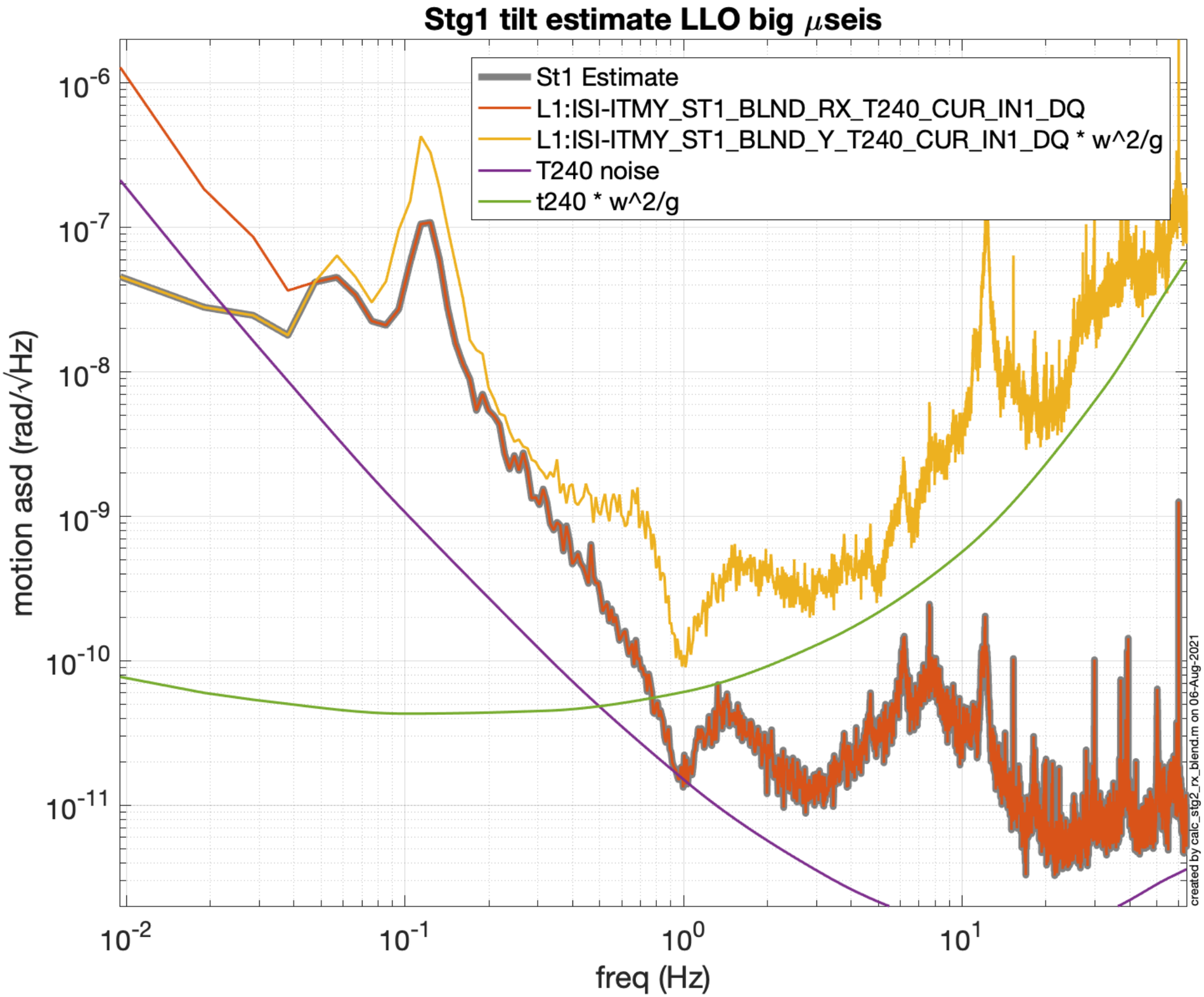

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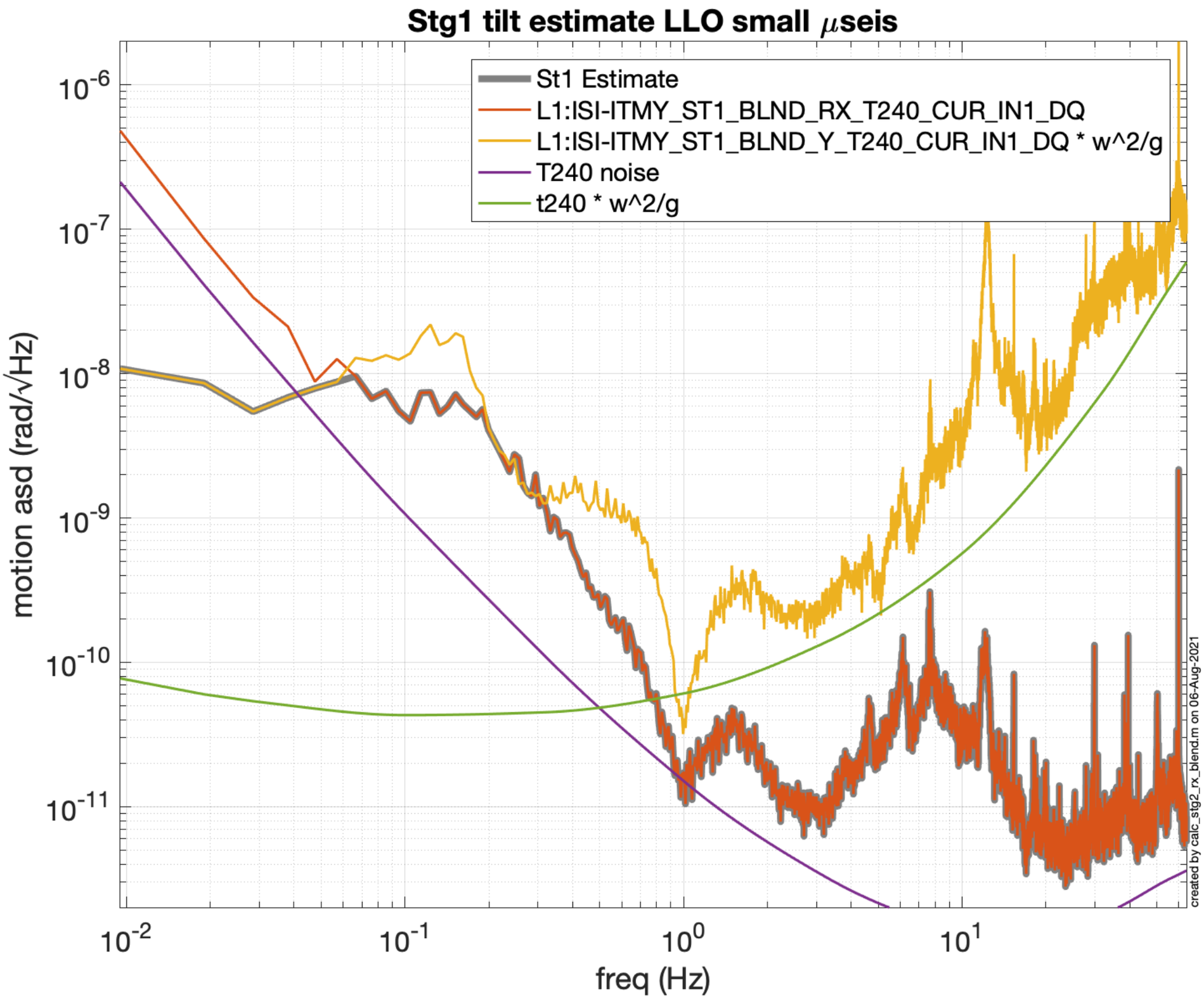
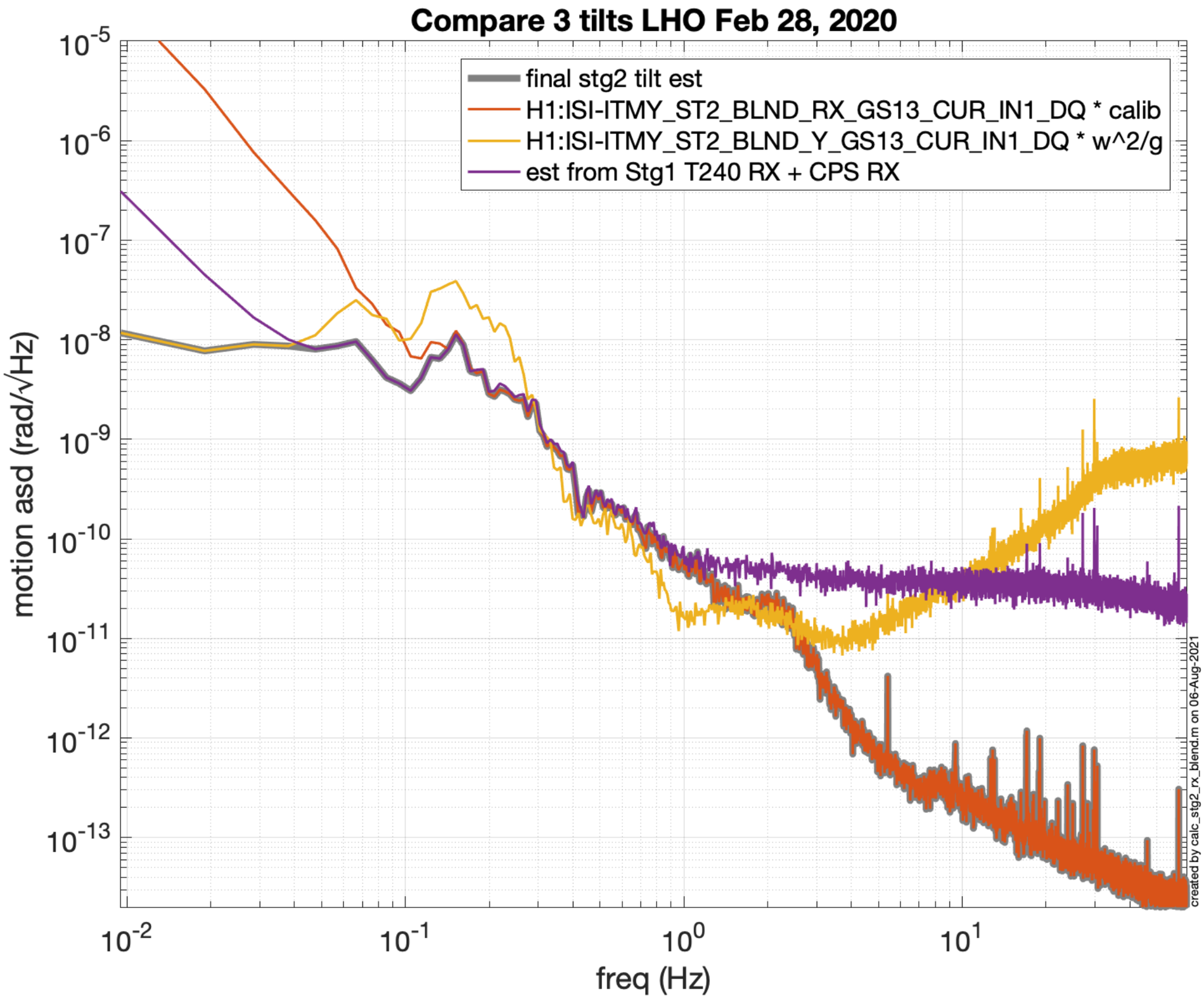


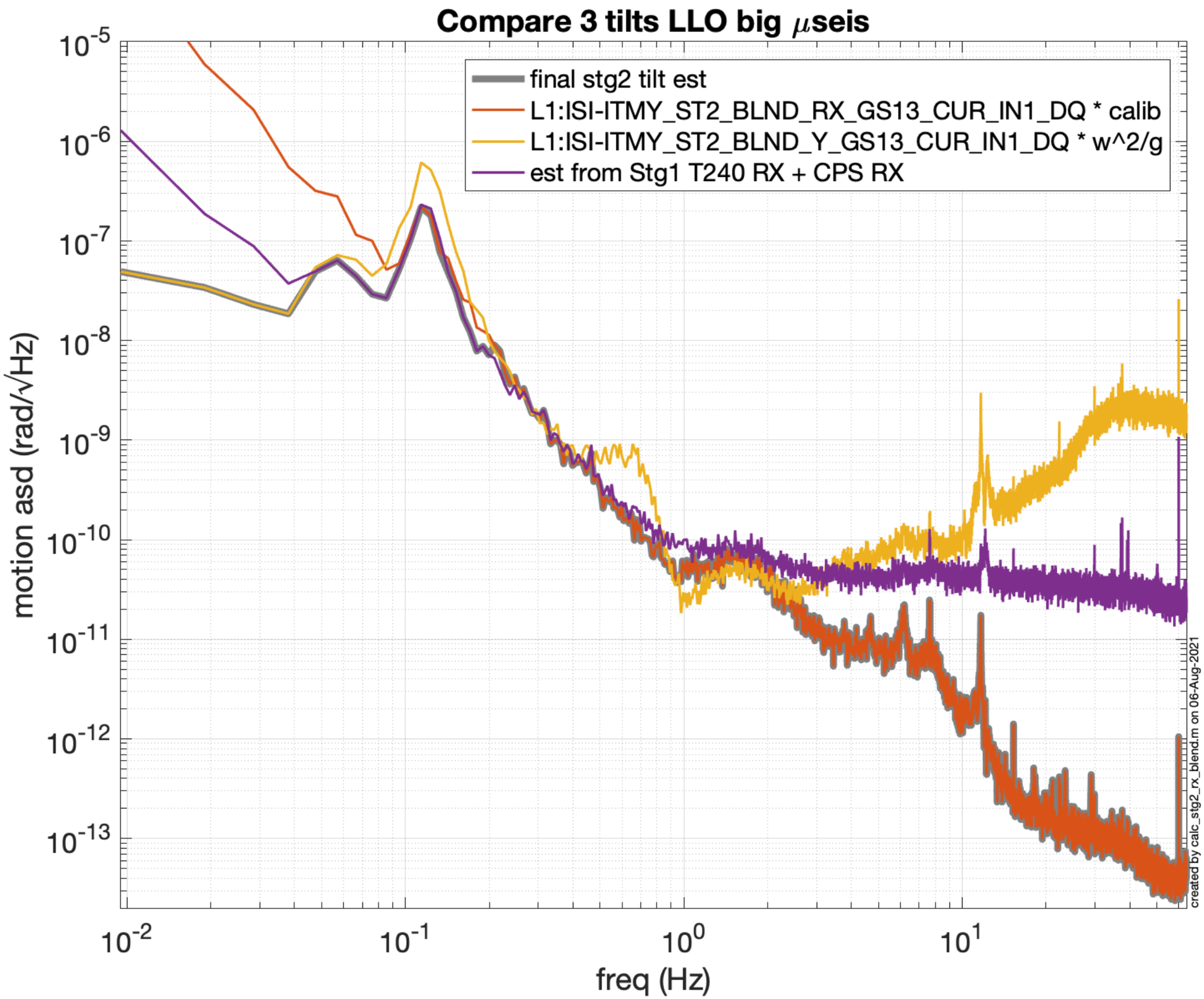
Tilt of stage 2

these are the 3 plots for the tilt estimates of stage 2

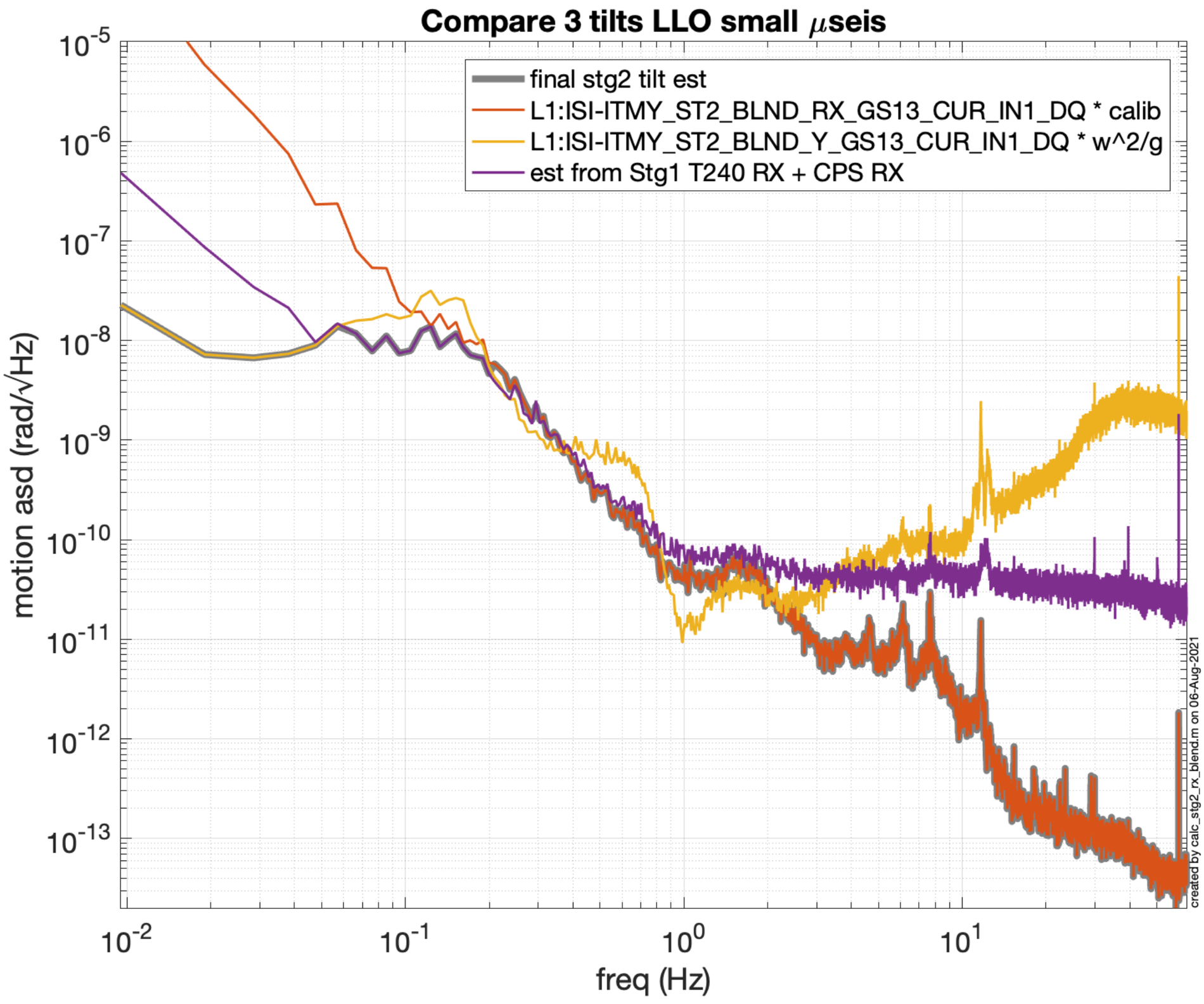
Improved tilt estimates - stage 2



Improved tilt estimates - stage 2



Improved tilt estimates - stage 2



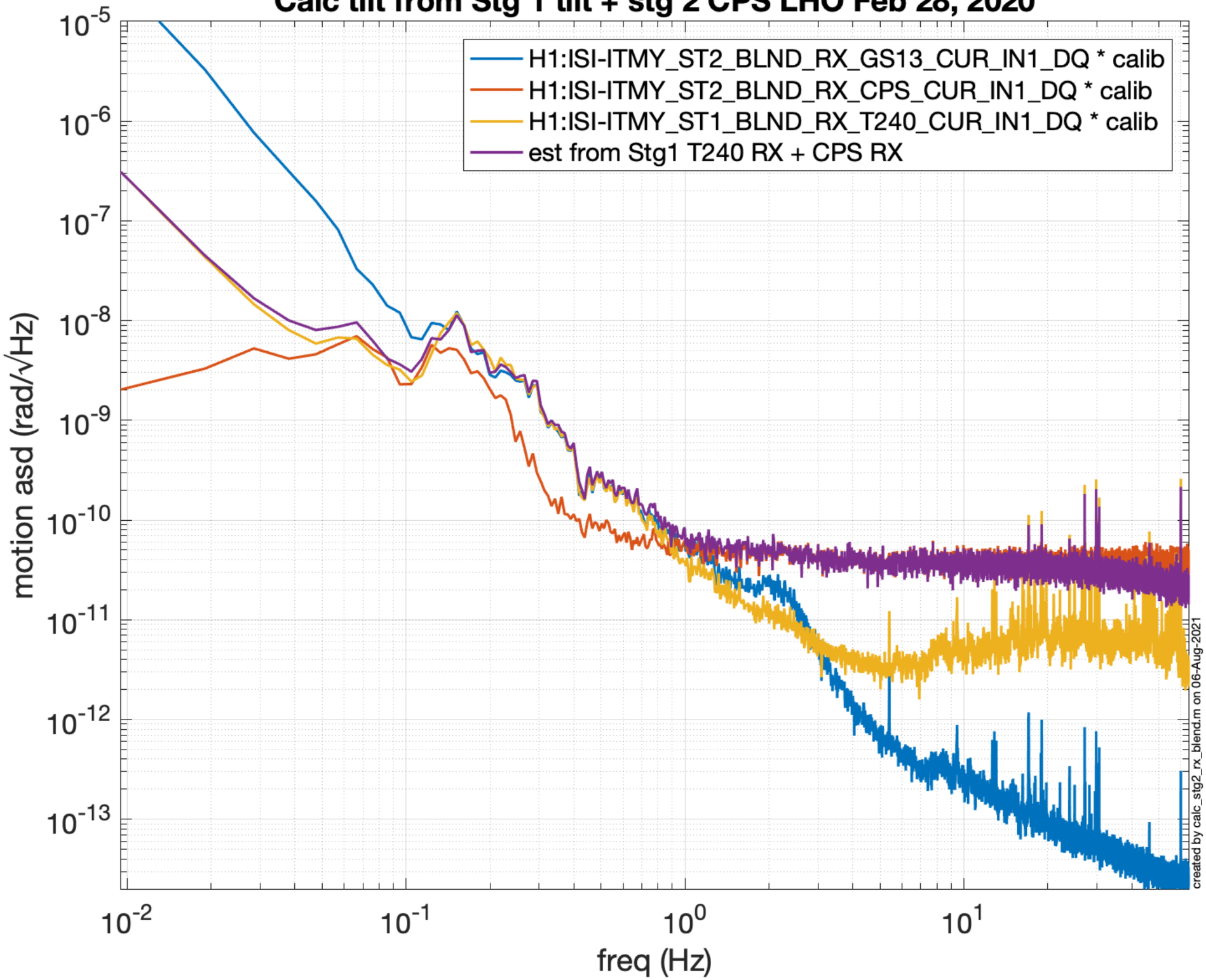
The ‘stg2 synth rx’

The ‘stage 2 synthetic rx’ is generated by adding the stage 1 T240 rX signal and the stage 2 (stage 1 to stage 2) CPS rX signals.
In the code, I did this by running the CPS through lsim with the T240 response, and then adding the T240 and CPS signals time signals.

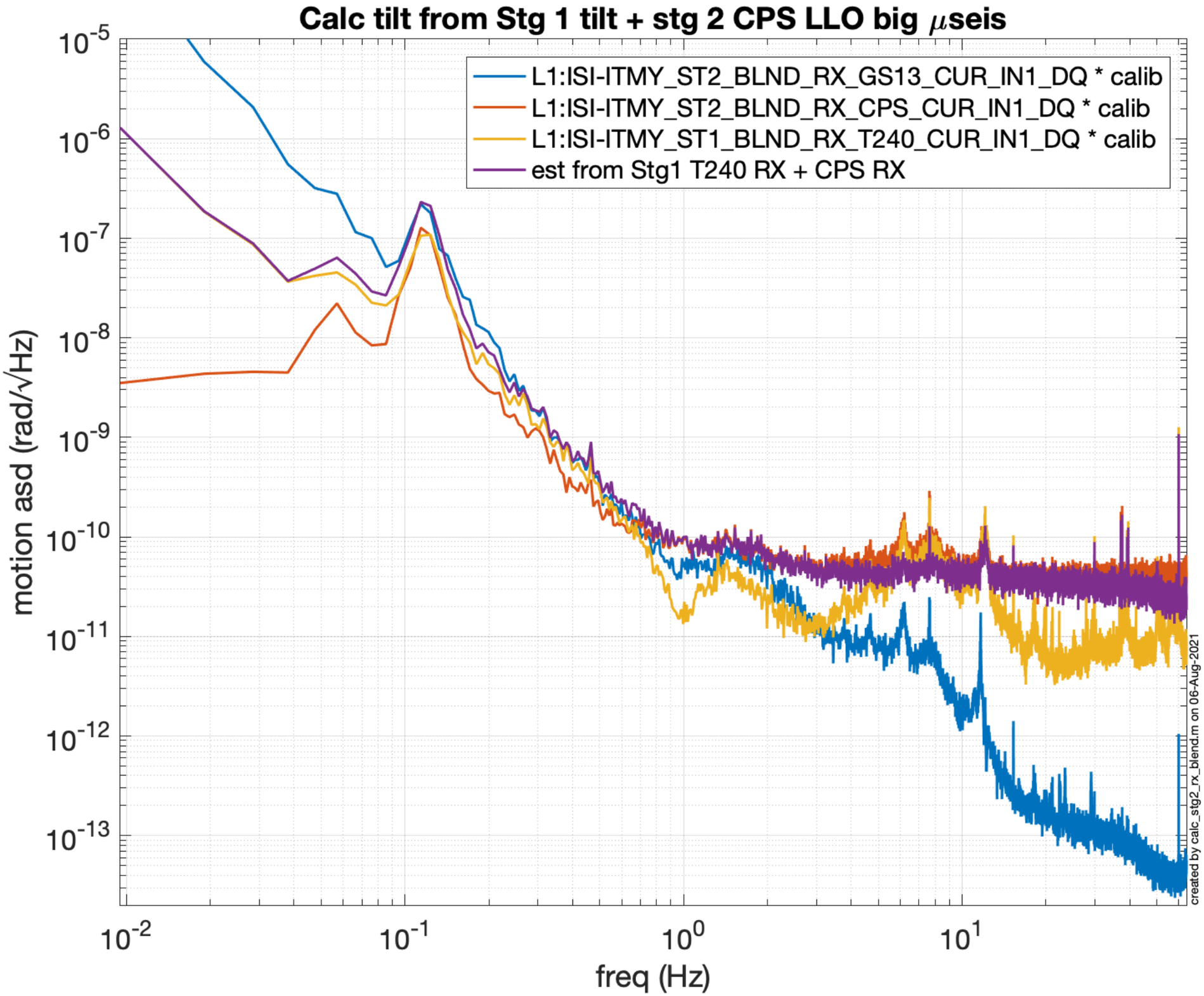
One can test the result by

- comparing ASDs of synth-rx & GS-13 rx
  (it matches well around 0.2 - 0.6 Hz)
- check coherence of synth-rx & GS-13 rx
  (also good in 0.2- 0.6 Hz)
- check coherence of synth-rx and GS-13 Y
  (this is better than GS-13 rX below 0.2 Hz, and worse above)

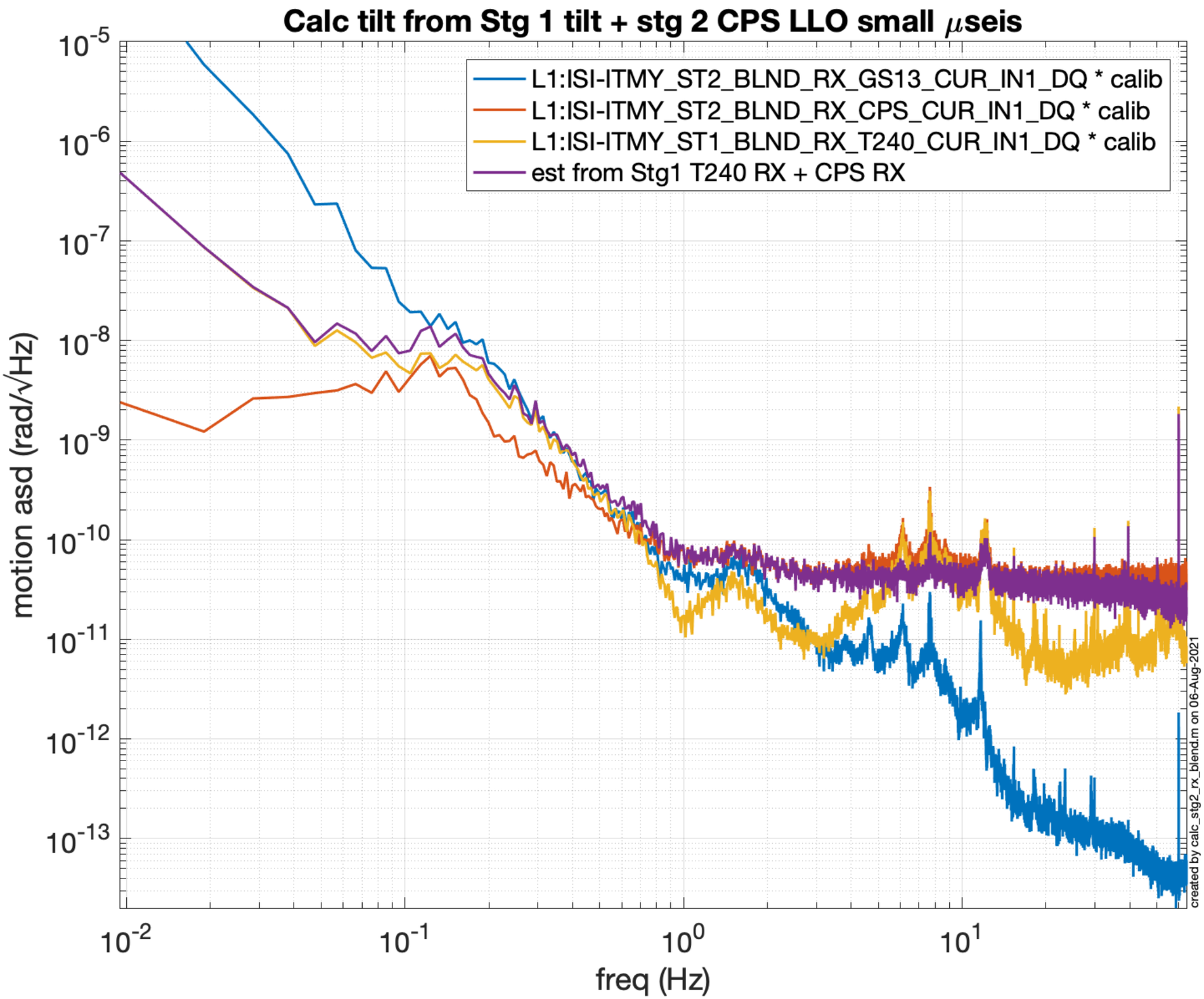
stg 2 tilt from stg 1 T240s



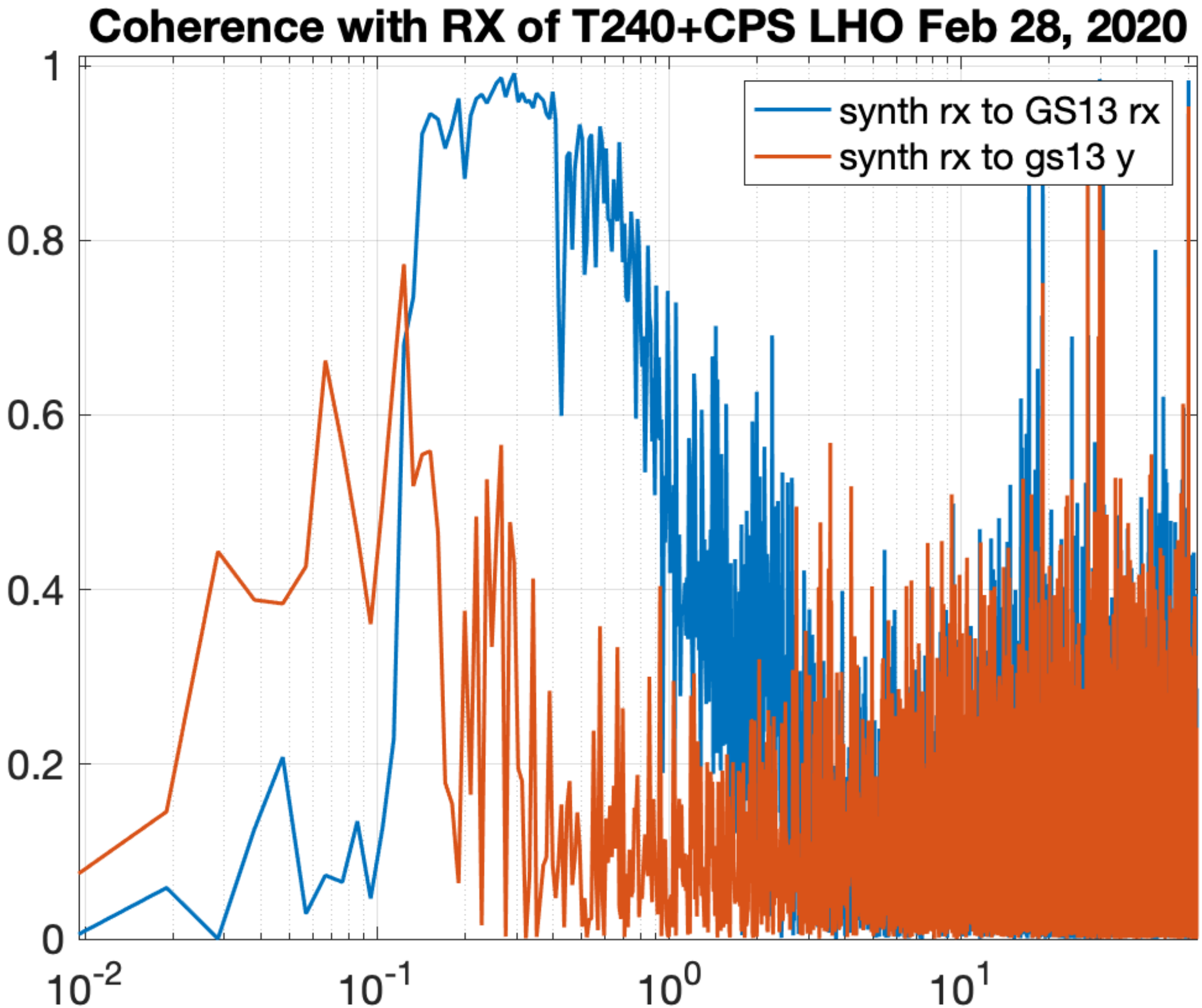
stg 2 tilt from stg 1 T240s



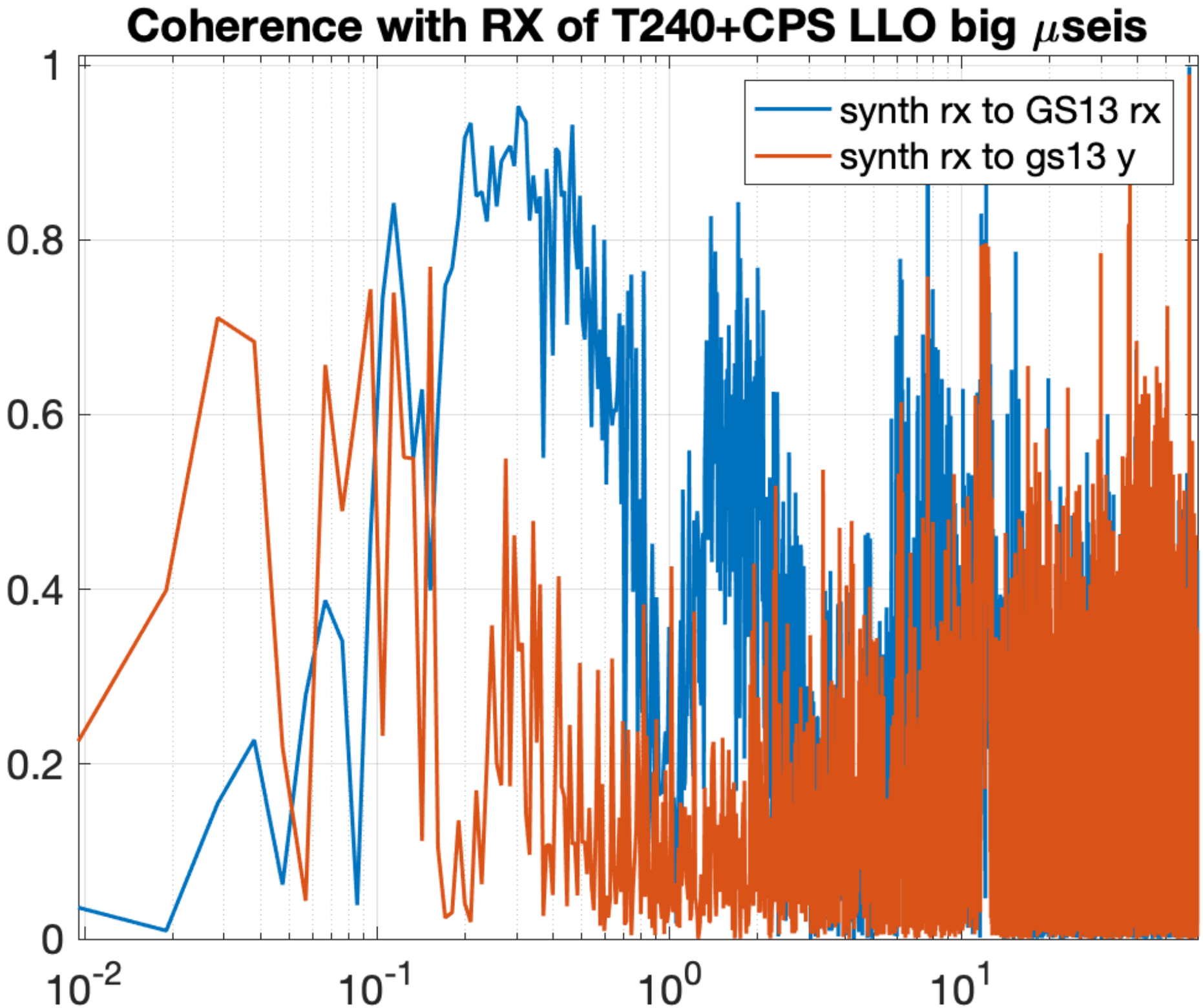
stg 2 tilt from stg 1 T240s



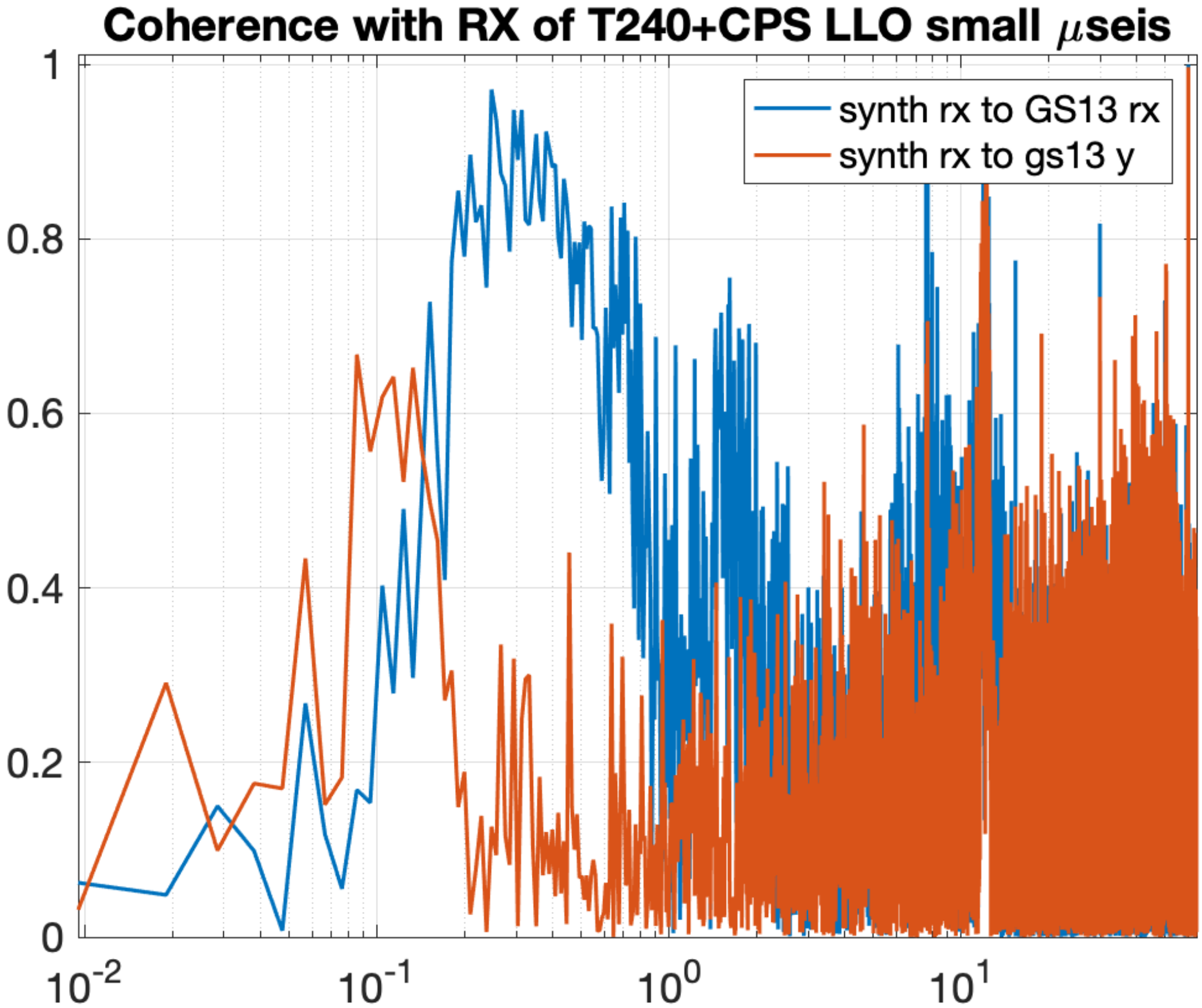
Coherence stg 2 and stg 1+CPS



Coherence stg 2 and stg 1+CPS



Coherence stg 2 and stg 1+CPS



Saved filters

tilt_800 is the new filter name.

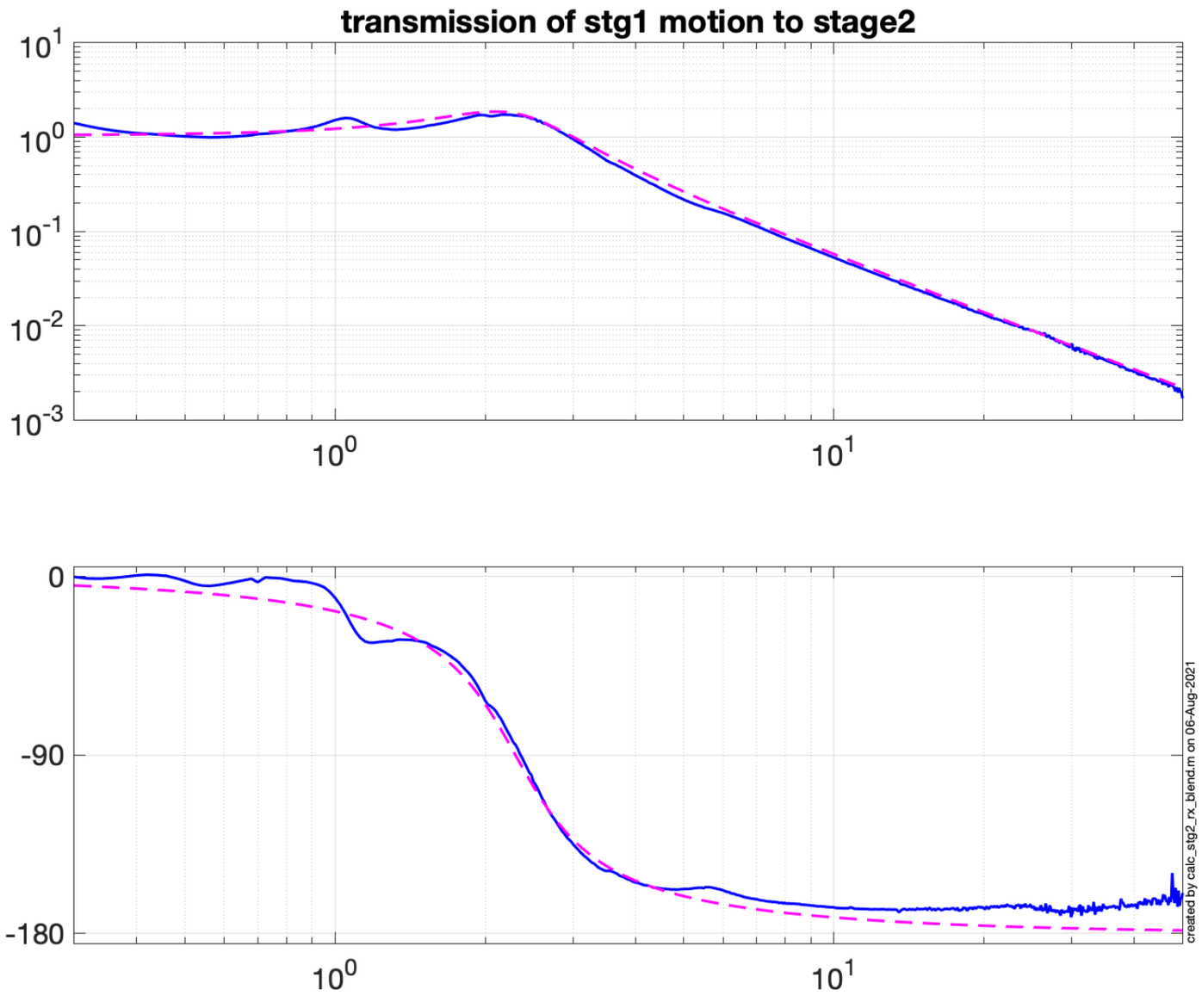
Choose bank 5 for the new filters, seems unused at both sites
(although this is from an older filter file)
should include 8 filters: CUR & NXT, CPS & GS-13, RX & RY

```
>> LLO_filts.ITMX_ST2_BLND_RY_GS13_CUR(:).name
ans = '750mHz'
ans = '<empty>'
ans = '250mHz'
ans ='100mHz'
ans = '<empty>'  -> '1Hz_tilt'
ans = '<empty>'
ans = '<empty>'
ans = '<empty>'
ans = '<empty>'
ans = '250aug'


>> LHO_filts.ITMY_ST2_BLND_RY_GS13_CUR(:).name
ans = 'Start'
ans = 'T750mHz'
ans = '250mHz'
ans = '250mHz'
ans = '<empty>'  -> '1Hz_tilt'
ans = '<empty>'
ans = '<empty>'
ans = '<empty>'
ans = '<empty>'
ans = '<empty>'
```

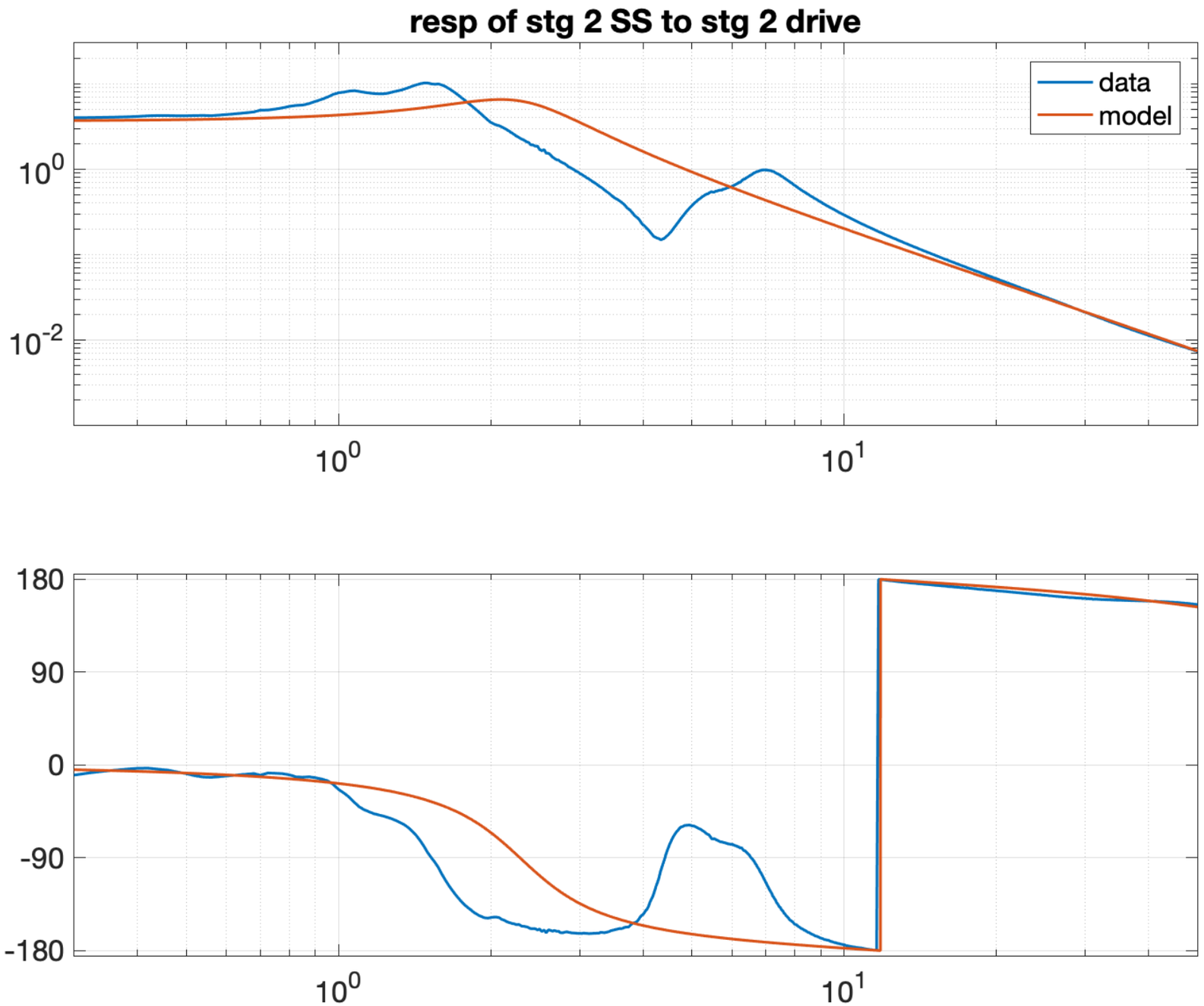
Plant model

Plant data from
Mechanical plant (Passive transmission) is stage 2motion / stage 1 motion.
Calc as (stg 2 resp/ stg 1 drive) / (stg 1 resp/ stg 1 drive)
2 poles at 2.3 Hz, 73 degrees.



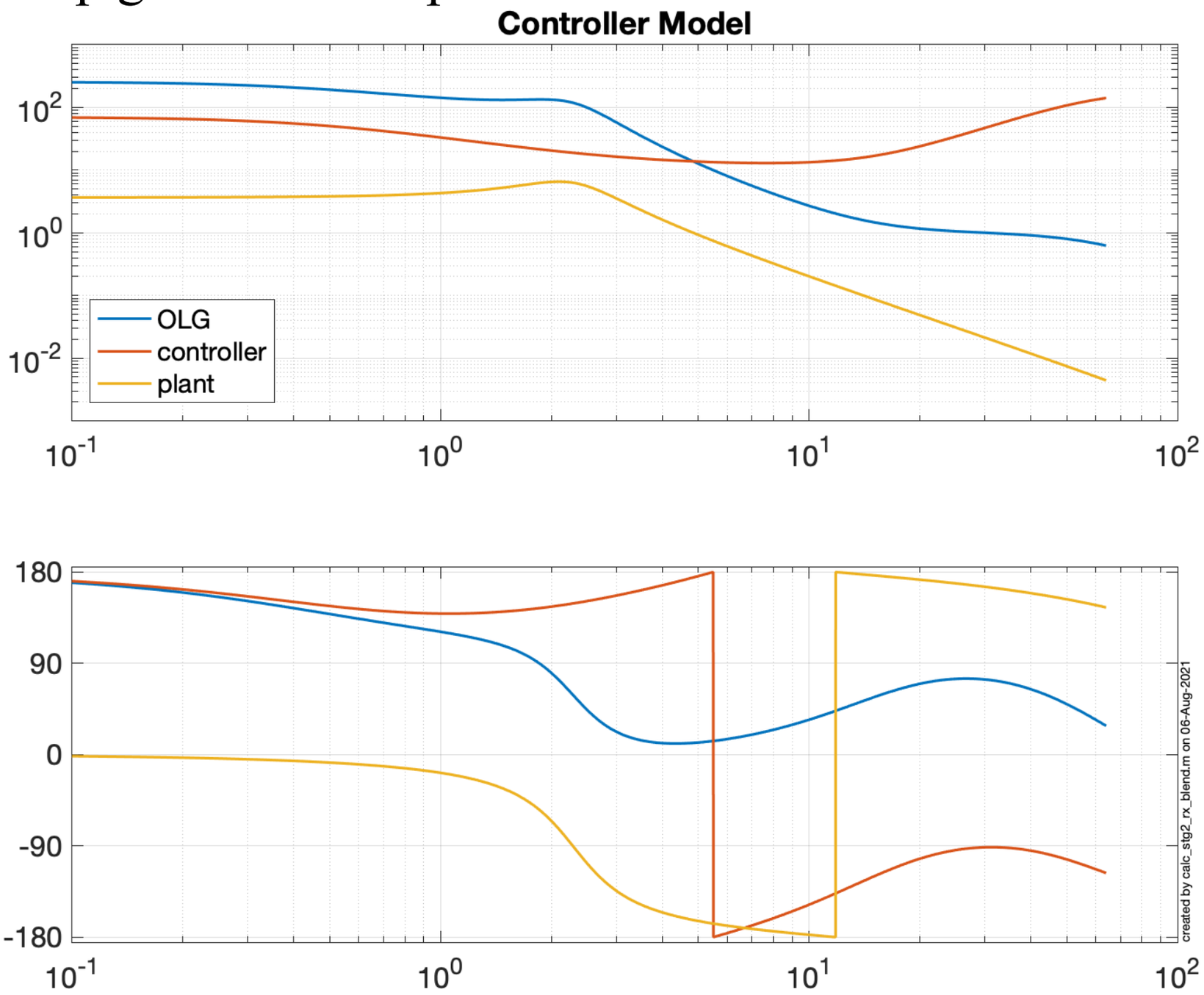
Control Plant

The control plant is the mechanical plant scaled to match the driven TF of (stage 2 SS/ stage 2 drive) at 30 Hz.



Isolation loop

Simple controller, since the plant model is too simple above 30 Hz.
30 Hz upper unity gain, 10 Hz gain of ~ 3
- limited loop gain limits rx performance about ~ 5 Hz



Open loop gain and Sensitivity