Estimates of HAM-ISI motion for A+

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1 Summary

This is a quick note to document the estimated motion of the HAM-ISI suspension points. This is meant to aid preparation for the A+ proposal, in particular to help set the performance requirements for the new suspensions intended to transfer Local Oscillator for the balanced homodyne readout from HAM3 to the detection point. At many frequencies the performance of the suspension points is better than the Advanced LIGO requirements, and at some it is worse; we may decide that a new set of requirements should be set for the HAM performance in A+, and this document can serve as a starting point for that discussion.

This document is only a brief estimate of performance reached during O2. The main time chosen for analysis is around the time of GW170817, because it seemed auspicious. It would be wise to do a more complete, statistical analysis, but that is beyond this scope. The time chosen is during the evening, so the 1-3 Hz motion of the floor is small. We compare this time with a time of higher floor motion and a time with large microseismic motion to get a sense of the impact of the motion inputs. Ground motion is important at the microseism, somewhat important from 1-10 Hz as the performance transitions from active to passive, and quite relevant above 10 Hz where most of the performance is passive. However the ground motion above 5 Hz is quite stationary in these data sets, so the performance is as well.

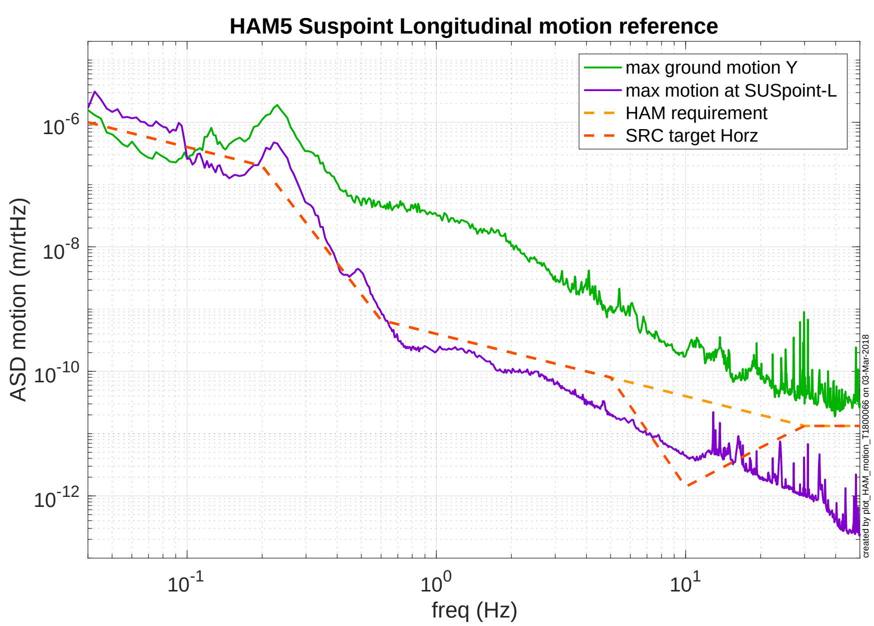

Figure 1: Reference curve for the motion of Suspoint Point L on HAM 5. The table motion and the ground motion are the maximum motion at each frequency based on several data sets. Details are shown in figure 4. The data set for the purple curve is saved as HAM5_ref.long in the matlab file HAM5_ref_curvesv1.mat, as described in section 6.

In general, above 1 Hz the HAM-ISI beats the basic Advanced LIGO noise curve, or just meets it at a few frequencies above 12 Hz. However, for updated targets for the SRM cavity optics (HAM 4 and 5), the performance is close, but not reliably below the target curves.

2 Constructing the Reference Curve for Suspension Point Longitudinal Motion

The suspension point motion is the best measure of ISI performance. We show the motion for the suspension point of optics on the table because the rotational motions of the tables, particularly pitch, usually dominate the motion here. Do not use the table translation as the primary measure of performance. Many people have fallen into this trap and we all regret it now. The projections described in detail in T1100617. We assume that the transverse motion is similar to the longitudinal motion, or could be made to be similar. The 'typical' motion was picked from 2:00 to 5:00 UTC on Aug. 17. 2017. Both interferometers were locked at this time, and the ground was neither very loud nor very quiet. Figures 10 and 11 show the ground motion BLRMS for the times chosen.

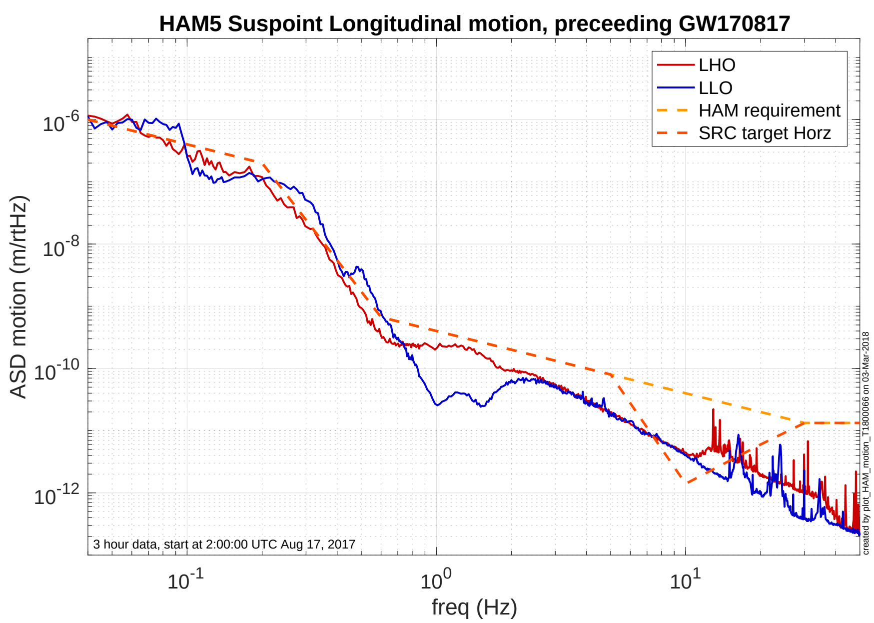

Figure 2: Longitudinal Suspension point motion of HAM5. GPS start time 1186970417, channels (H1/L1):ISI-HAM5_SUSPOINT_SR3_EUL_L_DQ

Figure 3 shows the comparison of the LLO Ham-5 ISI performance at 3 different times: 'typical', 'high micro-seism', and 'large-athropogenic'. The table motion at the microseism scales linearly with the ground motion for times of big input. The 1-3 motion during time of large anthropogenic motion is increased, but less that the motion of the ground, and the motion above 4 Hz is nearly identical during all these times. This is likely because the input spectrum above 4 Hz is reasonably stationary. When one includes the 'typical' motion from LHO, one can take the maximum motion at each frequency and make a reference curve, as shown in figure 4.

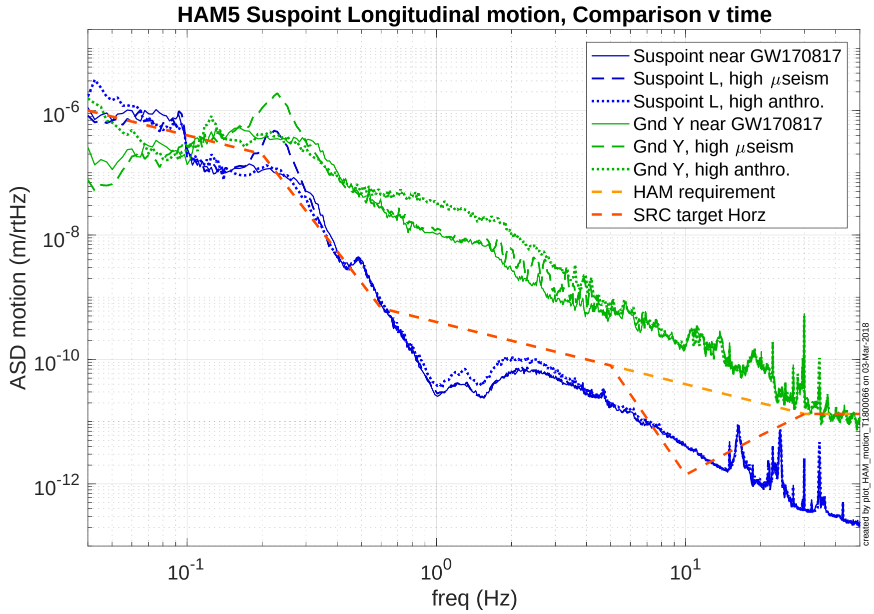

Figure 3: Comparison of LLO HAM5 Suspoint motion with 3 different ground input spectra.

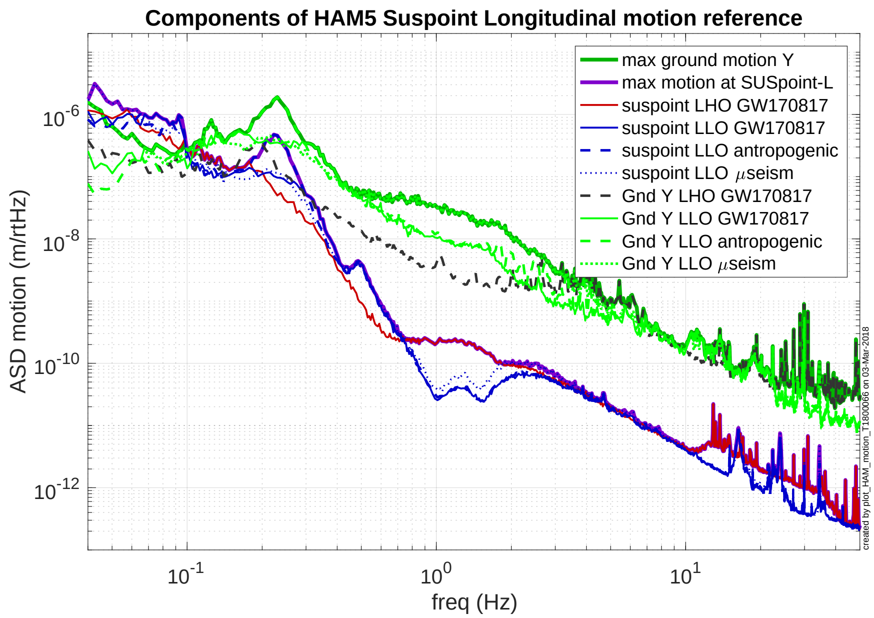

Figure 4: Component curves used to make the reference suspension point L curve.

3 Reference Curve for Vertical Motion

A reference curve for the vertical motion has also been constructed using the same method. Here again, the vertical motion at the suspension point is a bit larger that the vertical motion in the cartesian basis of the ISI because the suspensions are not centered on the table and so pick up some of the rx and ry motion.

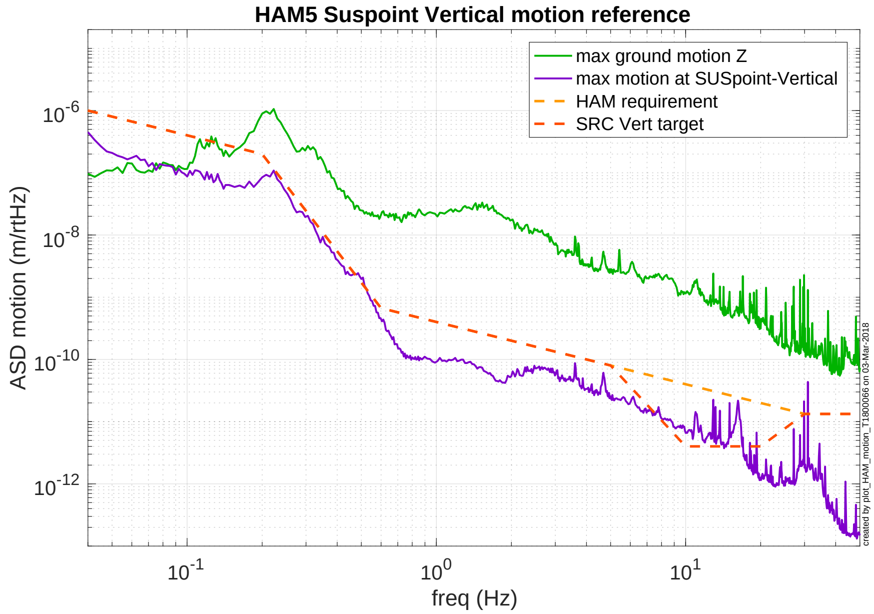

Figure 5: Reference curve for the motion of Suspoint Point Vertical motion on HAM 5. The table motion and the ground motion are the maximum motion at each frequency based on several data sets. Details are shown in figure 6. The data set for the purple curve is saved as HAM5_ref.vert in the matlab file HAM5_ref_curvesv1.mat, as described in section 6.

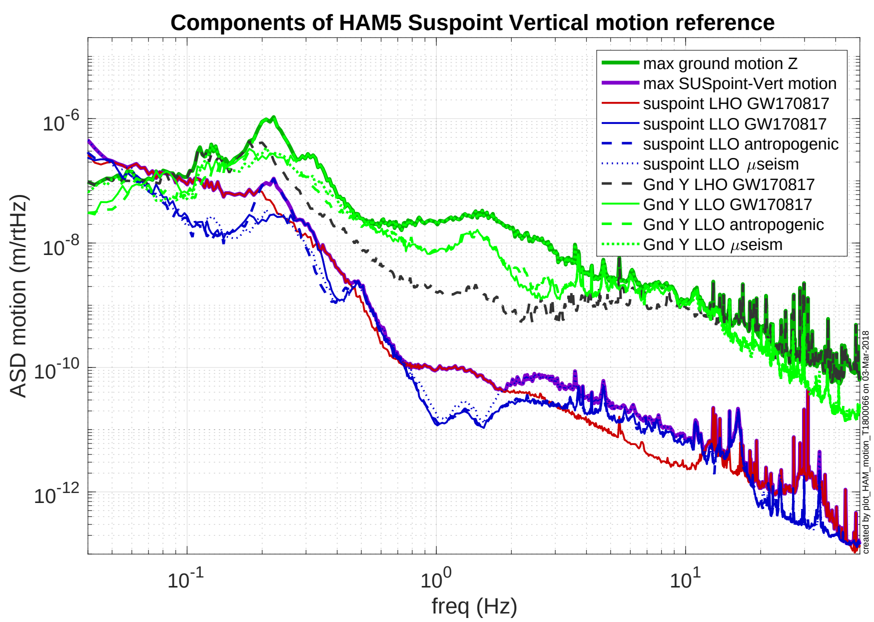

Figure 6: Component curves used to make the reference suspension point Vertical curve.

4 Motion in other DOFs

The motion for the other DOFs on the ‘typical’ day are shown here. Figures 7 - 8 show the other DOFs which are probably relevant, namely pitch and yaw. Pitch and Yaw will be about the same at RX and RZ of the platform.

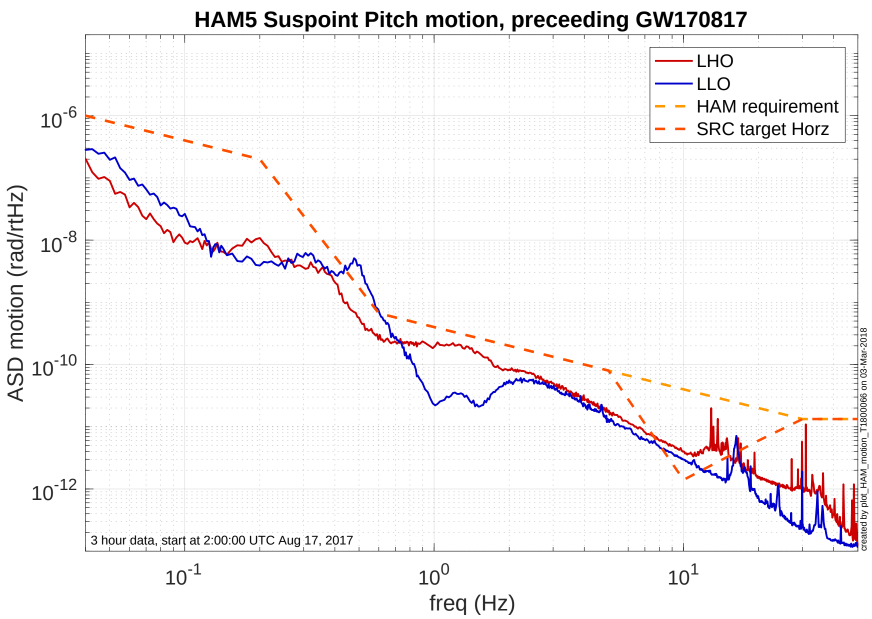

Figure 7: Pitch Suspension point motion of HAM5. GPS start time 1186970417, channels (H1/L1):ISI-HAM5_SUSPOINT_SR3_EUL_P_DQ

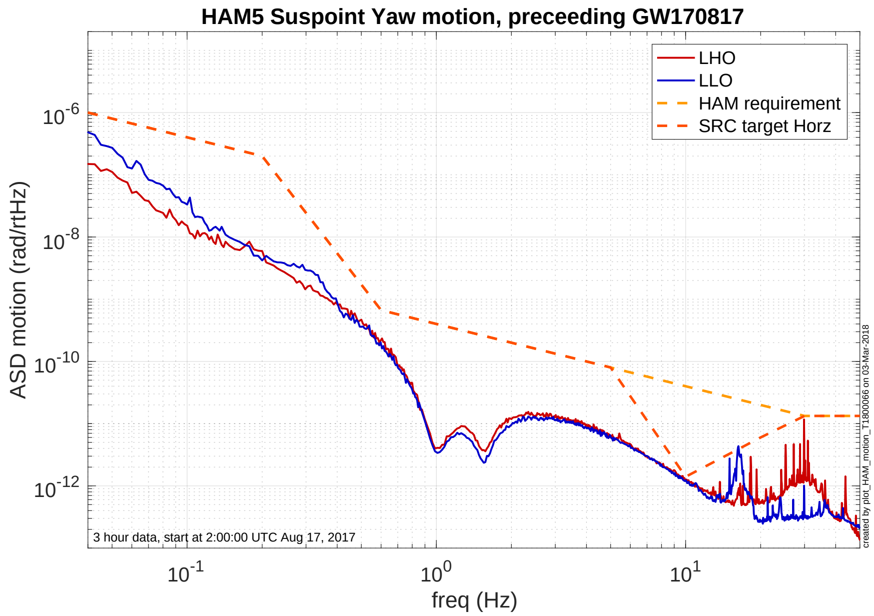

Figure 8: Yaw Suspension point motion of HAM5. GPS start time 1186970417, channels (H1/L1):ISI-HAM5_SUSPOINT_SR3_EUL_Y_DQ

5 Pitch is Annoying

The suspension point motion for the HAM5 chamber is dominated by tilt above 1 Hz. Figure 9 shows that the translation motion of the HAM5 ISI is below the SRC target, but when you add the pitch motion, the challenge is clear. It is not certain how much this can be improved.

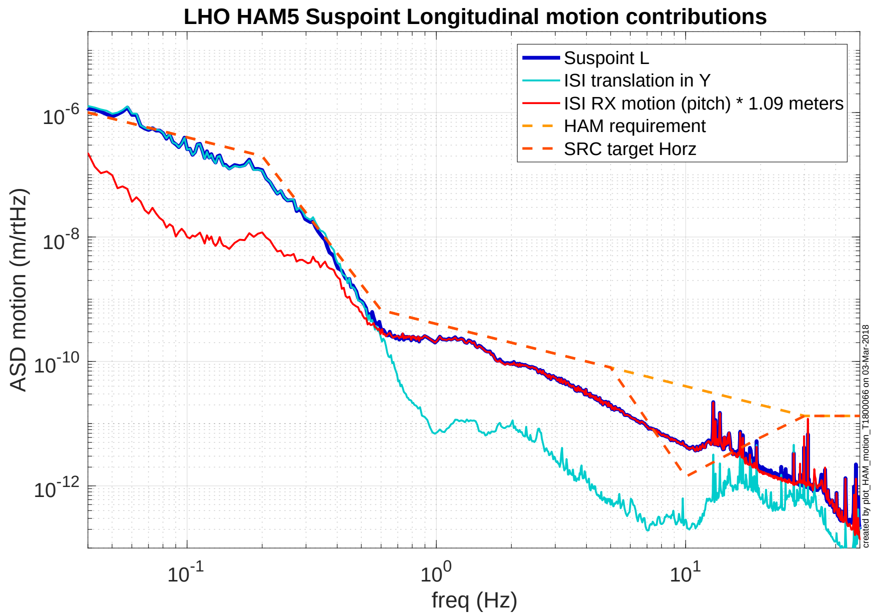

Figure 9: Contributions to the Suspension point L motion at LHO HAM5. The pitch (RX) contribution dominates above 1 Hz.

The matrix to convert the HAM5-ISI Cartesian coordinate system to the SR3 suspension point's Euler Basis is ISI2SUSprojections.h1.prm.CART2EUL. The value of this matrix is

	X	Y	RZ	Z	RX	RY
Long	-0.014	0.9999	-0.1691	0	-1.0958	-0.0153
Trans	-0.9999	-0.014	0.4578	0	0.0153	-1.0958
Vert	0	0	0	1	0.4554	0.1755
Roll	0	0	0	0	-0.014	0.9999
Pitch	0	0	0	0	-0.9999	-0.014
Yaw	0	0	1	0	0	0

Table 1: Transformation matrix from the Cartesian Basis of the HAM5-ISI to the Euler Basis of the SR3 Suspension Point. Longitudinal motion at the Suspension Point is dominated by Y and rX, but also includes contributions from X, RZ, and RY.

6 Data Files

All of the data and matlab files are in the seismicSVN at
SeismicSVN/seismic/Common/Documents/T1800066_typical_HAM_motion/
The main calculation and plotting file is **plot_HAM_motion_T1800066.m**.

The data for the reference curves is saved in the .mat file
HAM5_ref_curvesv1.mat
This file is in the SVN and in the T1800066 file card and contains a data structure called HAM5_ref.
The fields of HAM5_ref are:
HAM5_ref.freq: frequency vector in Hz.

HAM5_ref.long and HAM5_ref.vert : Reference asds for HAM5 in m/rtHz.
HAM5_ref.req_orig: Original HAM requirement curve in m/rtHz.
HAM5_ref.req_SRC_V and HAM5_ref.req_SRC_H : target curves for the SRC HAMs, Vertical and Horizontal.

7 Other Remarks

Performance of the HAM tables and the HAM suspension points is good. There is probably room for improvement if it is deemed necessary, and the reference curves indicate that finding and eliminating the ground features above 15 Hz will likely help, as would improving the tilt performance. This is not a high priority at present, since this performance seems good enough, but this may change as other noise sources are eliminated. If the performance of A+ is limited by the reference curves, we need to know soon so that we can take some action and see what helps. A great deal of effort has gone into the design to date, so this is not a trivial task.

8 Ground Motion

We show the ground motion at the times used for these reference traces below in figures 10 and 11.

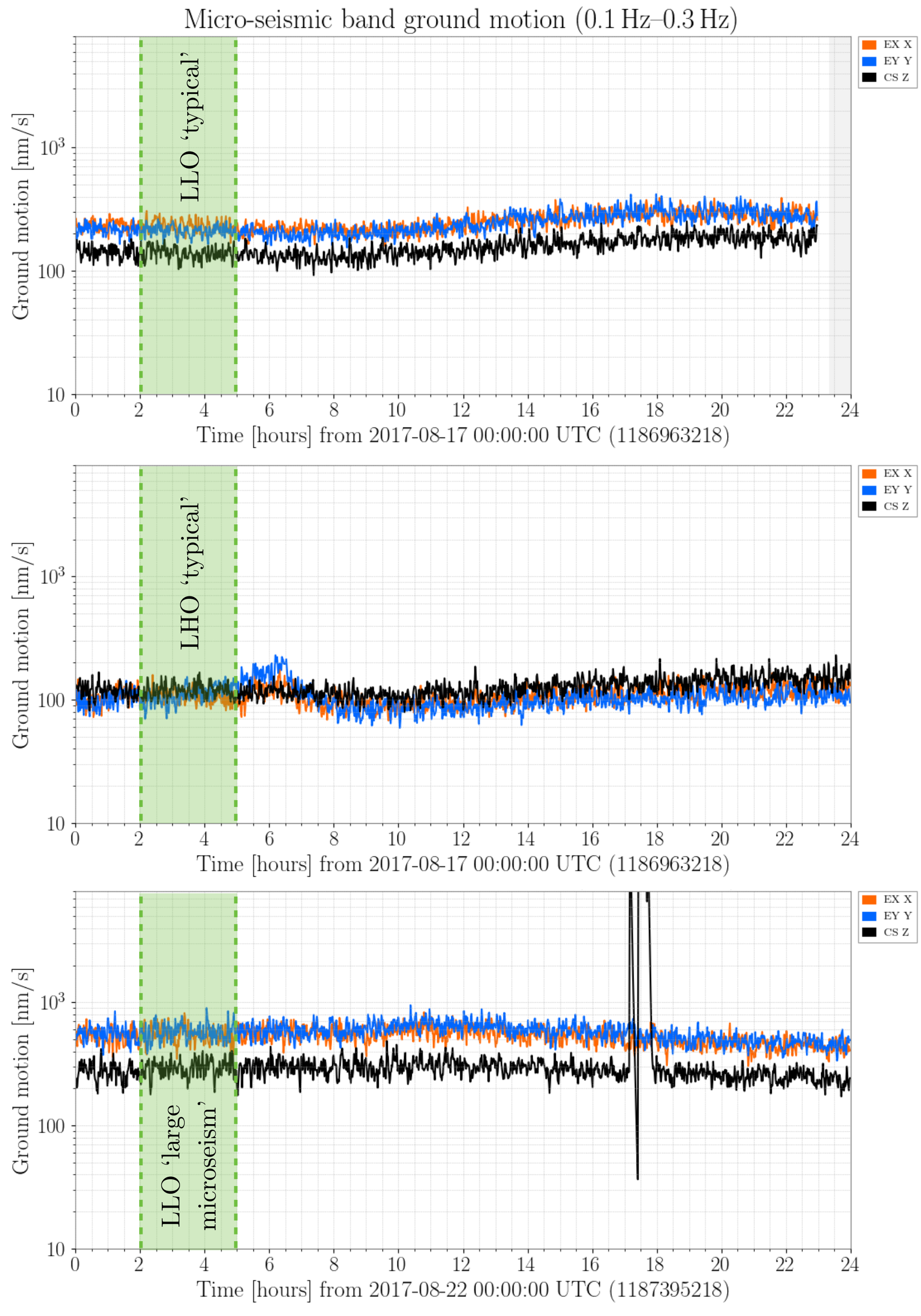

Figure 10: Ground motion BLRMS for the 'typical' and the 'high microseismic' time used to create the reference curve. The high microseism time was chosen because is roughly the largest microseism time when the LLO detector stayed locked during August. I've not calulated what percentile this falls into, and it is interesting that the biggest impact of this time comes from the motion just over 200 mHz, which is a higher frequency than is often seen.

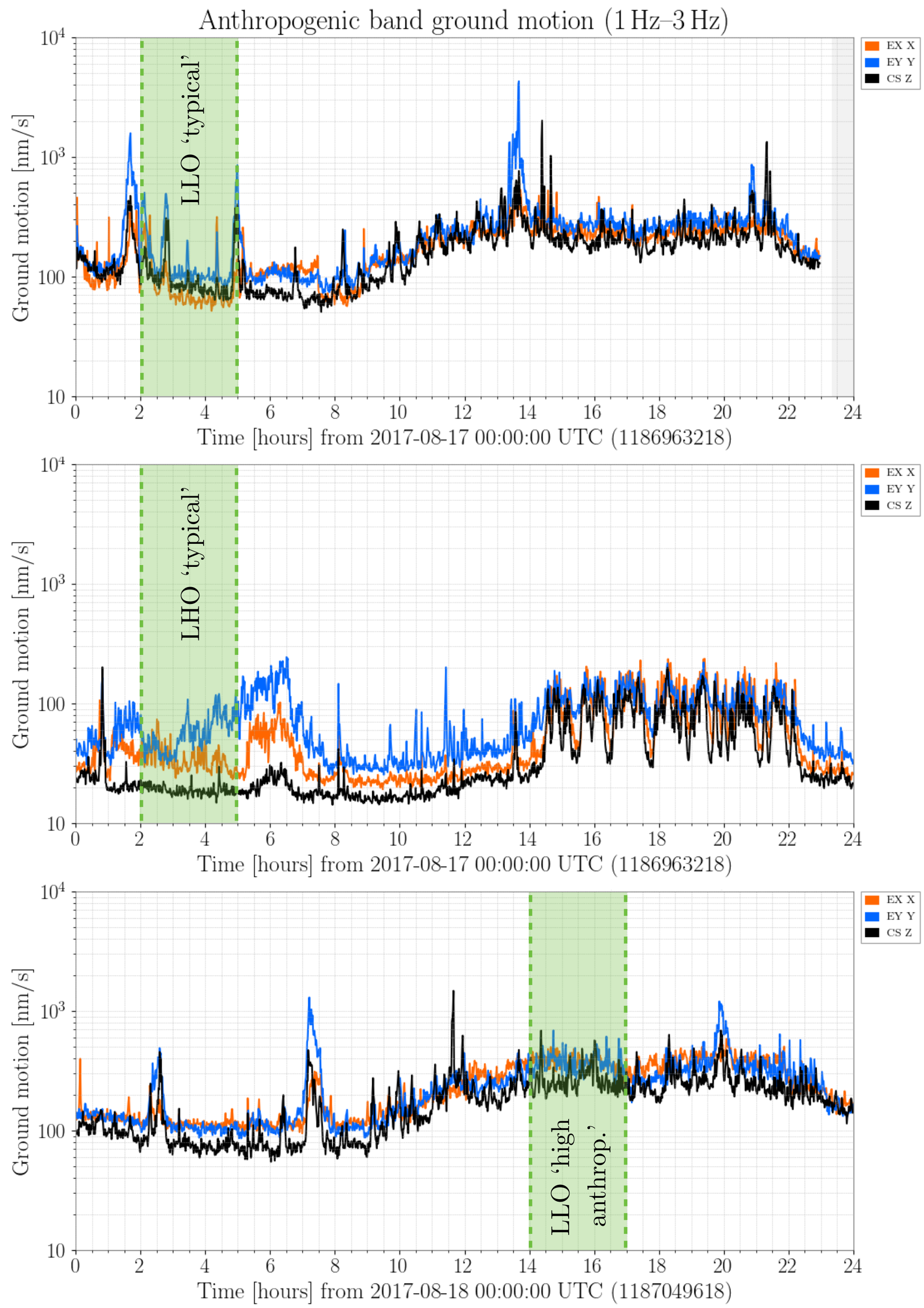

Figure 11: Ground motion BLRMS for the 'typical' and the 'high anthropogenic' time used to create the reference curve. It is worth noting that the motion of the ground is not very stationary during the 'typical' time. There is no certainty to how 'typical' this is.