Measurement and Mysteries of SRCL noise

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at the CSWG
special thanks to Anamaria and Jenne

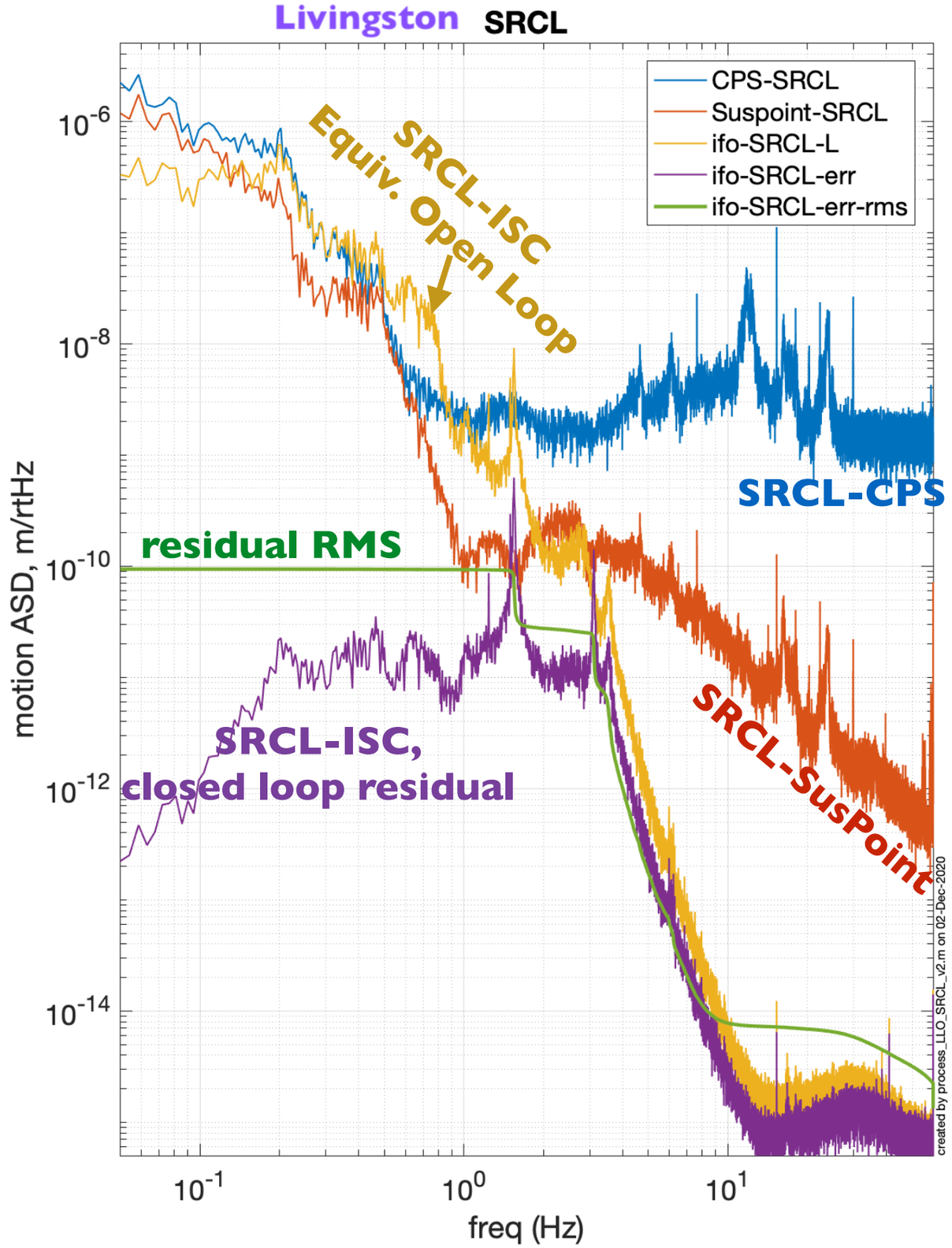
Why look at SRCL?

- All the aux DOFs impact noise in DARM
- When I first looked, SRCL Length was worst offender at LHO
- ISI motion dominates below ~0.7 Hz. I think we should install SPI length and angle controls between the ISIs to stabilize the relative motion below 1 Hz (see e.g. G2001539)
- Noise above 30-40 Hz is from the optical sensing of SRCL
- 1-4 Hz strongly correlated with MICH controls.
- OSEM noise is critical from 4-10 Hz.
- Ways to reduce SRCL coupling to DARM -
  - reduce inputs to SRCL noise and motion
  - reduce the SRCL bandwidth
    = improves DARM if SRCL is sensor noise, but not if it's real motion.
  - improve the SRCL FF - low freq. stability helps this.

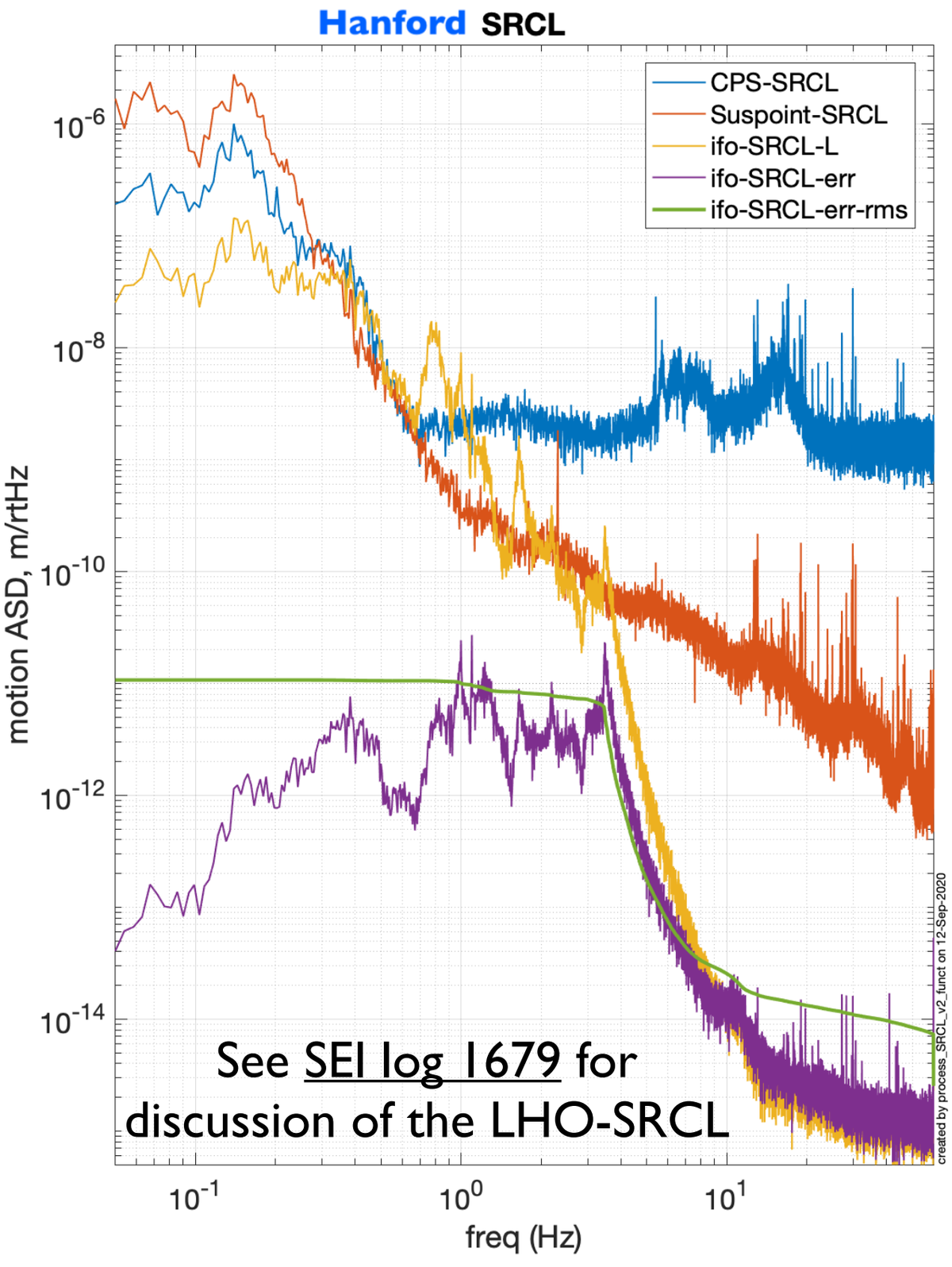
LLO SRCL control

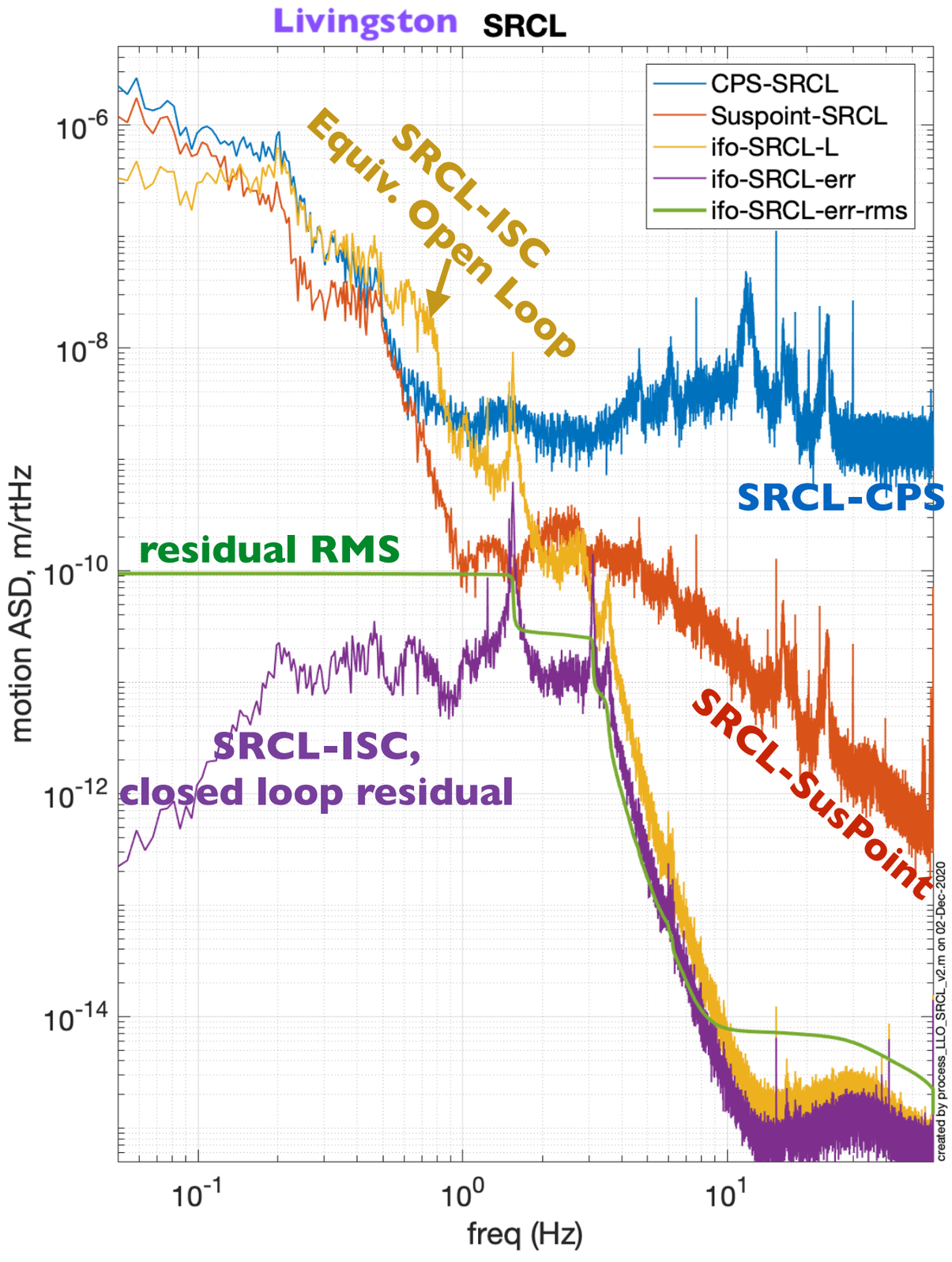
- 3 measures of SRCL (ISI-CPS, ISI-GS-13, and SRCL IFO signals) are reasonable consistent, so the calibration is not crazy.
- How can we reduce the bandwidth of the SRCL loop?
- RMS now dominated by:
  - SRC optic OSEM noise from 4-10 Hz
  - Peaks at 1.55, 3.11, & 3.53 Hz.
  - LF motion (from ISI) suppressed by loop
    less bandwidth would change this
- Motion below 10 Hz is real motion, so SRCL loop gain here is good.

Data from Feb 2020, see SEI log 1692 for details
Anamaria has recently updated the
ISC calibration by ~15%, not reflected here.

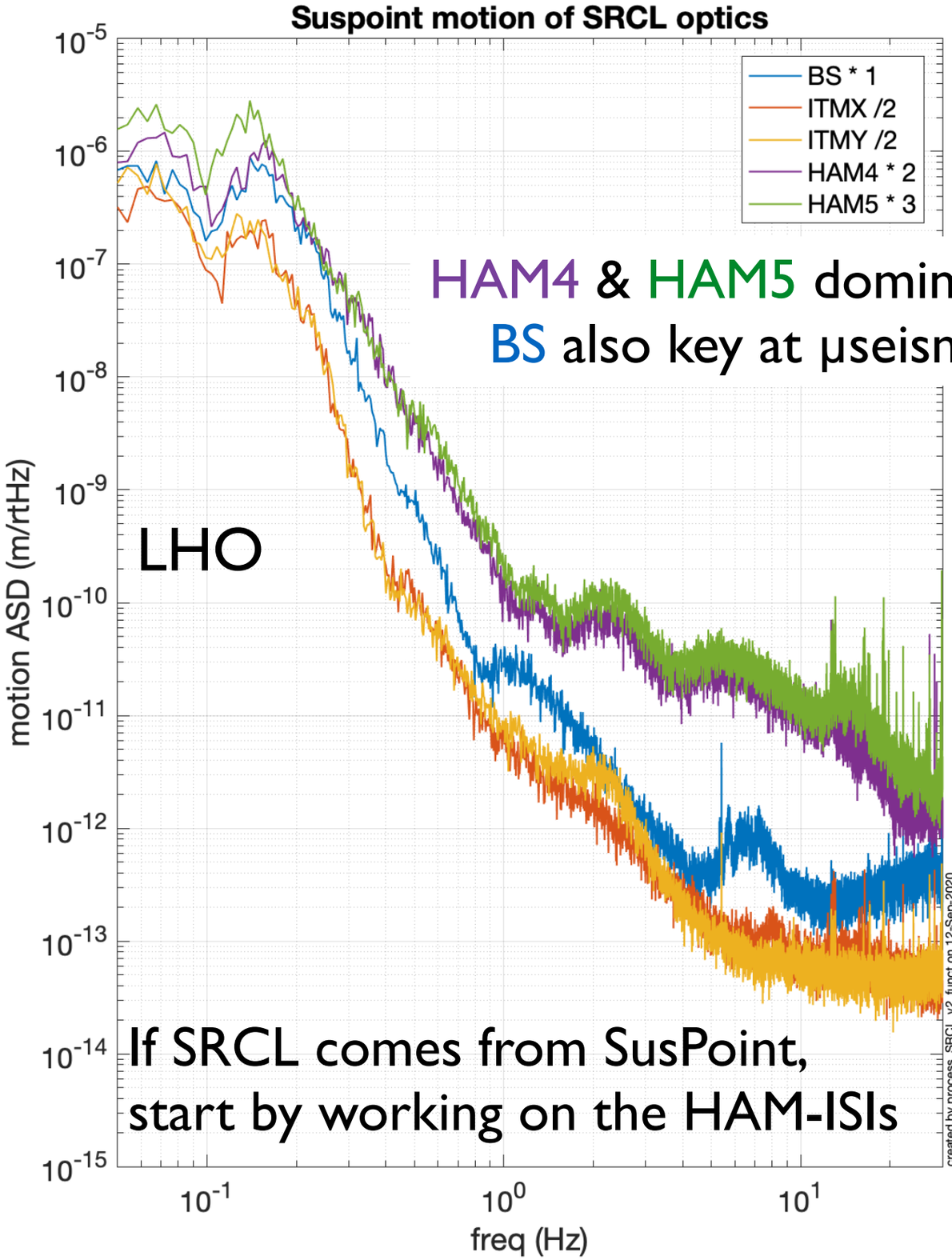


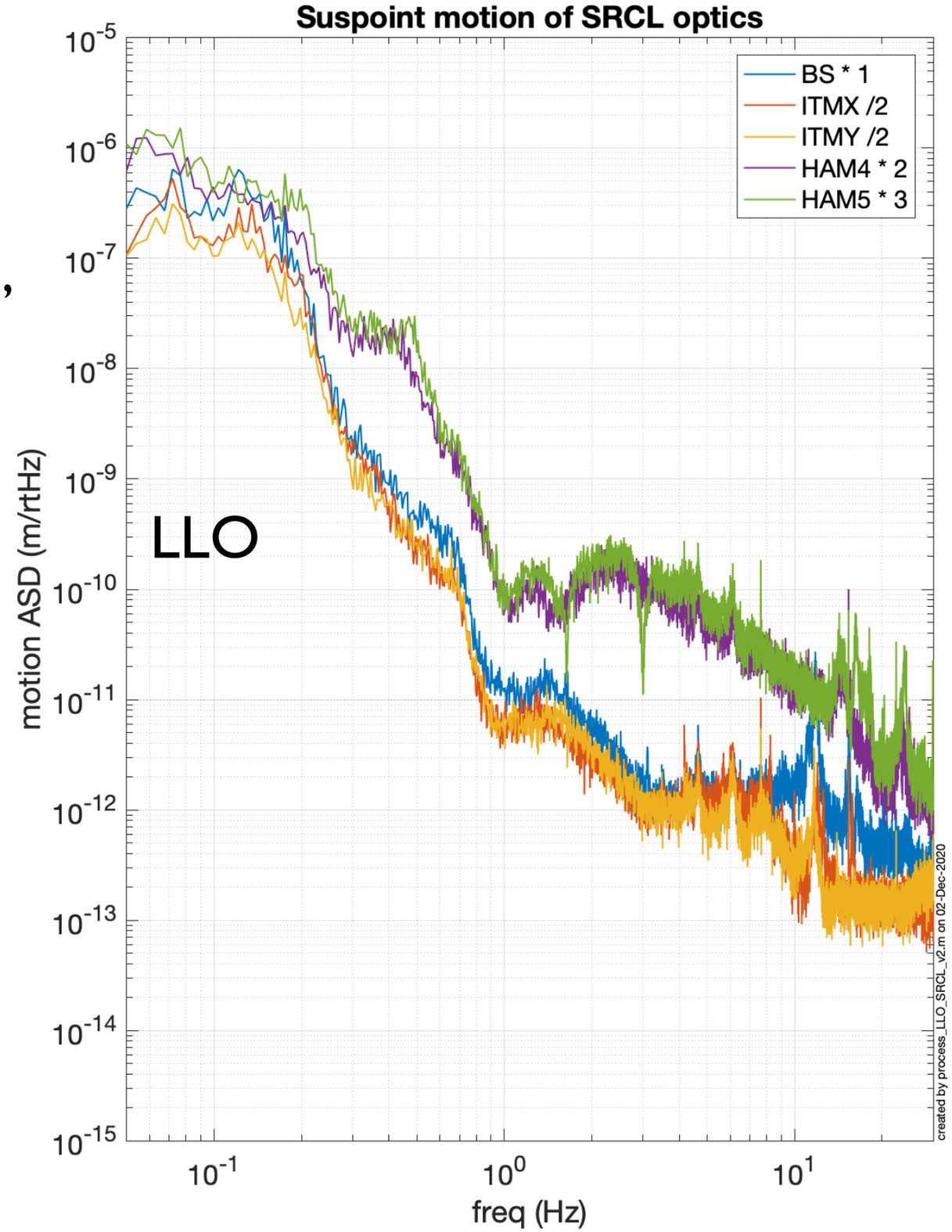
LHO is ~similar





SusPoint motion of SRCL



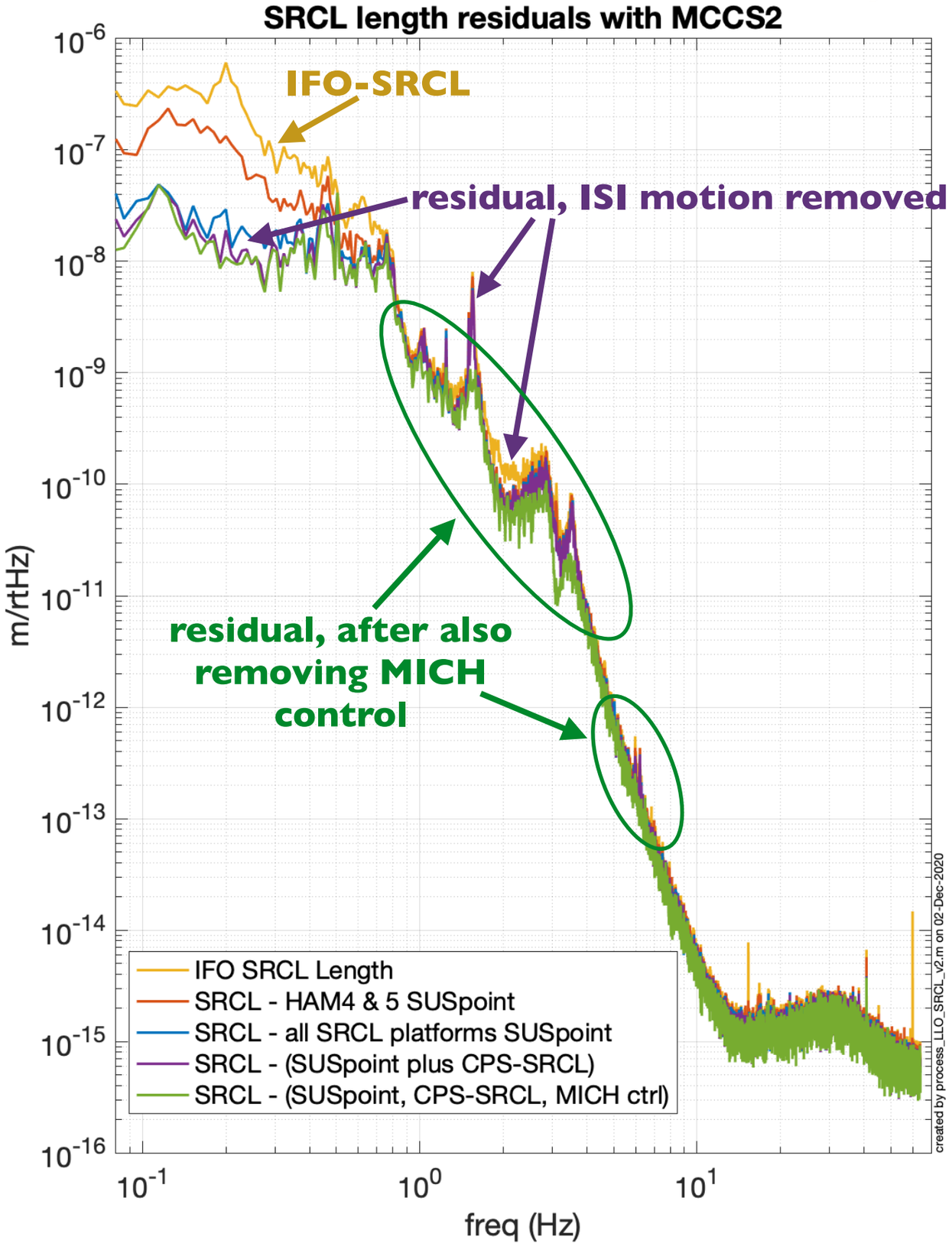


HAM4 & HAM5 dominate,
BS also key at μseism

If SRCL comes from SusPoint,
start by working on the HAM-ISIs

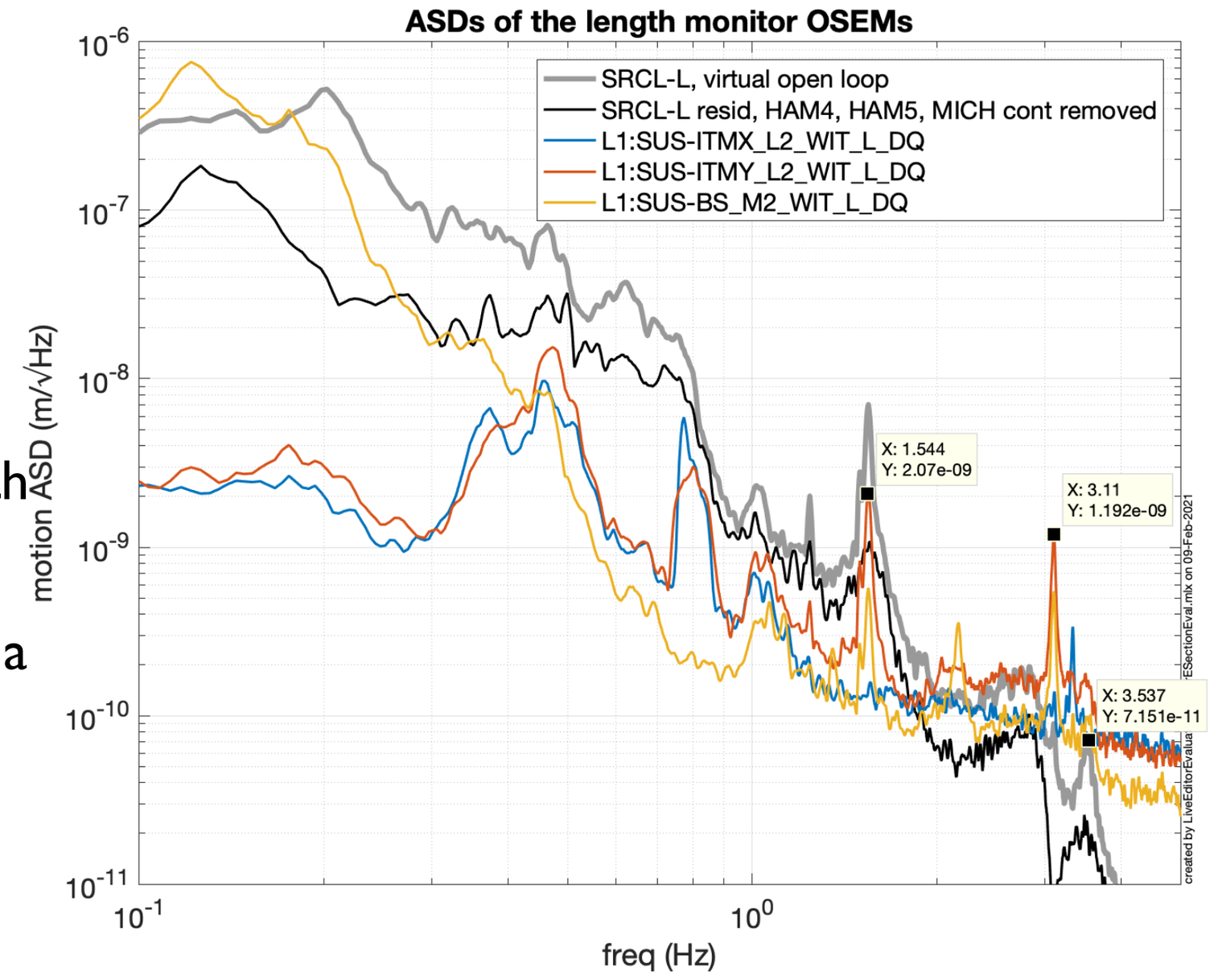
Use residuals to ID noise sources

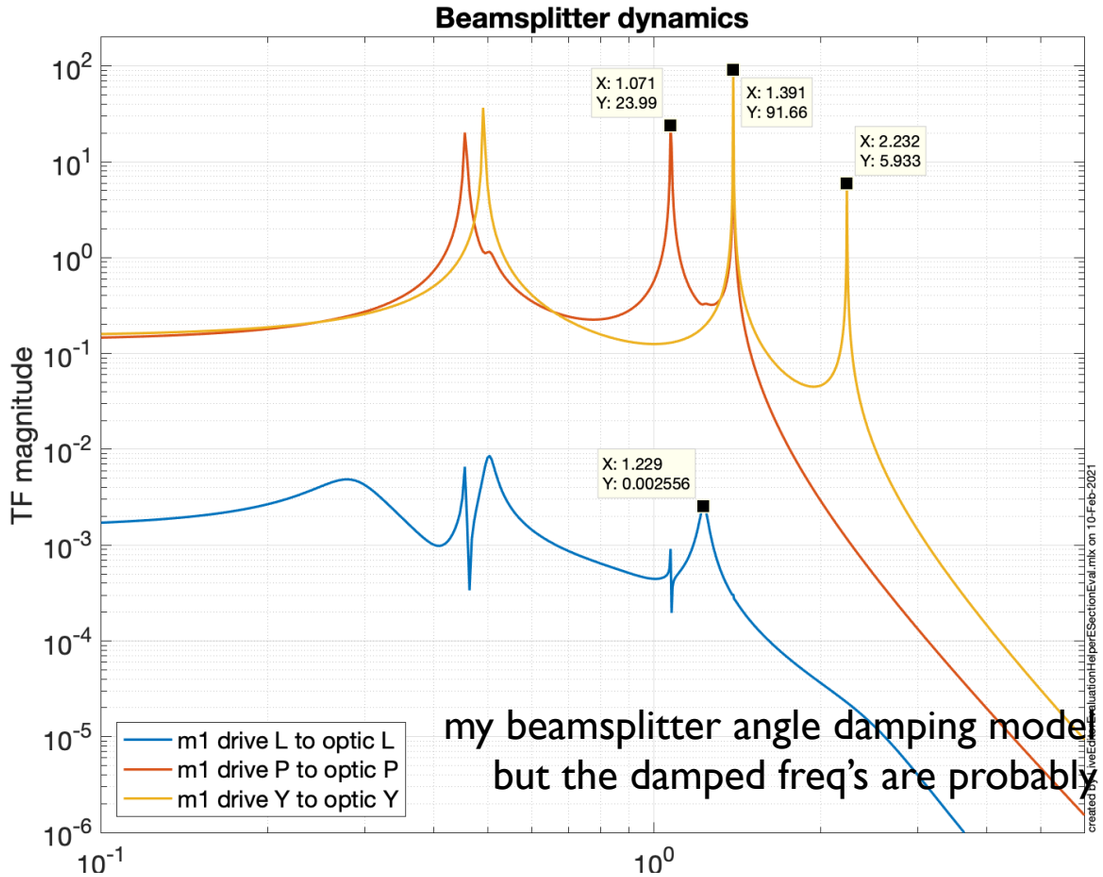
- Look at the equiv. open loop SRCL, remove various signals w/ MCCS2 and look at what's left.
- Compare yellow to Purple, Removing ISI motion helps below 0.7 Hz, and around 2 Hz.
- ISI removal doesn't help the 1-4 Hz peaks
- Purple to Green
  - also remove MICH control,
- Notice peaks at 1.55, 3.11, & 3.53 Hz



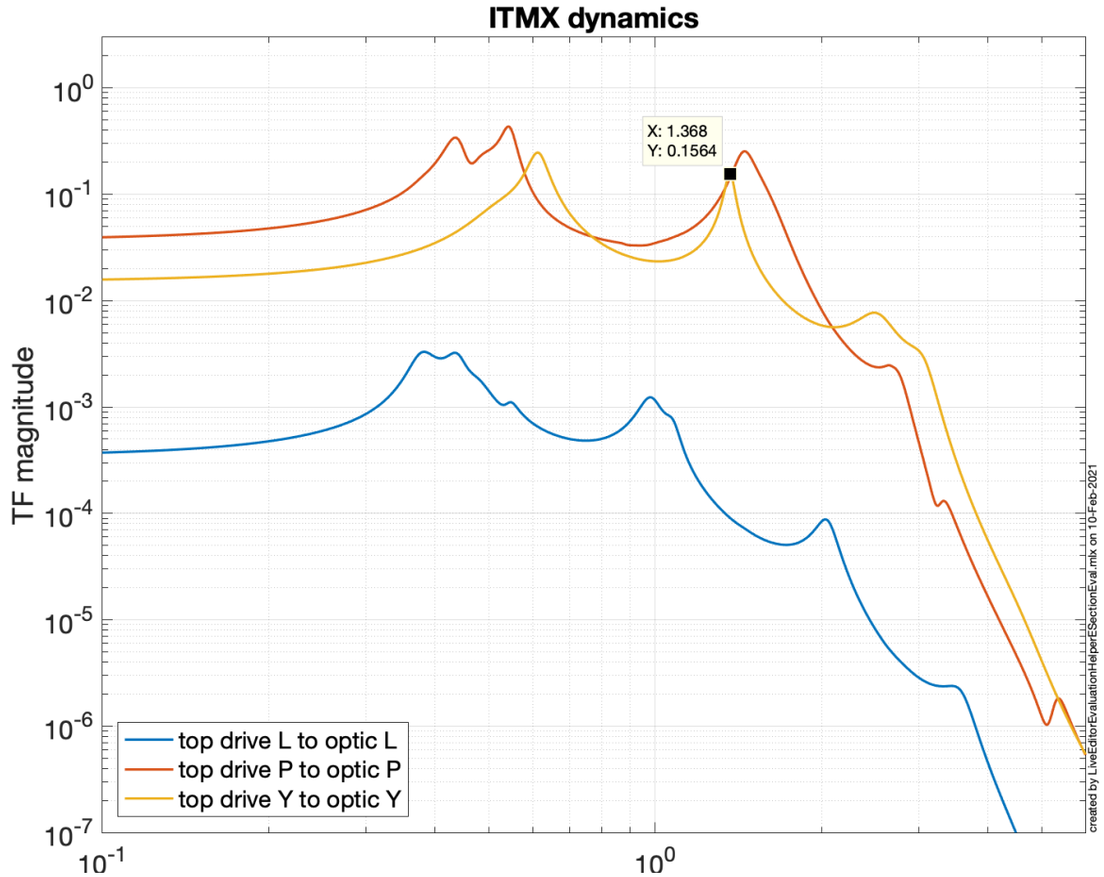
1-4 Hz, MICH control

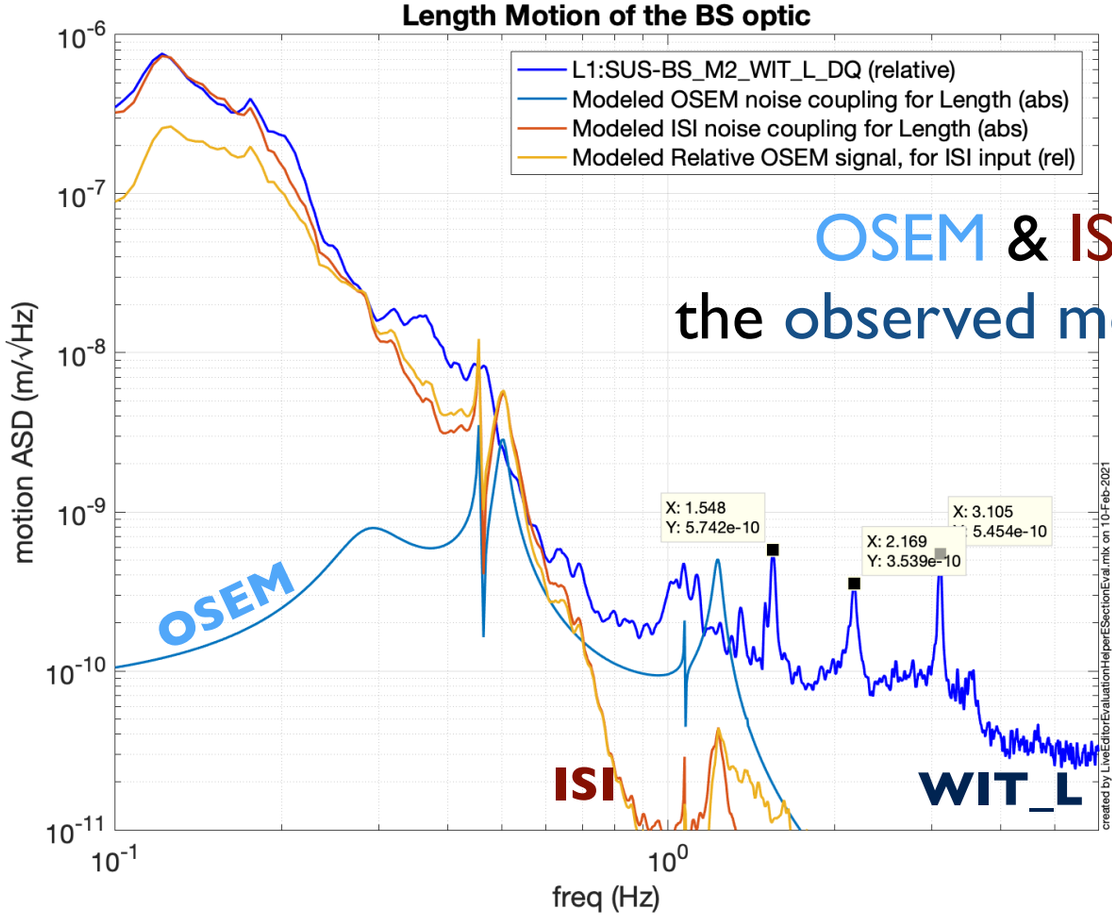
- Residual only shows correlation, not causation
- SRCL peaks are at 1.55, 3.11, & 3.53 Hz
- 1.55 and 3.11 appear on the beamsplitter and ITMY Length Osems - but these are not Length modes of ITMY or beamsplitter)
- A good MICH analysis would be a good next step.
- Likely related to ISC controls, since it is not a simple relationship to the ISI motion or OSEM noise.
- No obvious matching of peaks - maybe related to ASC?



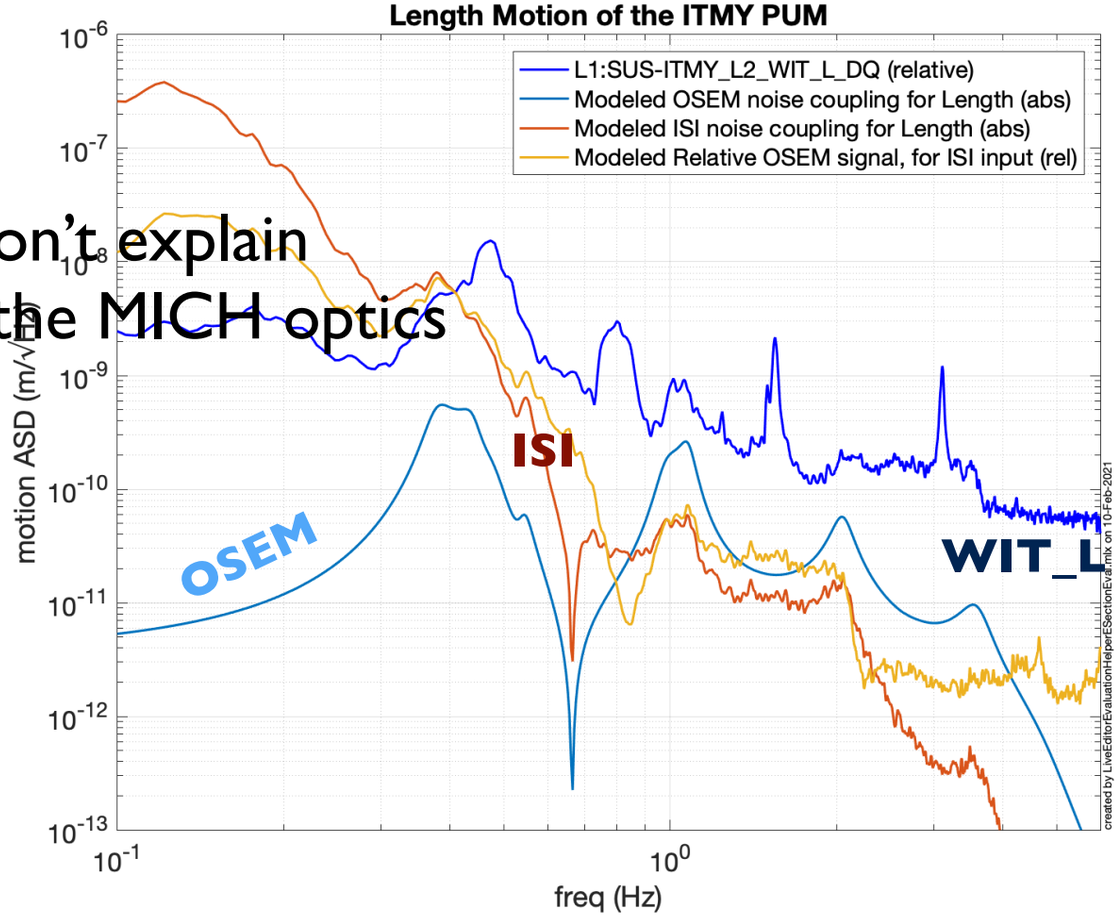


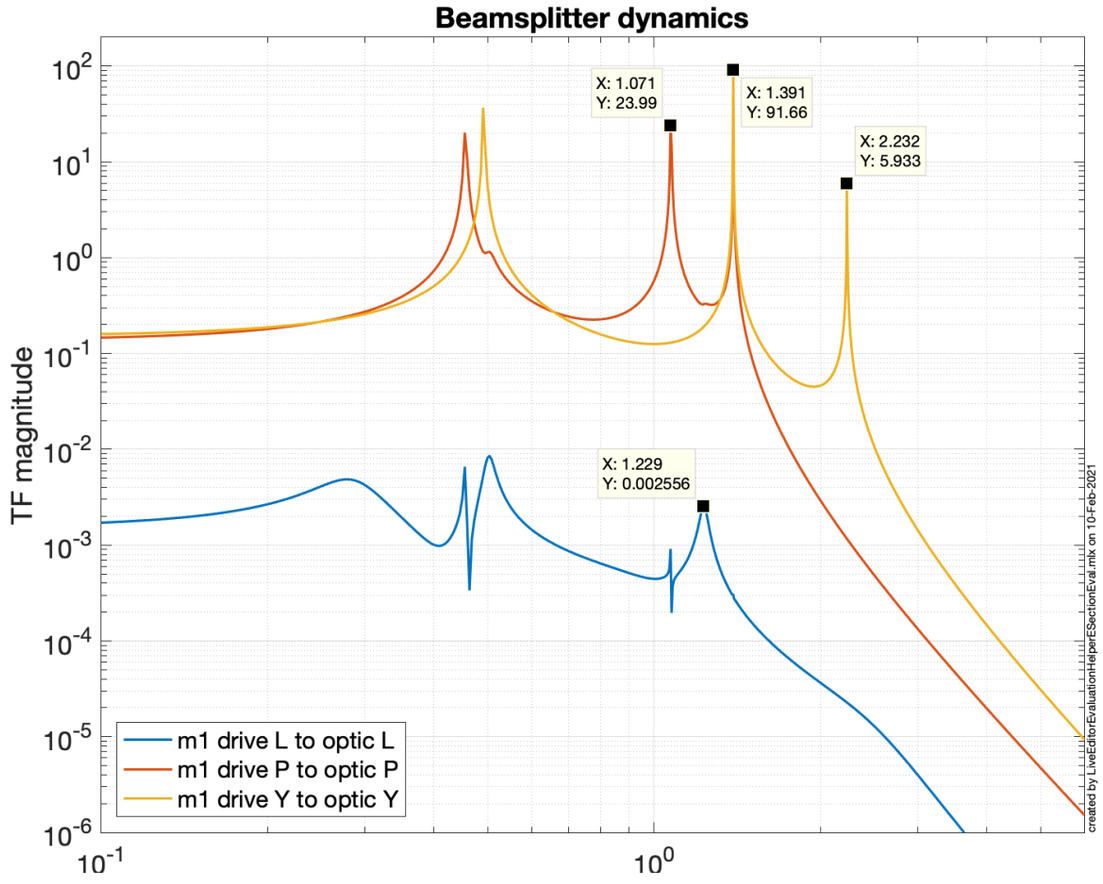
my beamsplitter angle damping mode is busted,
but the damped freq's are probably similar

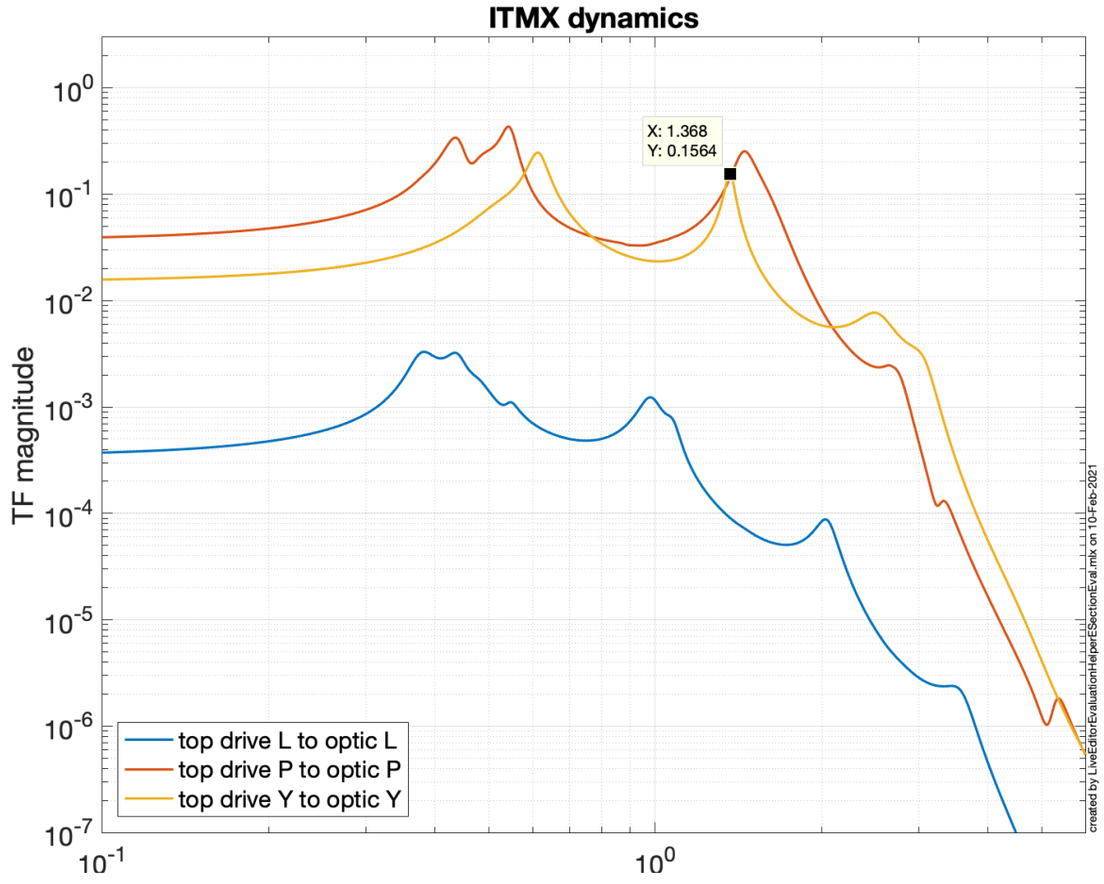


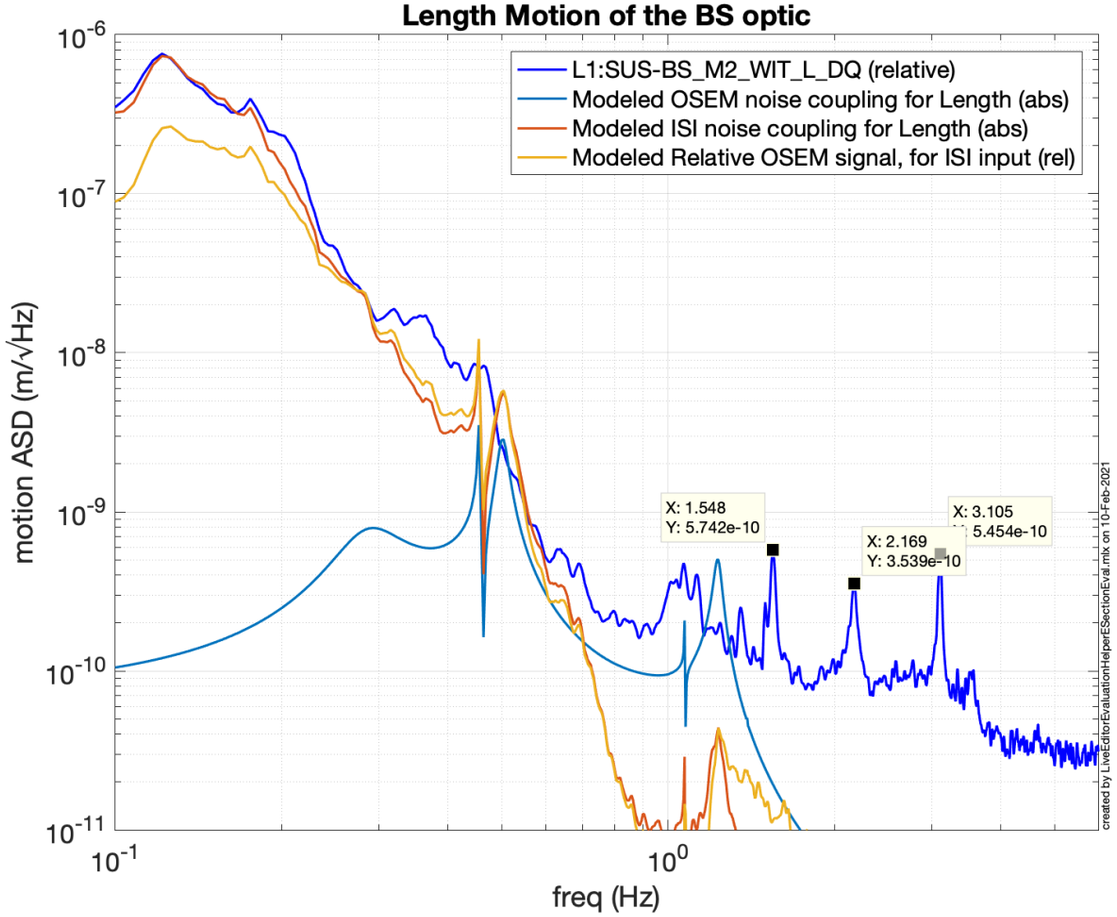


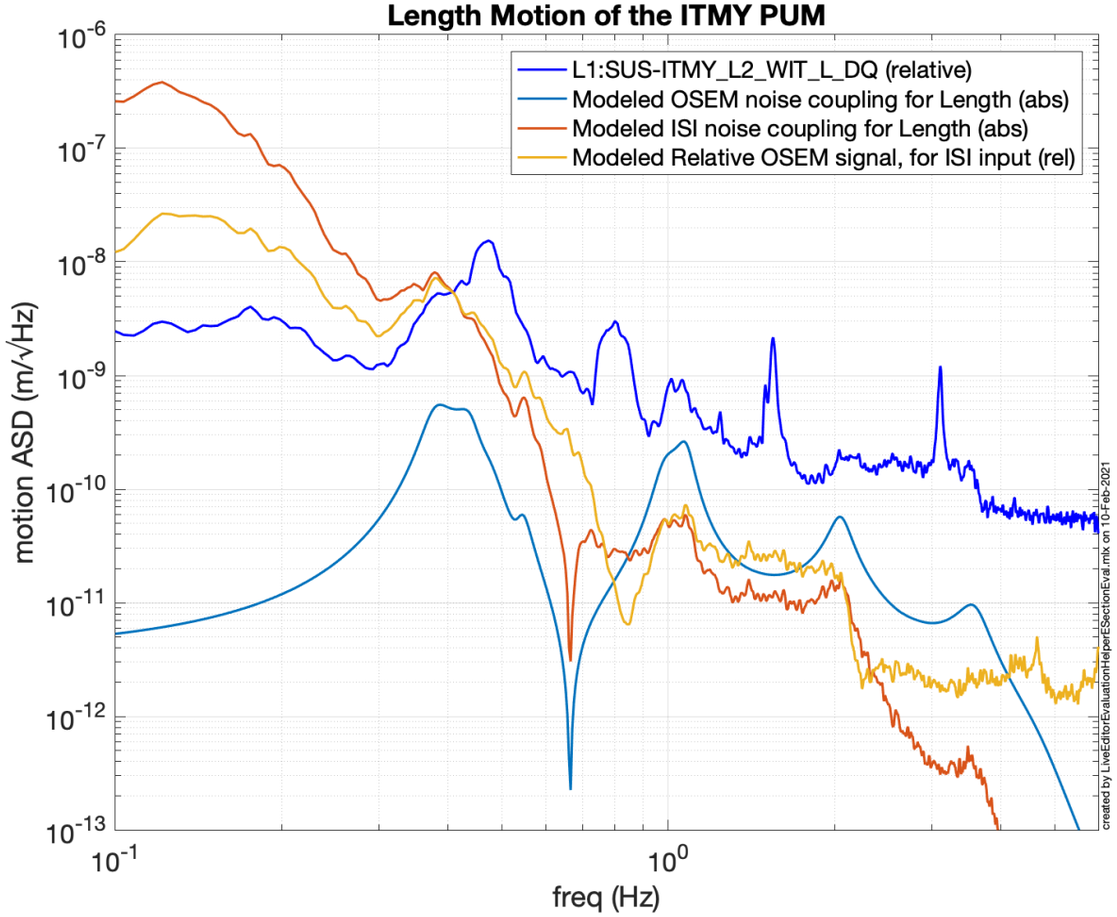
OSEM & ISI noise don't explain
the observed motion of the MICH optics




Beamsplitter dynamics
TF magnitude
X: 1.071
Y: 23.99
X: 1.391
Y: 91.66
X: 2.232
Y: 5.933
X: 1.229
Y: 0.002556
m1 drive L to optic L
m1 drive P to optic P
m1 drive Y to optic Y
created by LiveEditorEvaluationHelperESectionEval.mlx on 10-Feb-2021


ITMX dynamics
TF magnitude
X: 1.368
Y: 0.1564
top drive L to optic L
top drive P to optic P
top drive Y to optic Y
created by LiveEditorEvaluationHelperESectionEval.mlx on 10-Feb-2021


Length Motion of the BS optic
motion ASD (m/√Hz)
freq (Hz)
L1:SUS-BS_M2_WIT_L_DQ (relative)
Modeled OSEM noise coupling for Length (abs)
Modeled ISI noise coupling for Length (abs)
Modeled Relative OSEM signal, for ISI input (rel)
X: 1.548
Y: 5.742e-10
X: 2.169
Y: 3.539e-10
X: 3.105
5.454e-10
created by LiveEditorEvaluationHelperESectionEval.mlx on 10-Feb-2021

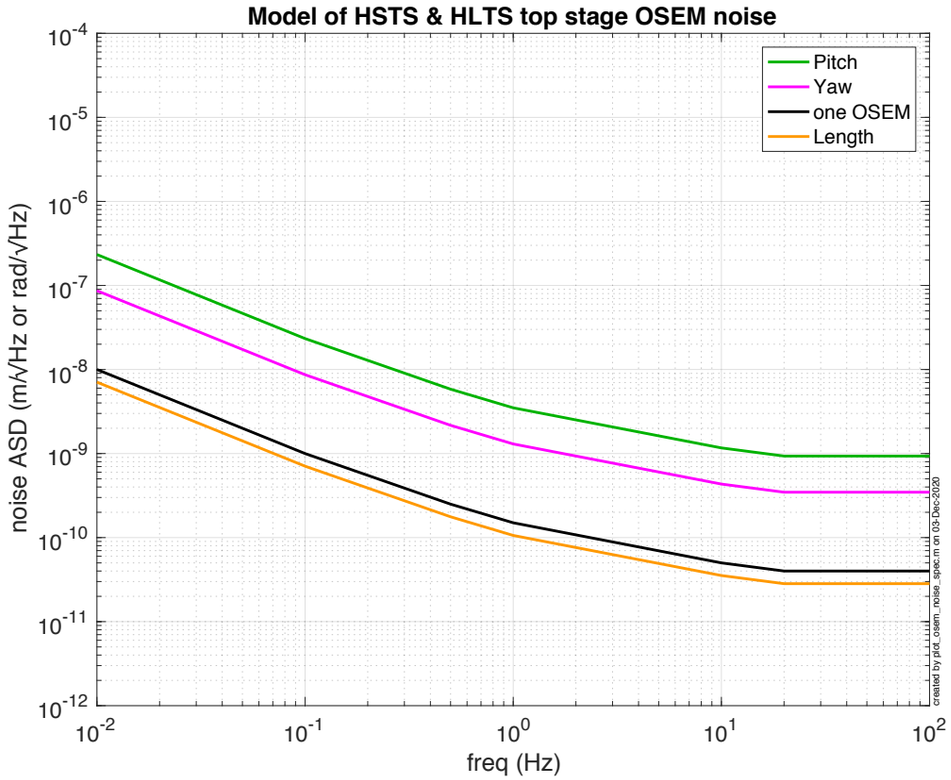

Length Motion of the ITMY PUM
motion ASD (m/√Hz)
freq (Hz)
L1:SUS-ITMY_L2_WIT_L_DQ (relative)
Modeled OSEM noise coupling for Length (abs)
Modeled ISI noise coupling for Length (abs)
Modeled Relative OSEM signal, for ISI input (rel)
created by LiveEditorEvaluationHelperESectionEval.mlx on 10-Feb-2021

OSEM noise 4-10 Hz

- Model the triple suspension using current damping controllers. Inputs are ISI input motion, and OSEM noise model from G2002065

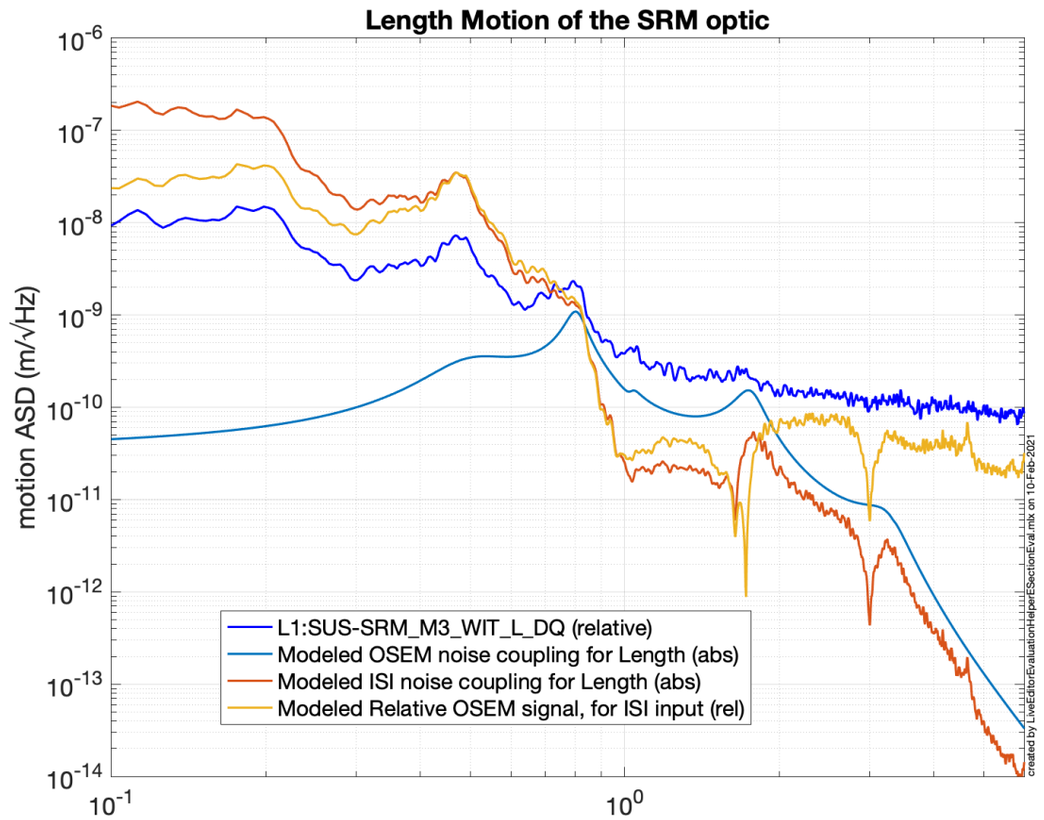
- OSEM noise couples through the damping loops

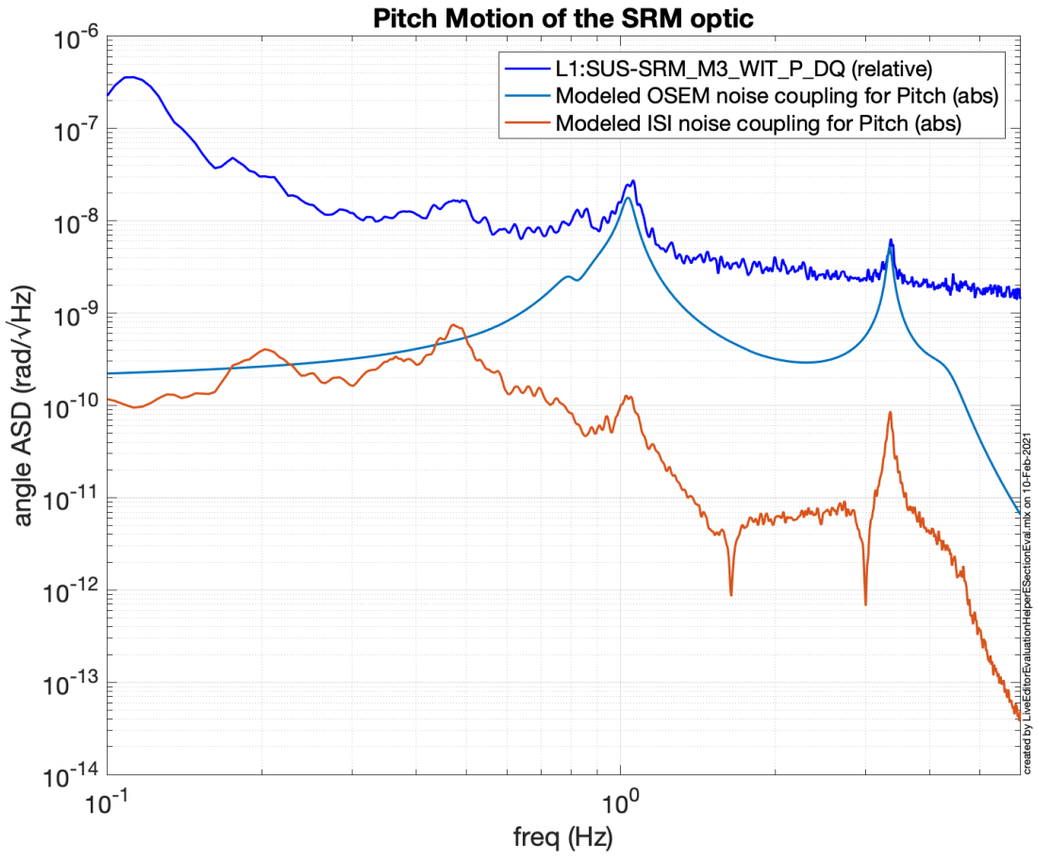
- ISI motion couples through the mechanical suspension and also through the damping loops.

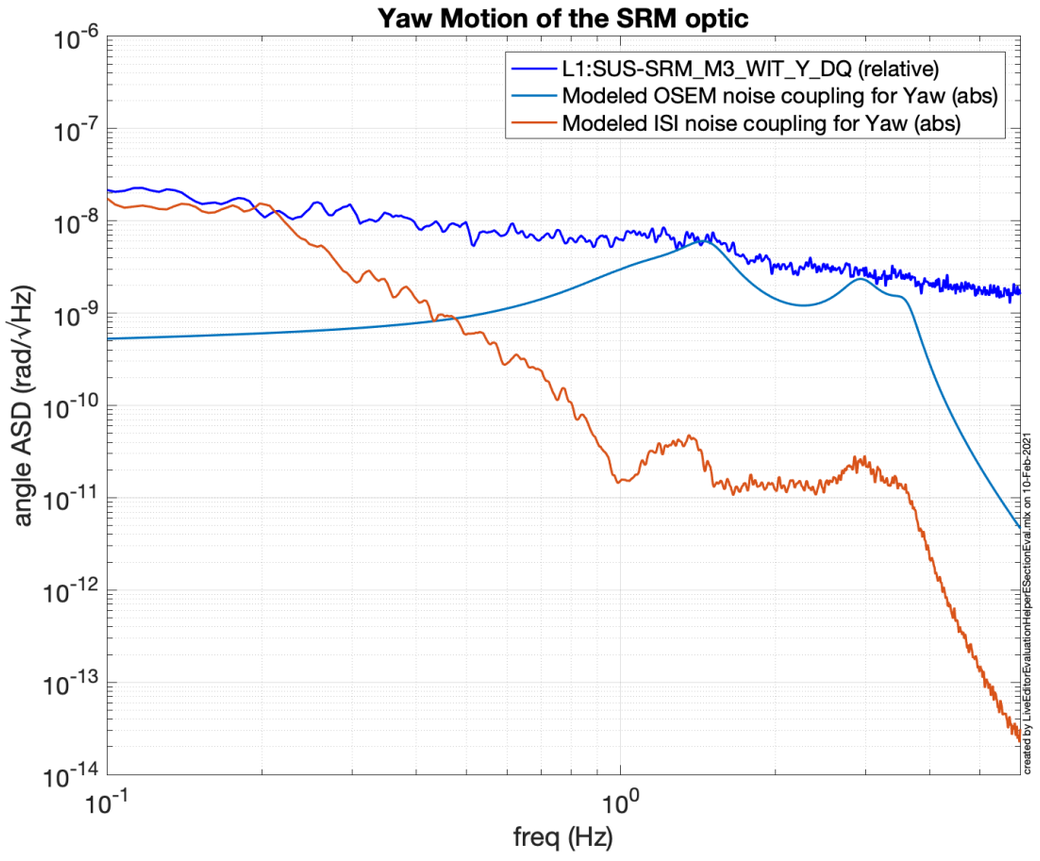


Check OSEM model with SRM

- OSEM noise is pretty good at predicting the WIT signals
- OSEM noise dominated ISI motion about 0.8 Hz, but it's pretty close for length







Measure cross couplings

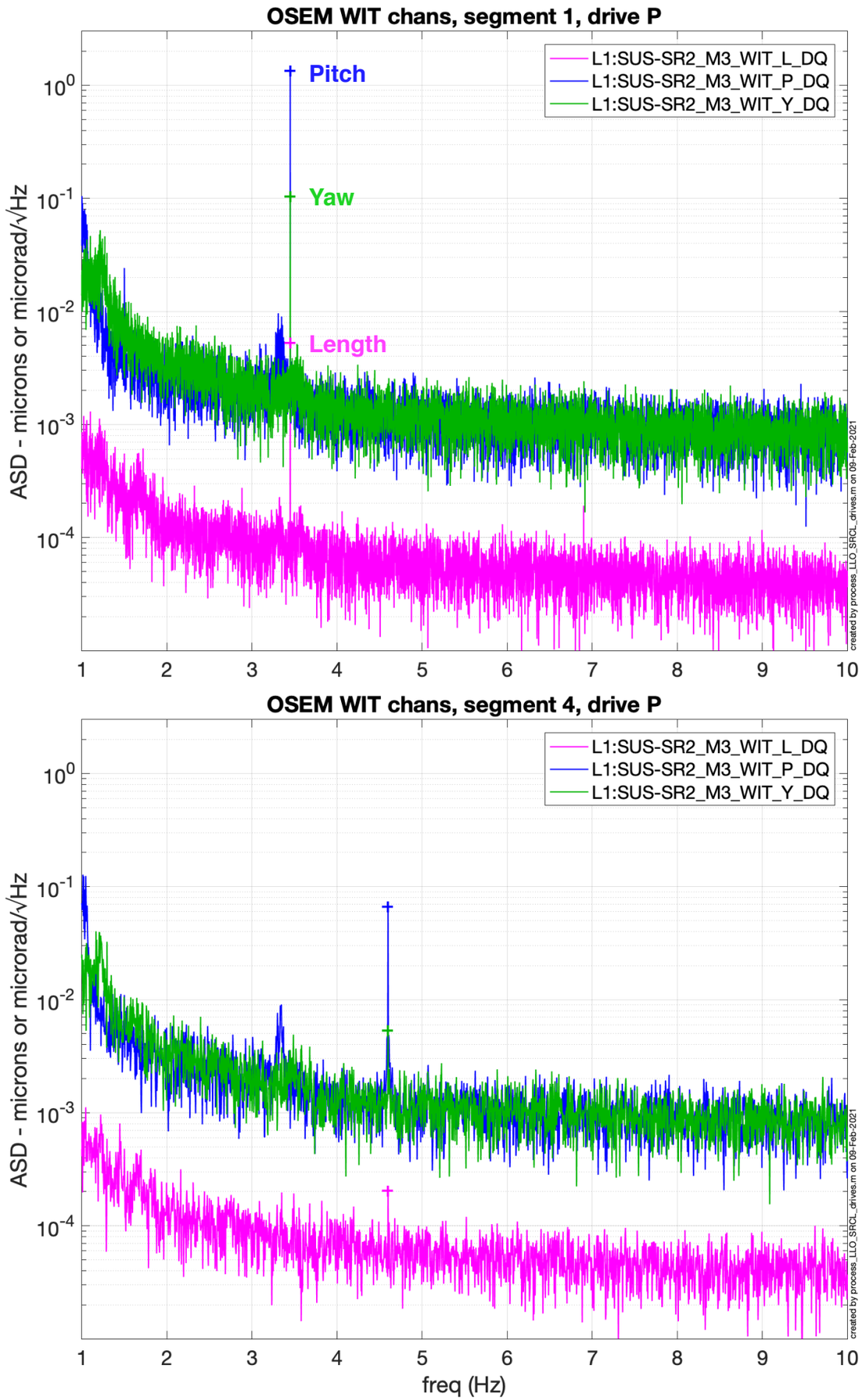
1 full day by Anamaria and Jenne. see LLO log 54867

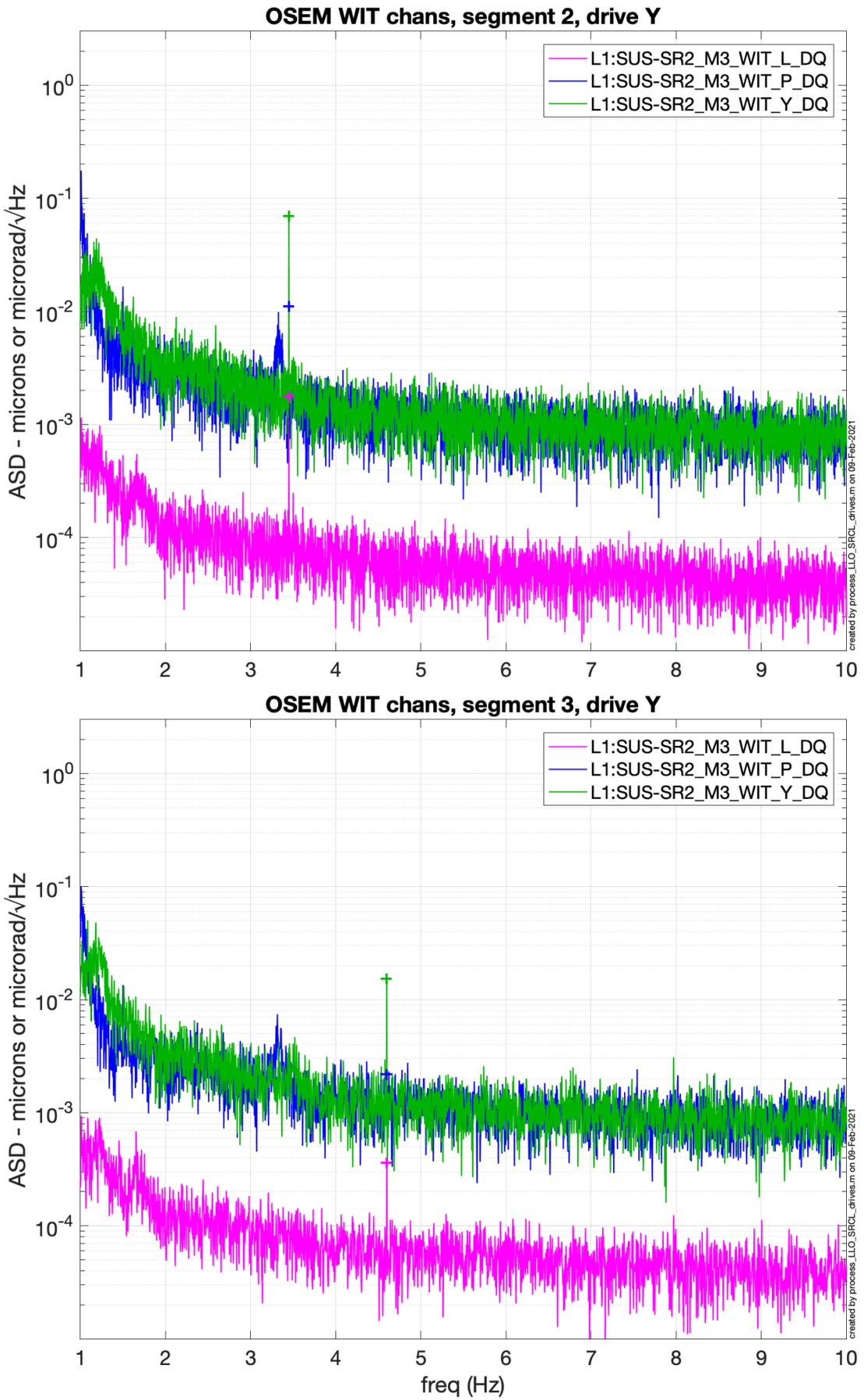
normalize each row by the OSEM response in the driven DOF

Table 1

DOF:Hz	SRCL Len norm/√Hz	ASC1_P norm/√Hz	ASC1_Y norm/√Hz	WIT_L norm/√Hz	WIT_P norm/√Hz	WIT_Y norm/√Hz
P:3.45 Hz	2.67E-03	2.67E-02	1.61E-03	3.91E-03 m/rad	1	7.76E-02 rad/rad
P:4.60 Hz	1.02E-03	1.92E-02	5.65E-03	3.06E-03 m/rad	1	7.99E-02 rad/rad
Y:3.45 Hz	5.55E-02	3.36E-02	1.35E-01	2.53E-02 m/rad	0.16 rad/rad	1
Y:4.60 Hz	4.79E-02	2.18E-02	5.89E-02	2.35E-02 m/rad	0.142 rad/rad	1
L:4.60 Hz	3.35E+00	2.89E+00	5.03E+00	1	3.46E+00	1.35E+01

- Drive at the error points for the SRCL ISC (ASC-SRC1_P/Y_EXC and LSC-SRCL_EXC)
- Measure at IN1 for that excitation point, and also CAL-CS_SRCL.
- The motion seen by ASC and the OSEMs is not really the same.
- Using the cross couplings seen by the OSEMs, 3.5e-3 m/rad Length/Pitch and 2.4e-2 m/rad Length/Yaw


OSEM WIT chans, segment 1, drive P
L1:SUS-SR2_M3_WIT_L_DQ
L1:SUS-SR2_M3_WIT_P_DQ
L1:SUS-SR2_M3_WIT_Y_DQ
Pitch
Yaw
Length
ASD - microns or microrad/√Hz
created by process_LLO_SRCL_drives.m on 09-Feb-2021

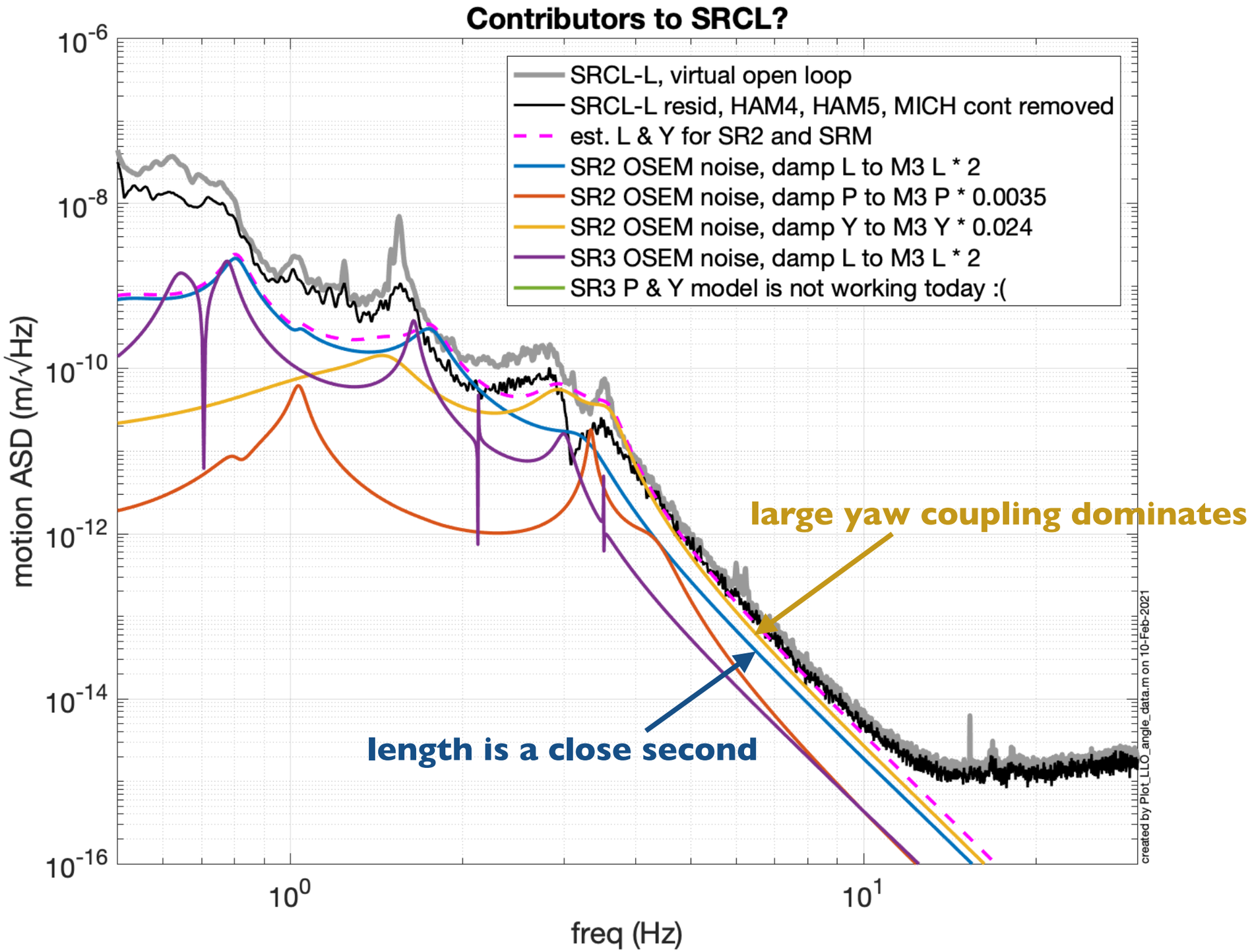

OSEM WIT chans, segment 2, drive Y
L1:SUS-SR2_M3_WIT_L_DQ
L1:SUS-SR2_M3_WIT_P_DQ
L1:SUS-SR2_M3_WIT_Y_DQ
ASD - microns or microrad/√Hz
created by process_LLO_SRCL_drives.m on 09-Feb-2021

OSEM WIT chans, segment 4, drive P
L1:SUS-SR2_M3_WIT_L_DQ
L1:SUS-SR2_M3_WIT_P_DQ
L1:SUS-SR2_M3_WIT_Y_DQ
ASD - microns or microrad/√Hz
freq (Hz)
created by process_LLO_SRCL_drives.m on 09-Feb-2021

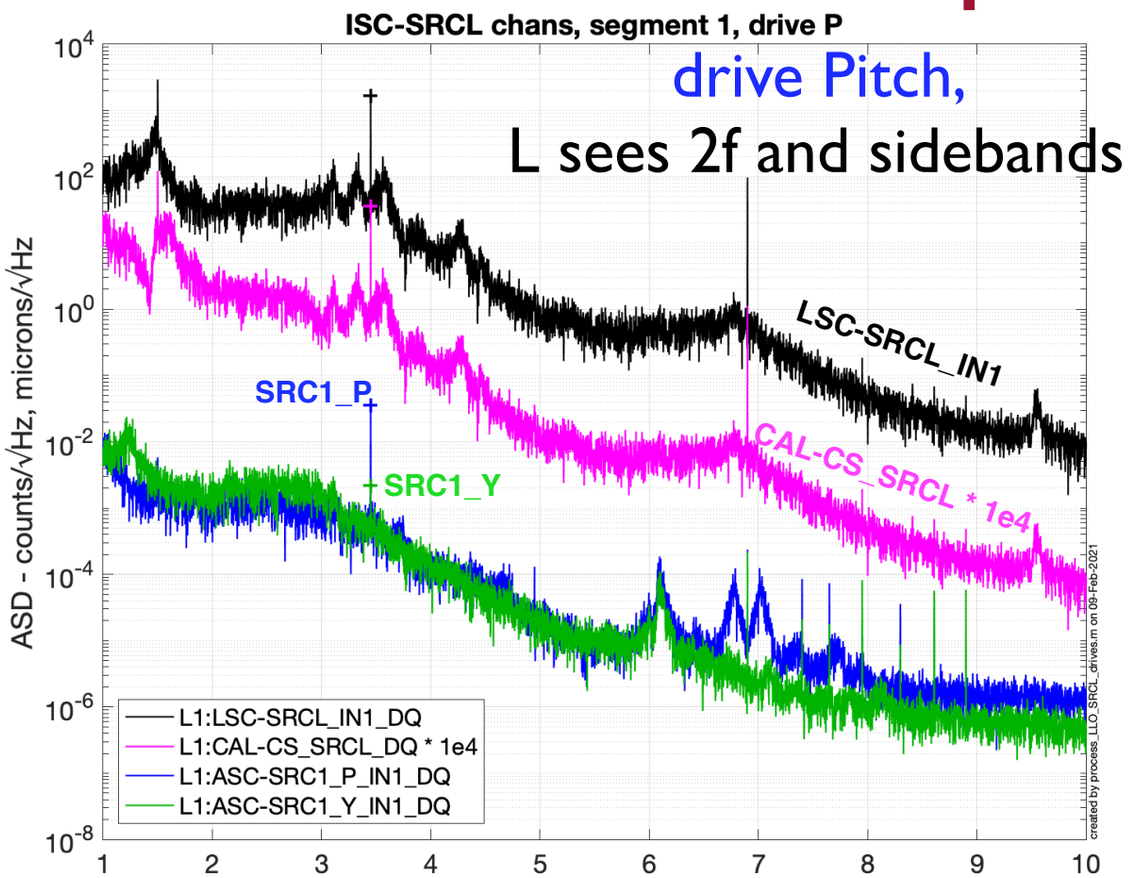
OSEM WIT chans, segment 3, drive Y
L1:SUS-SR2_M3_WIT_L_DQ
L1:SUS-SR2_M3_WIT_P_DQ
L1:SUS-SR2_M3_WIT_Y_DQ
ASD - microns or microrad/√Hz
freq (Hz)
created by process_LLO_SRCL_drives.m on 09-Feb-2021

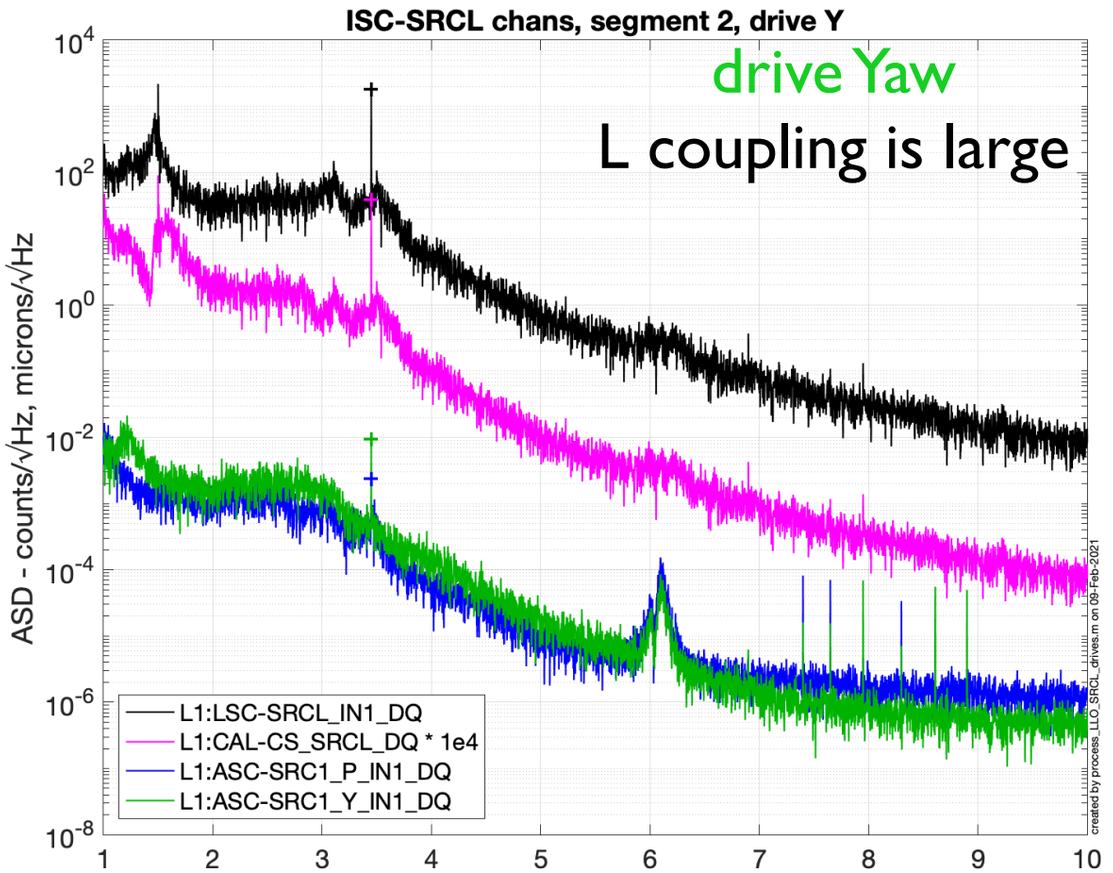
OSEM noise and SRCL

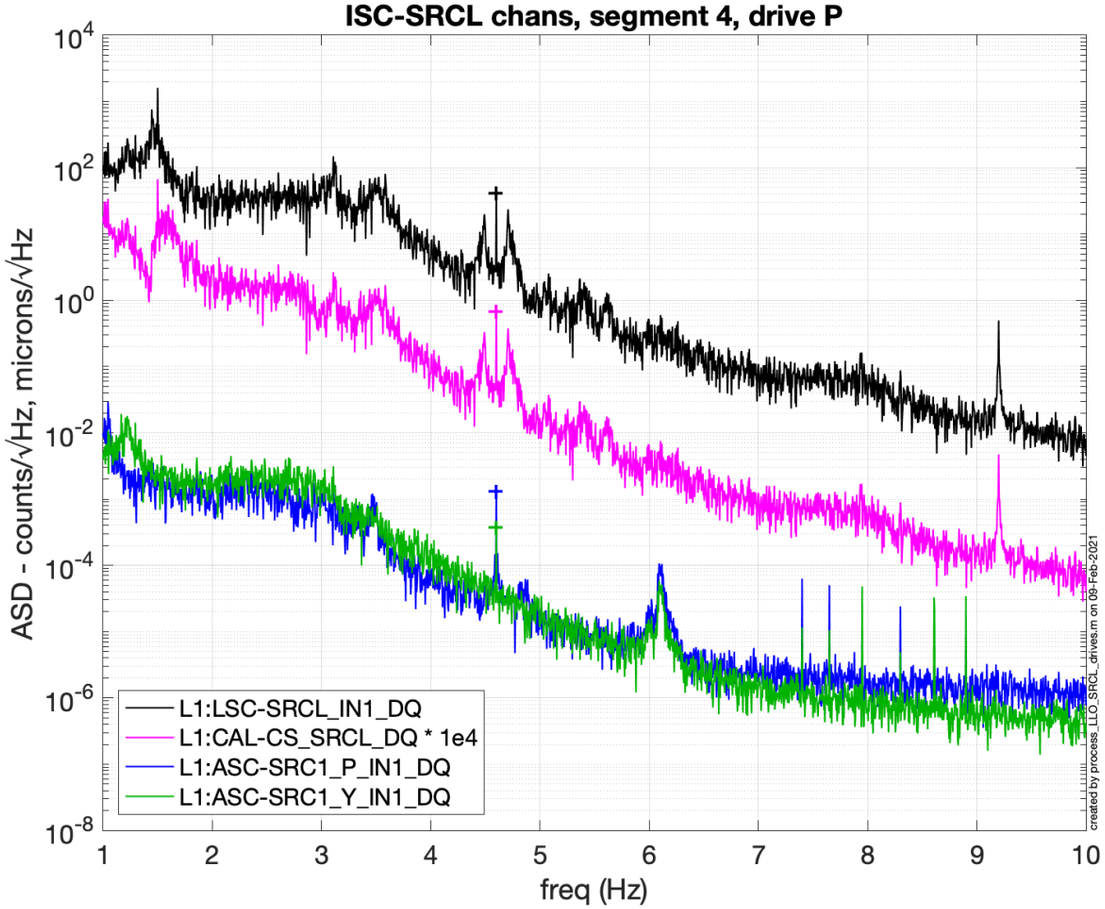
- OSEM noise is a pretty good explanation of LLO SRCL from 4 - 10 Hz
  - but - peaks are not quite right.

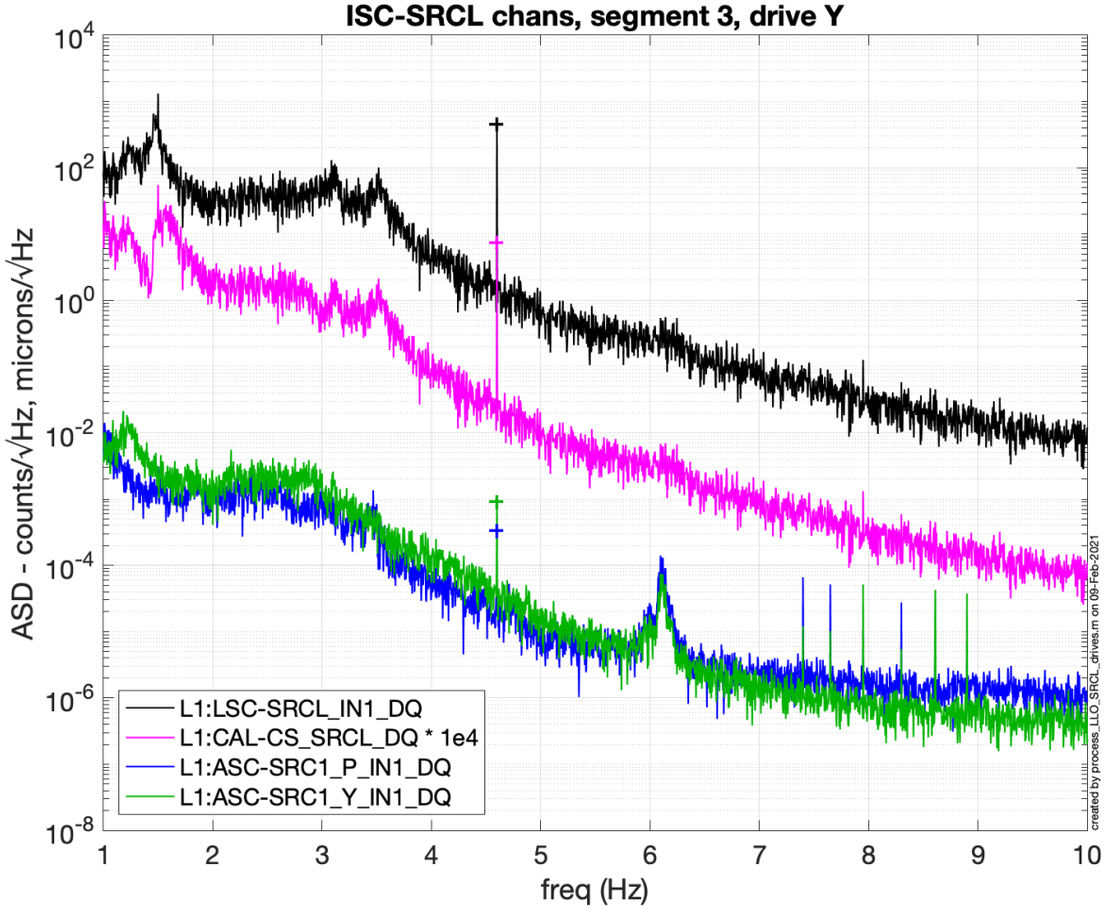


cross couplings, seen on ISC

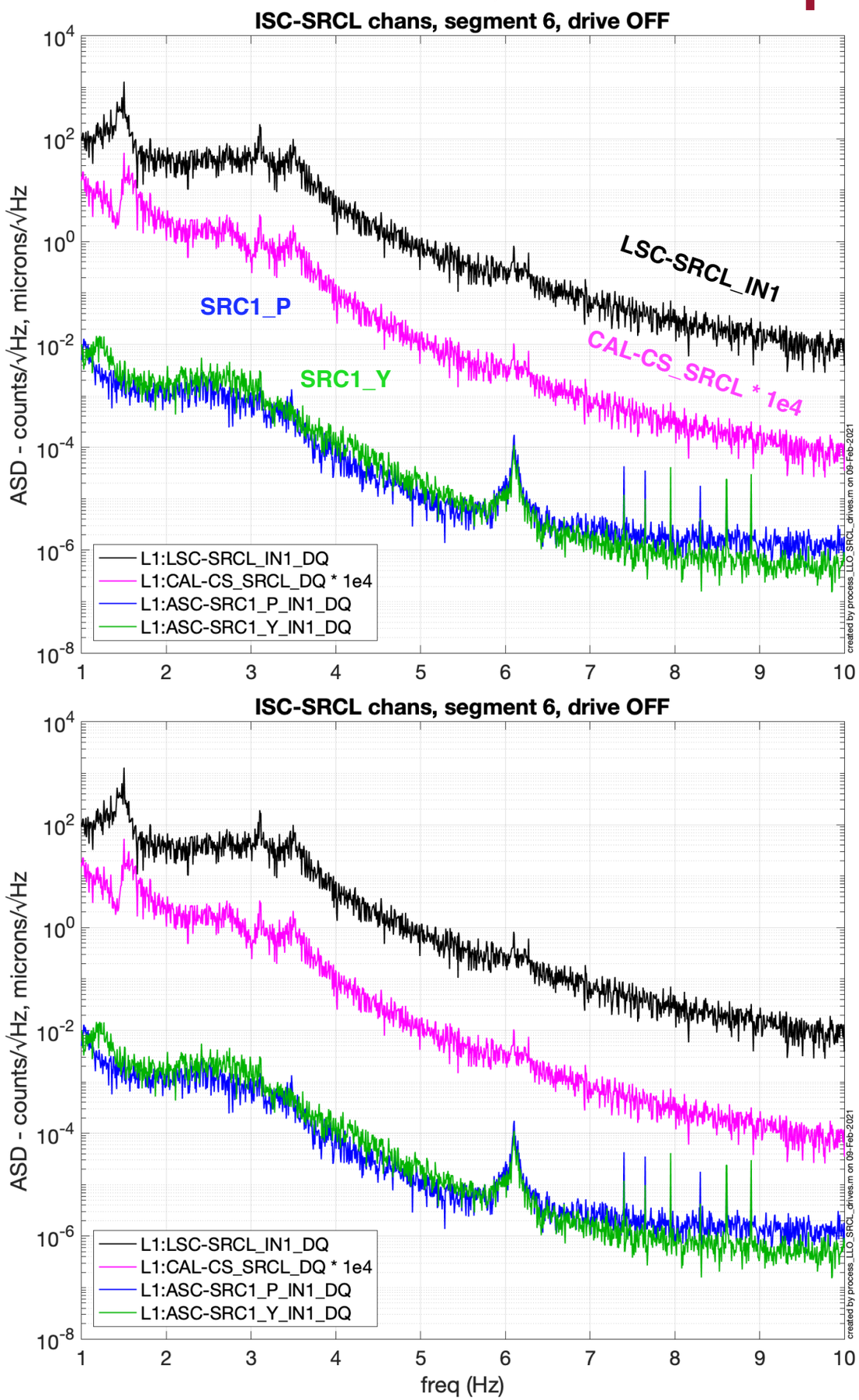


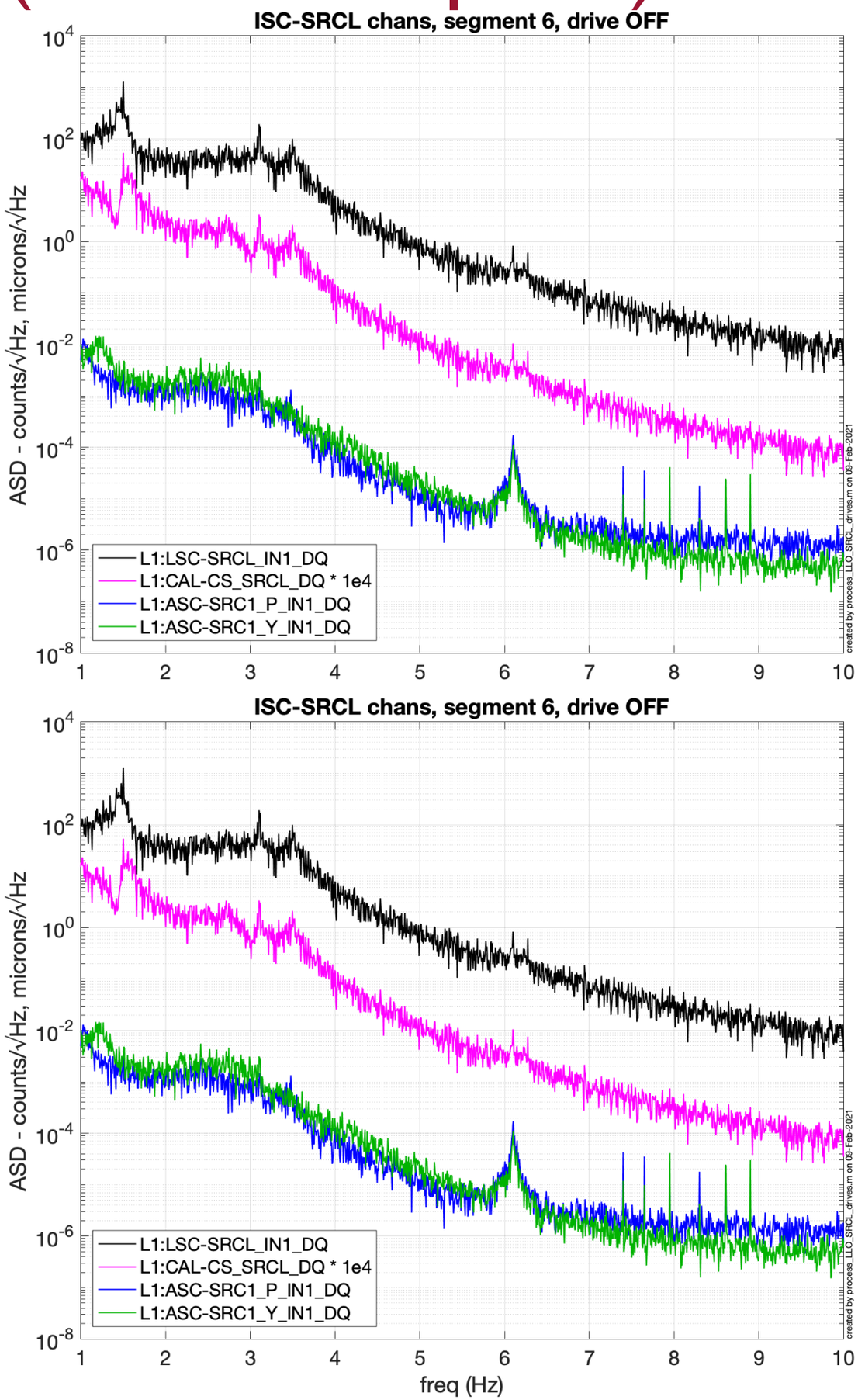






LSC drive off, to compare (4 identical plots)





OSEM vs. ISC is not consistent

Ratio of OSEM response / ISC response

Table 1

drive DOF:Hz	SR2_M3_WIT_L/ CAL-CS_SRCL	SR2_M3_WIT_P/ ASC-SRC1_P	SR2_M3_WIT_Y/ ASC-SRC1_Y/
P:3.45 Hz	1.46	37	48
P:4.60 Hz	3.0	52	14
Y:3.45 Hz	0.455	4.7	7.4
Y:4.60 Hz	0.49	6.5	17
L:4.60 Hz	0.298	1.2	2.7

- Drive at the error point for the SRLC ISC
- Measure at IN1 for that excitation point, and also CAL-CS_SRCL.
- The motion seen by ASC and the OSEMs is not really the same.
- Using the cross couplings seen by the OSEMs,

Conclusions

- SRCL noise seem to come from
  - ISI motion below 0.7 Hz
  - Something MICH related 1-4 Hz
  - OSEM noise and yaw coupling from 4-10 Hz
- LHO is ~ similar, see SEI log entries, but not quite the same
- It would be good to test the OSEM noise hypothesis
  (e.g maybe some 8Hz filter features in the damping loops?)
- It would be really good to look at PRCL and MICH
- ISC SRCL non-linear couplings from
  Pitch to Length may be an issue as well.