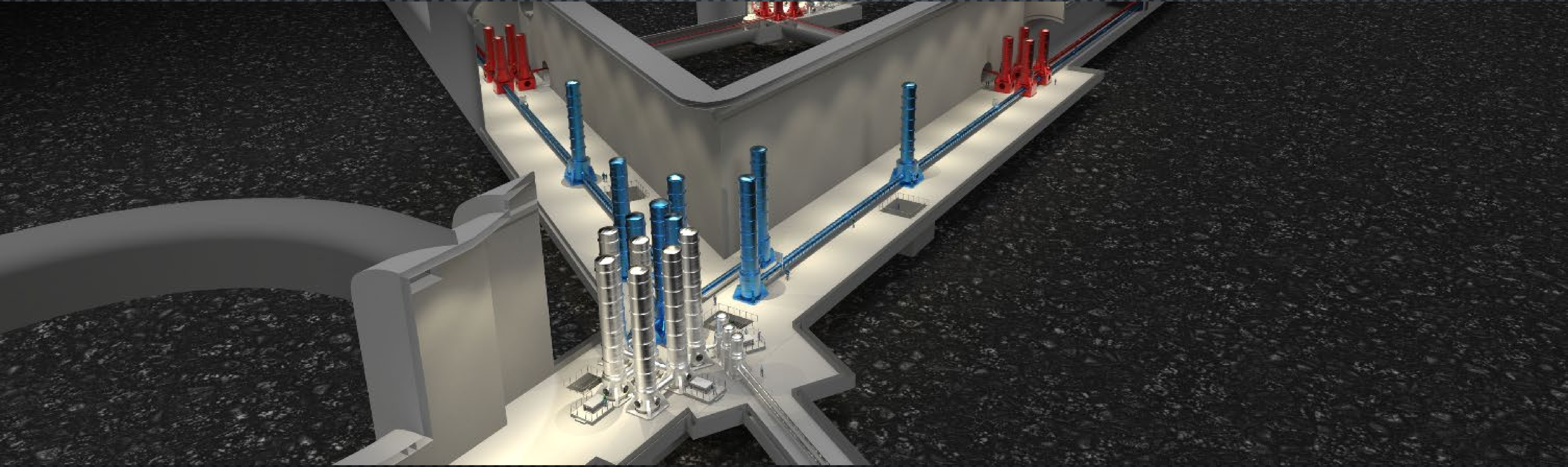
ET: LOW-FREQUENCY SENSITIVITY

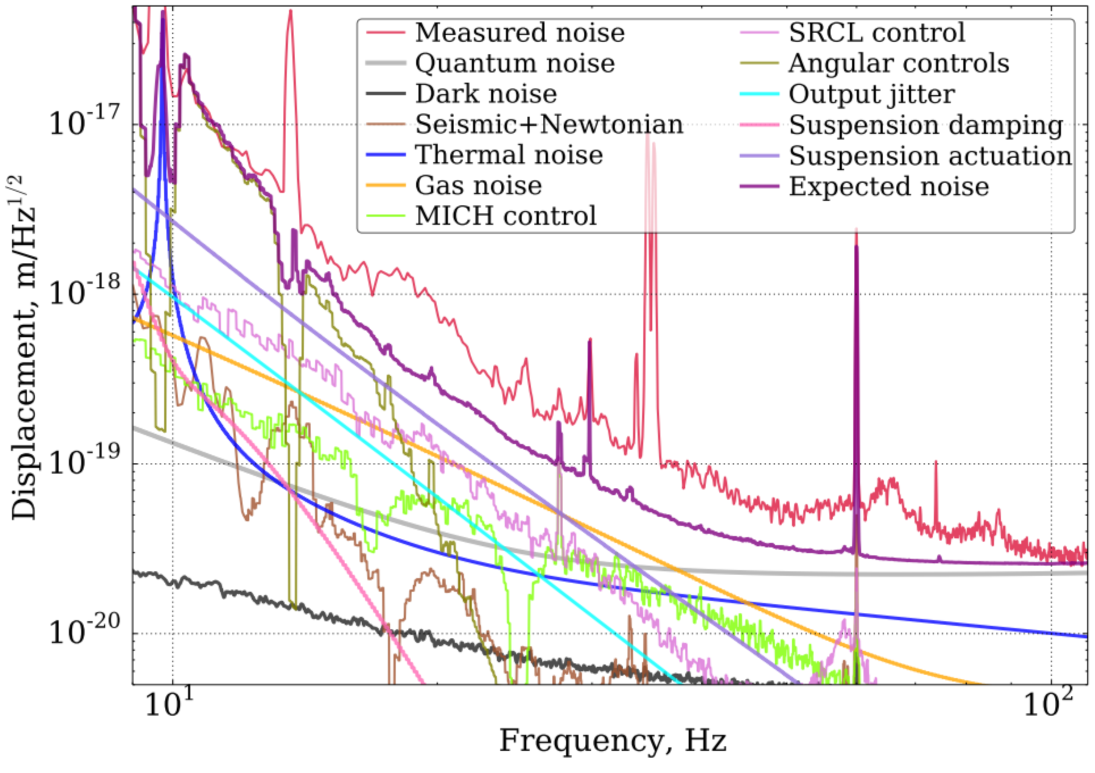


JAN HARMS & CONOR MOW-LOWRY

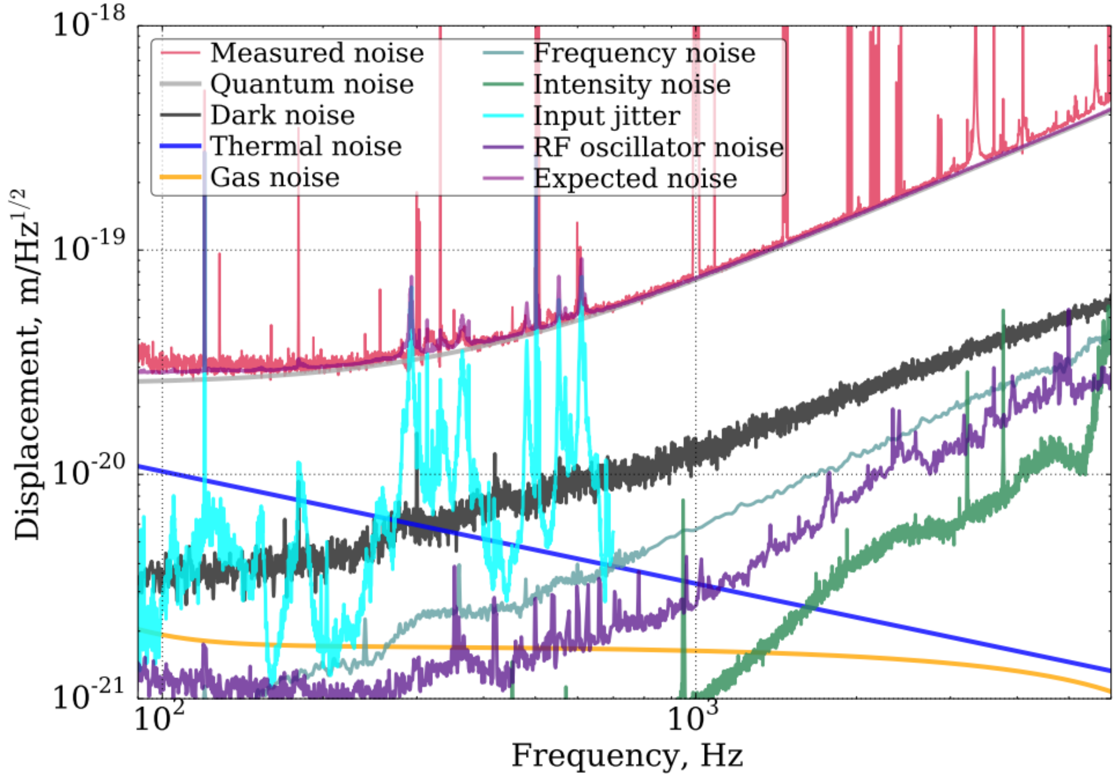
ANM AND LOW-F SENSITIVITY

- LOW-FREQUENCY NOISES IN GW DATA THAT ARE INFLUENCED BY INTERFEROMETER & SUSPENSION SENSING AND CONTROL
- LOW-FREQUENCY NOISES IN GW DATA THAT CAN BE MITIGATED BY ENVIRONMENTAL SENSING
- ANM IS NOT RESPONSIBLE FOR THE CONTROLS DESIGN OR MITIGATION OF MOST OF THESE NOISES
- ANM IS DEDICATED TO THE ANALYSIS OF LOW-F NOISE COUPLINGS, TO HIGHLIGHT DESIGN CHALLENGES, TO CREATE NOVEL ANALYSIS TOOLS, TO PROPOSE NEW MITIGATION STRATEGIES AND TO DESIGN SOME OF THEM

LIGO: LOW-F DETECTOR NOISE



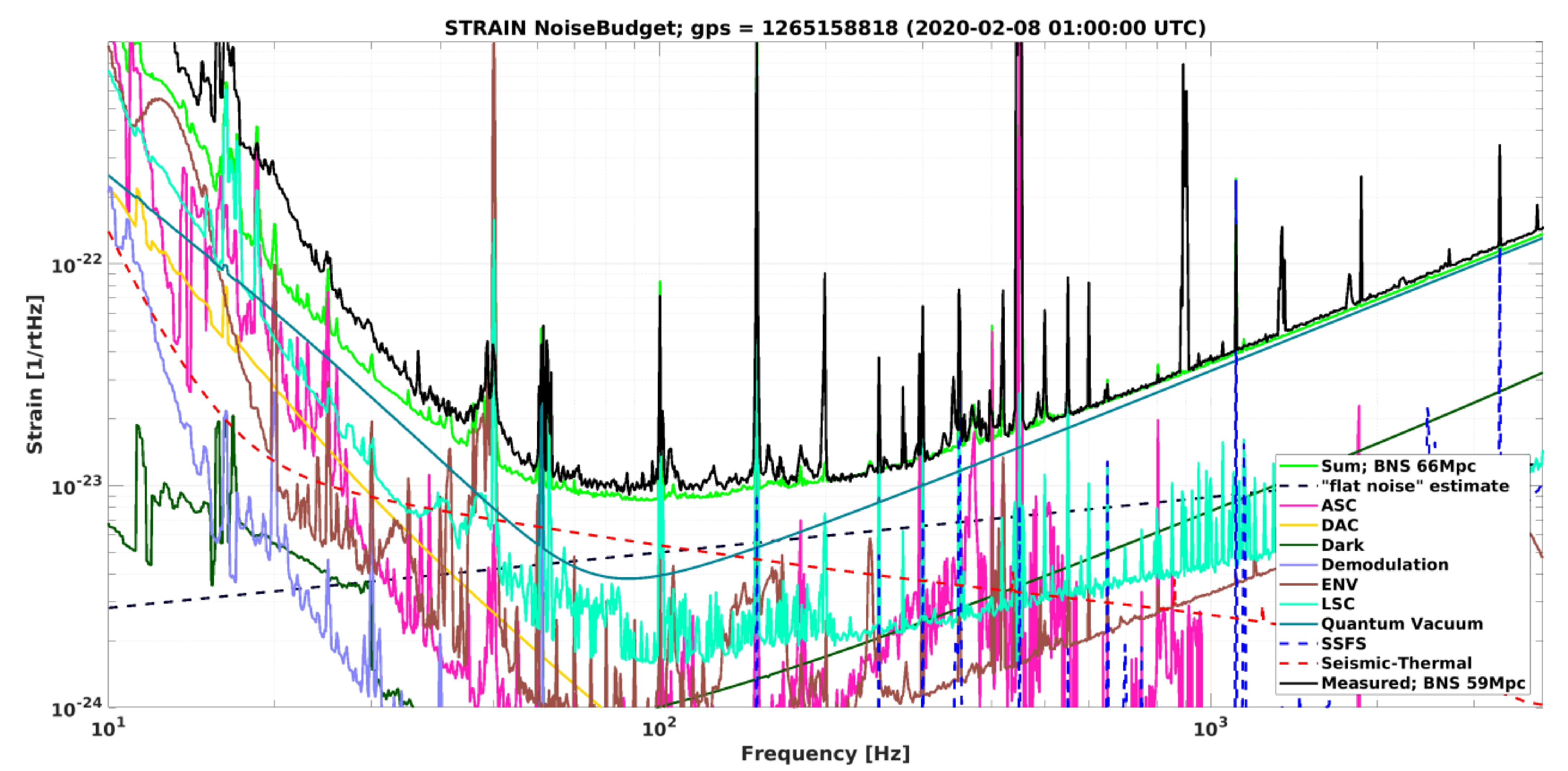
(a) LIGO Livingston Observatory



(b) LIGO Hanford Observatory

Martynov et al, Phys. Rev. D 93, 112004 (2016)

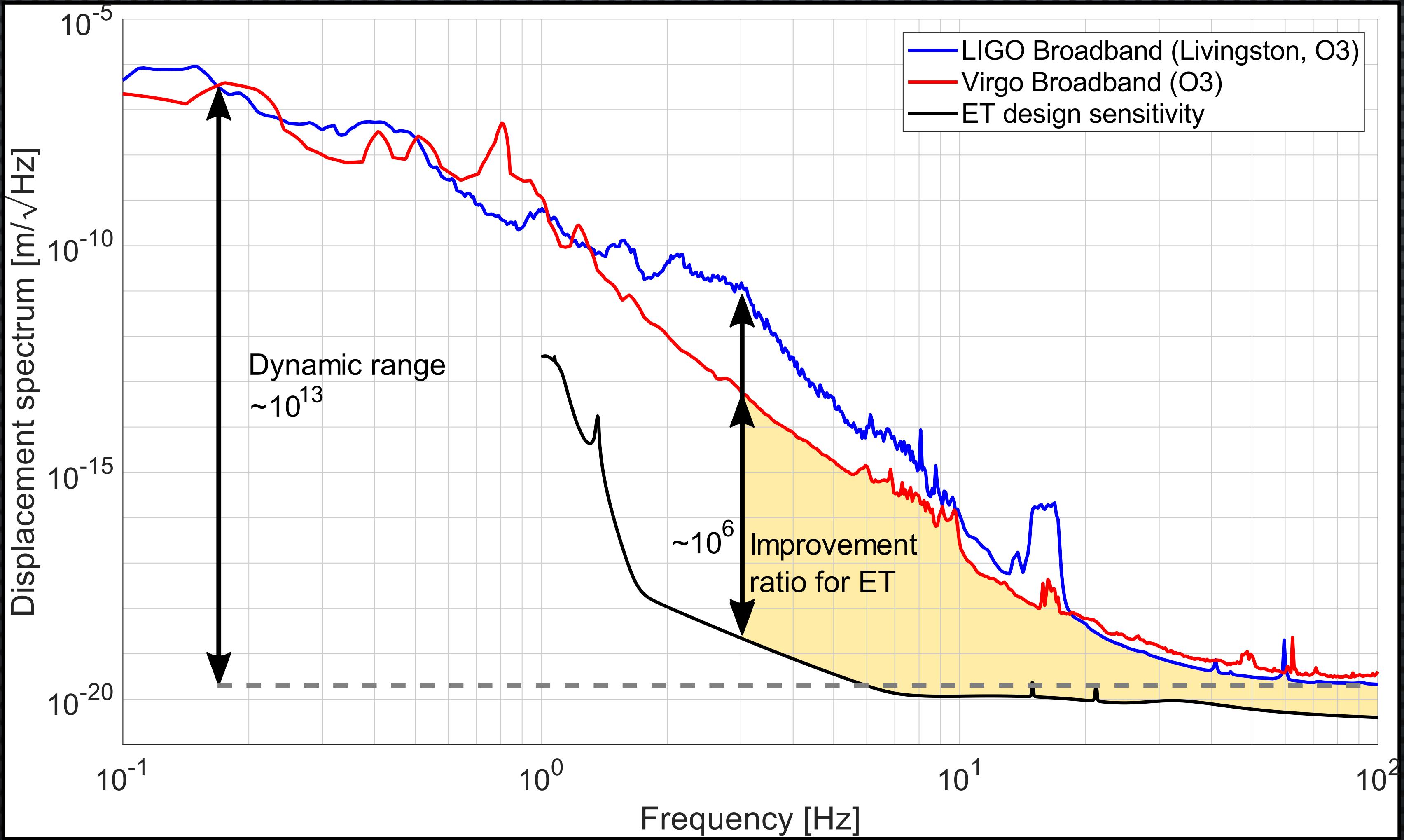
VIRGO: LOW-F DETECTOR NOISE



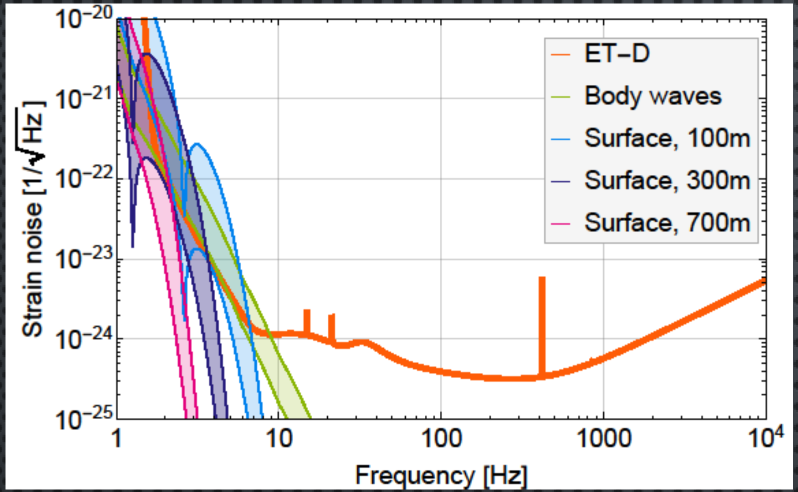
THE 4 ANM NOISE CATEGORIES

- AUXILIARY DEGREES OF FREEDOM
  (ANGULAR CONTROL, DAMPING OF SUSPENSION RESONANCES, CONTROL OF RECYCLING CAVITIES AND CENTRAL MICHELSON)
- ACTIVE SEISMIC ISOLATION
  (SENSOR NOISE, TILT-TO-HORIZONTAL COUPLING, INTER-PLATFORM MOTION)
- NEWTONIAN NOISE, MAGNETIC FLUCTUATIONS
- SCATTERED-LIGHT NOISE

THE ET LOW-F CHALLENGE

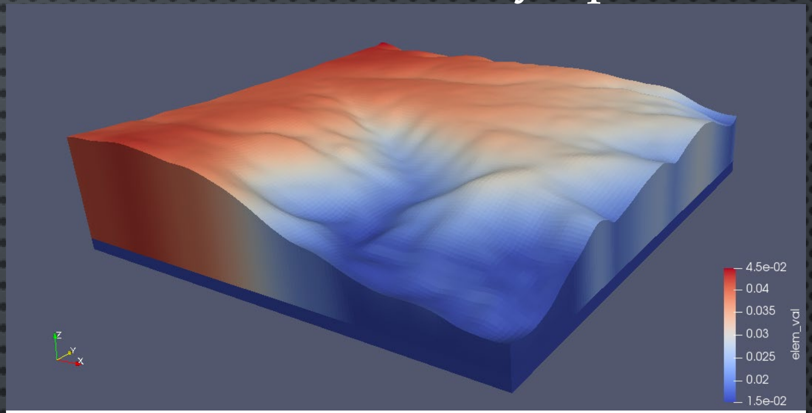


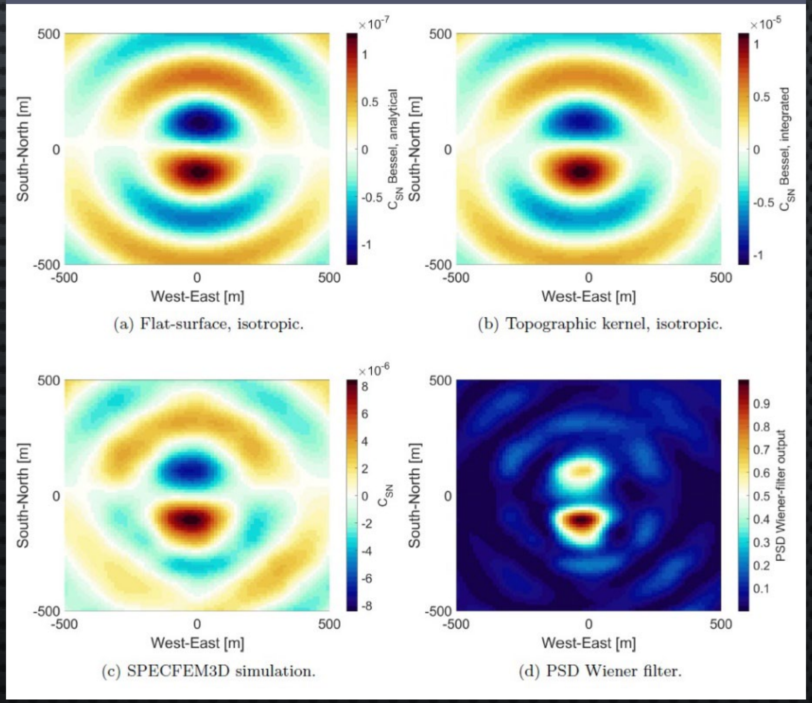
NEWTONIAN GRAVITATIONAL NOISE

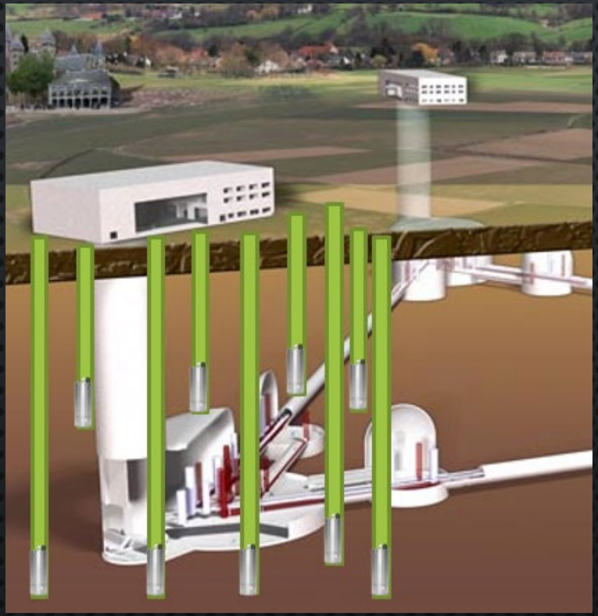


Underground construction greatly reduces, but does not completely remove, Newtonian gravitational noise from atmospheric and seismic fields.

Finite-Element Simulations + seismic correlation data for array optimization



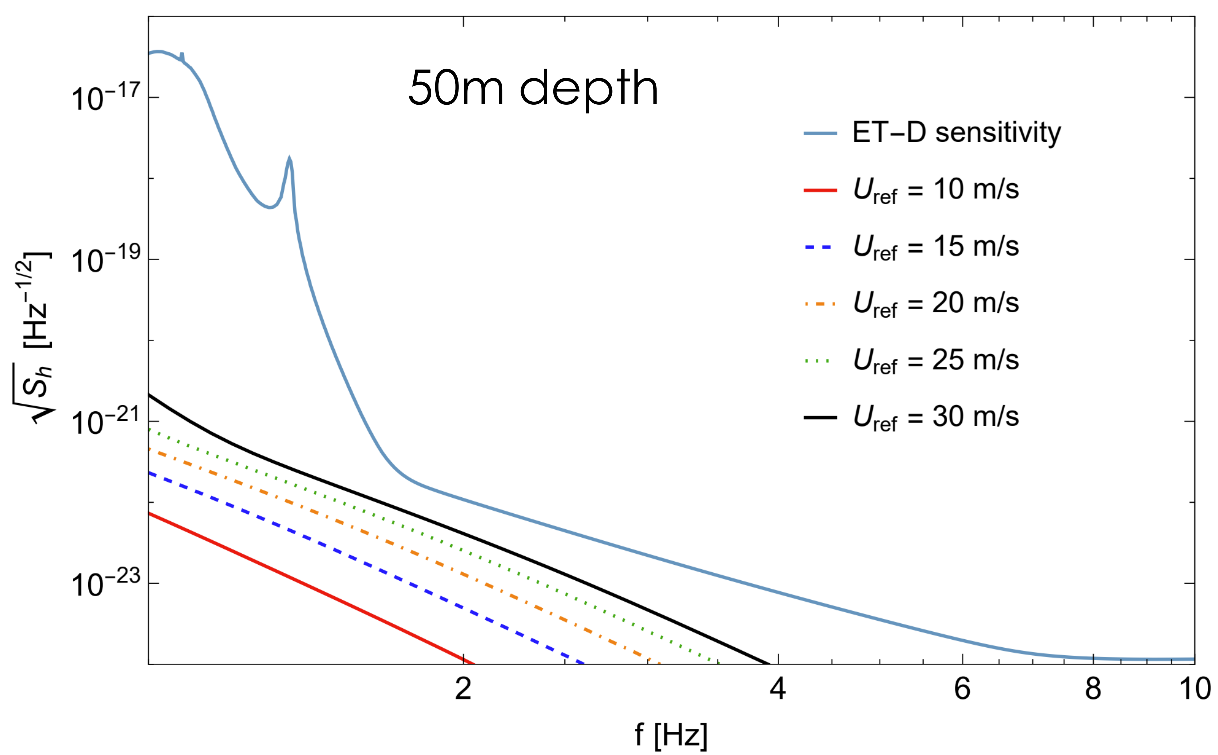




Newtonian noise must be subtracted using data from sensor networks. One of the most complex design tasks for Einstein Telescope.

ATMOSPHERIC NN

New study: NN from atmospheric temperature fields cannot be neglected even underground

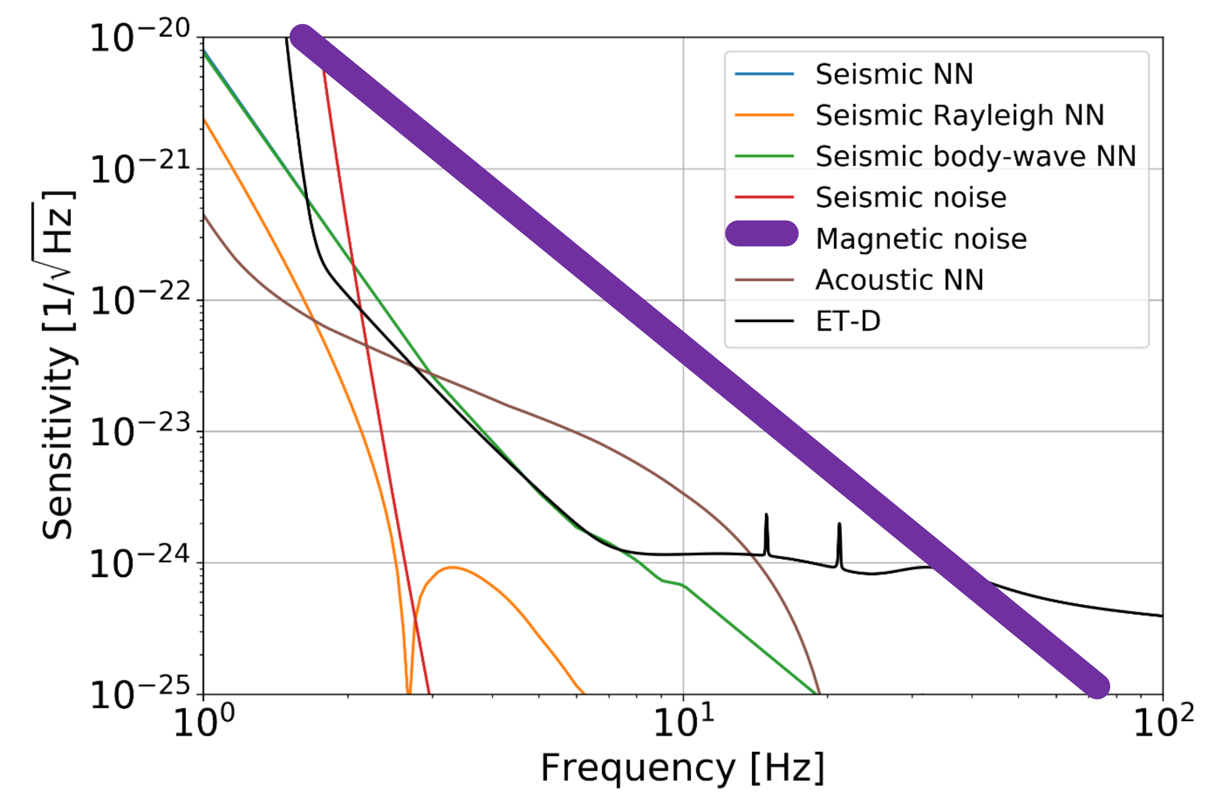


Brundu et al, PRD 106, 064040 (2022)

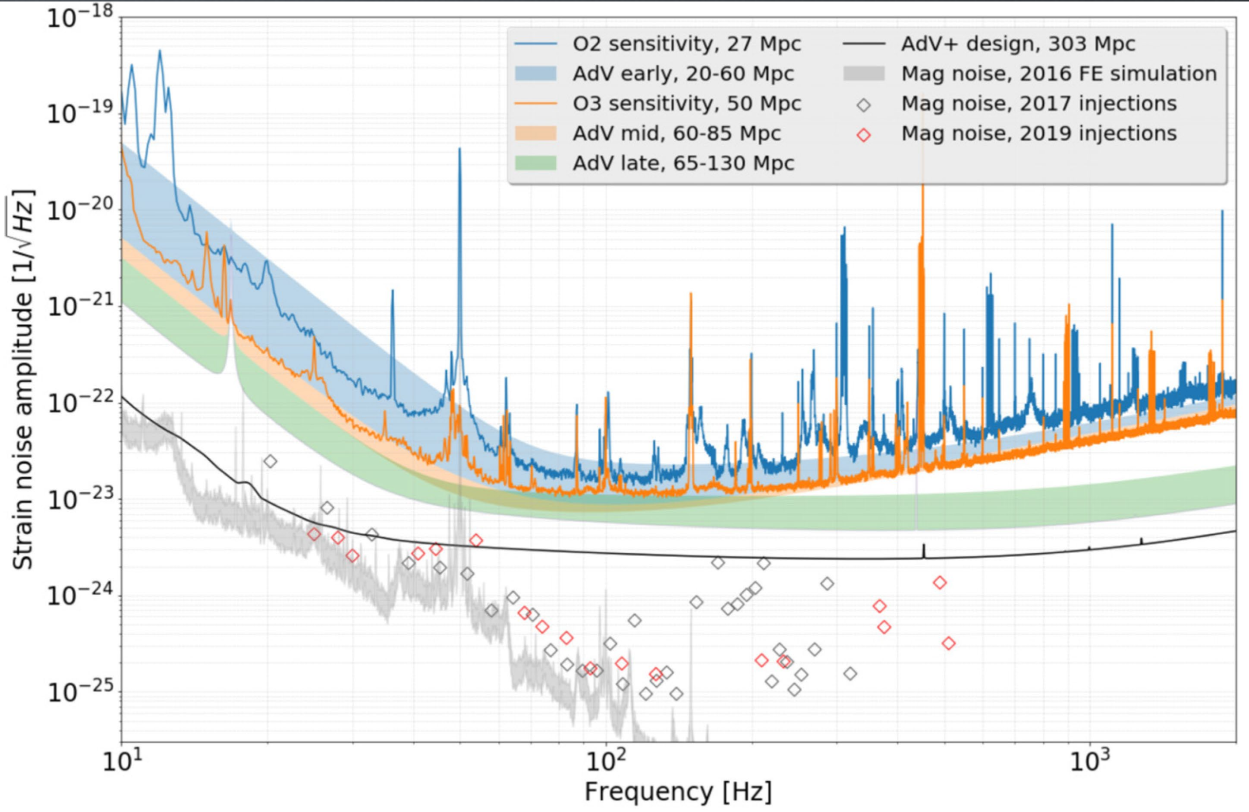
"World First: Ontario Council Includes Infrasound in Wind Farm Noise Law"

MAGNETIC NOISE

If we don't do better than LIGO/Virgo (payload design, electronics design, reduced magnetic fluctuations)



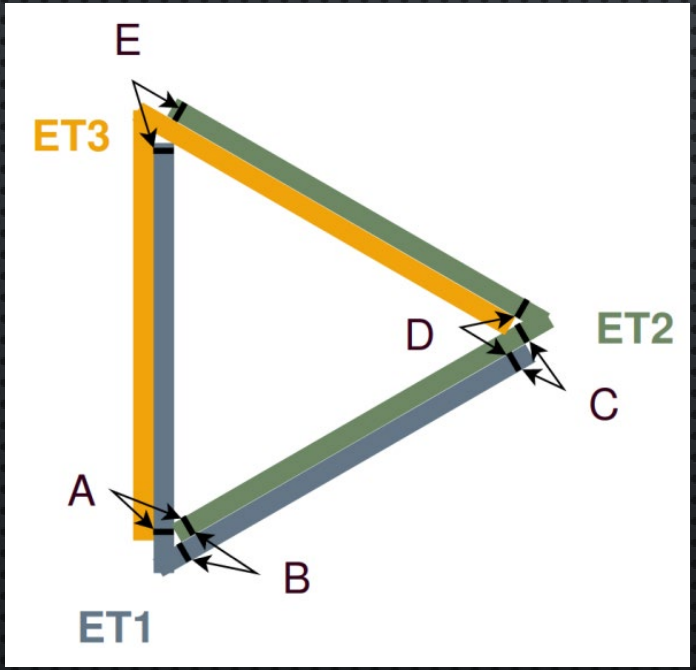
Magnetic noise in Virgo

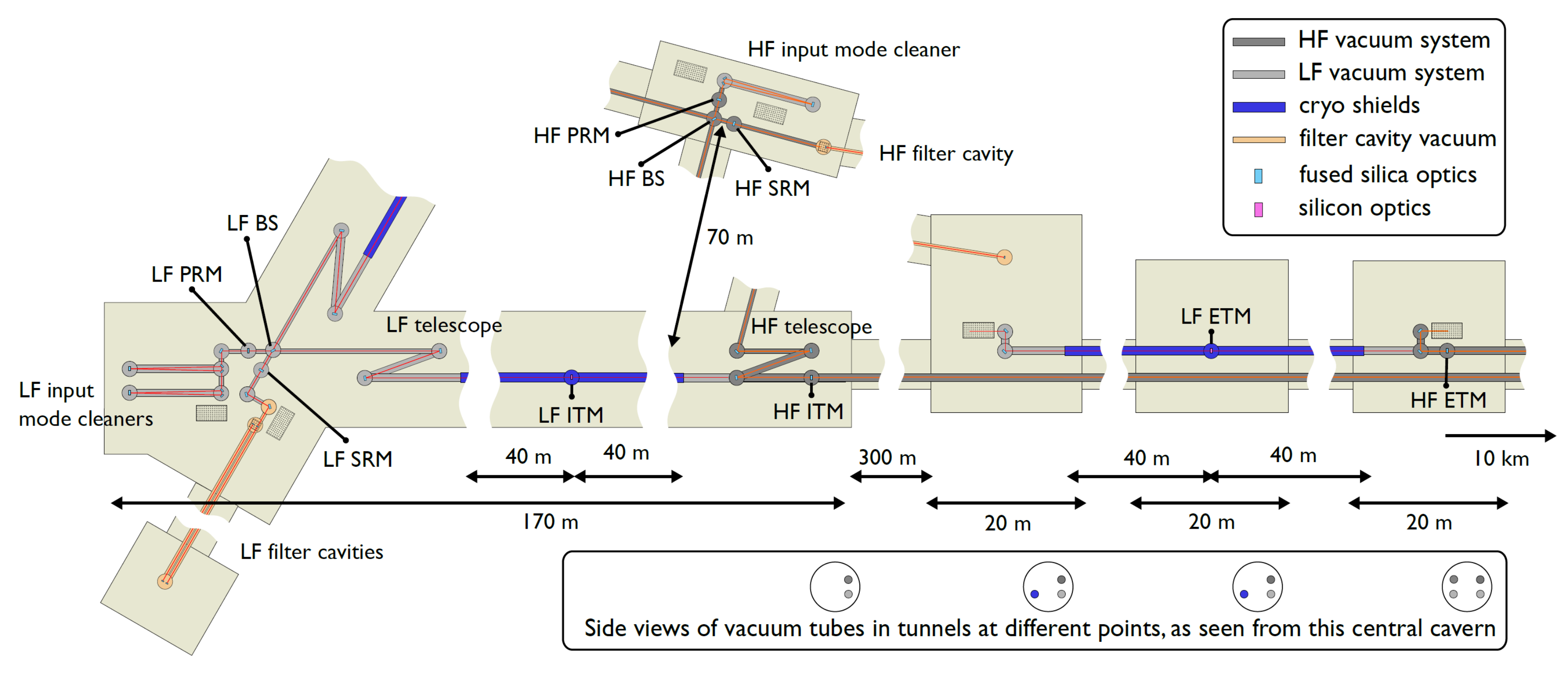


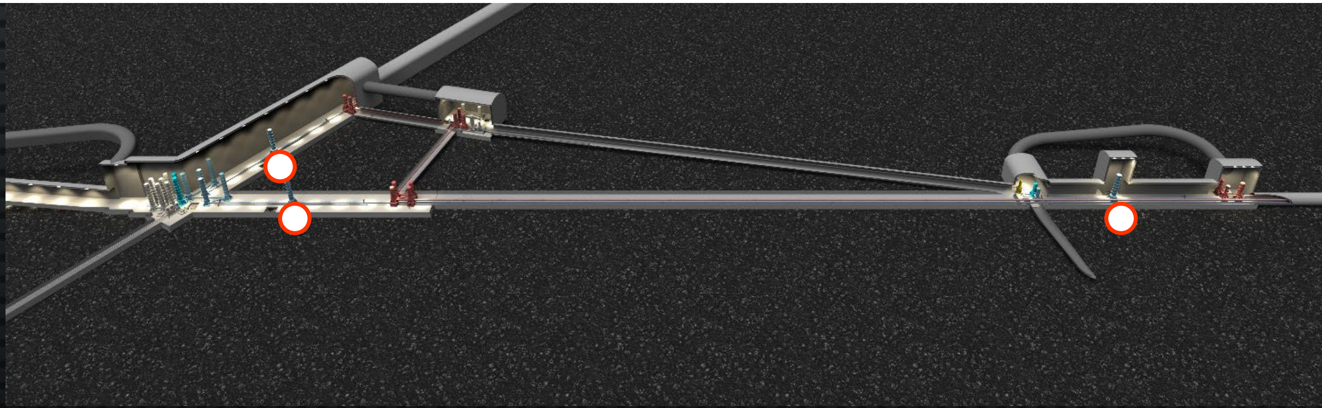
Cirone et al, CQG 36, 225004 (2019)

CORRELATED NEWTONIAN NOISE

A&D: 460m, 60deg
B&C: 430m, 0deg
E: 490m, 120deg

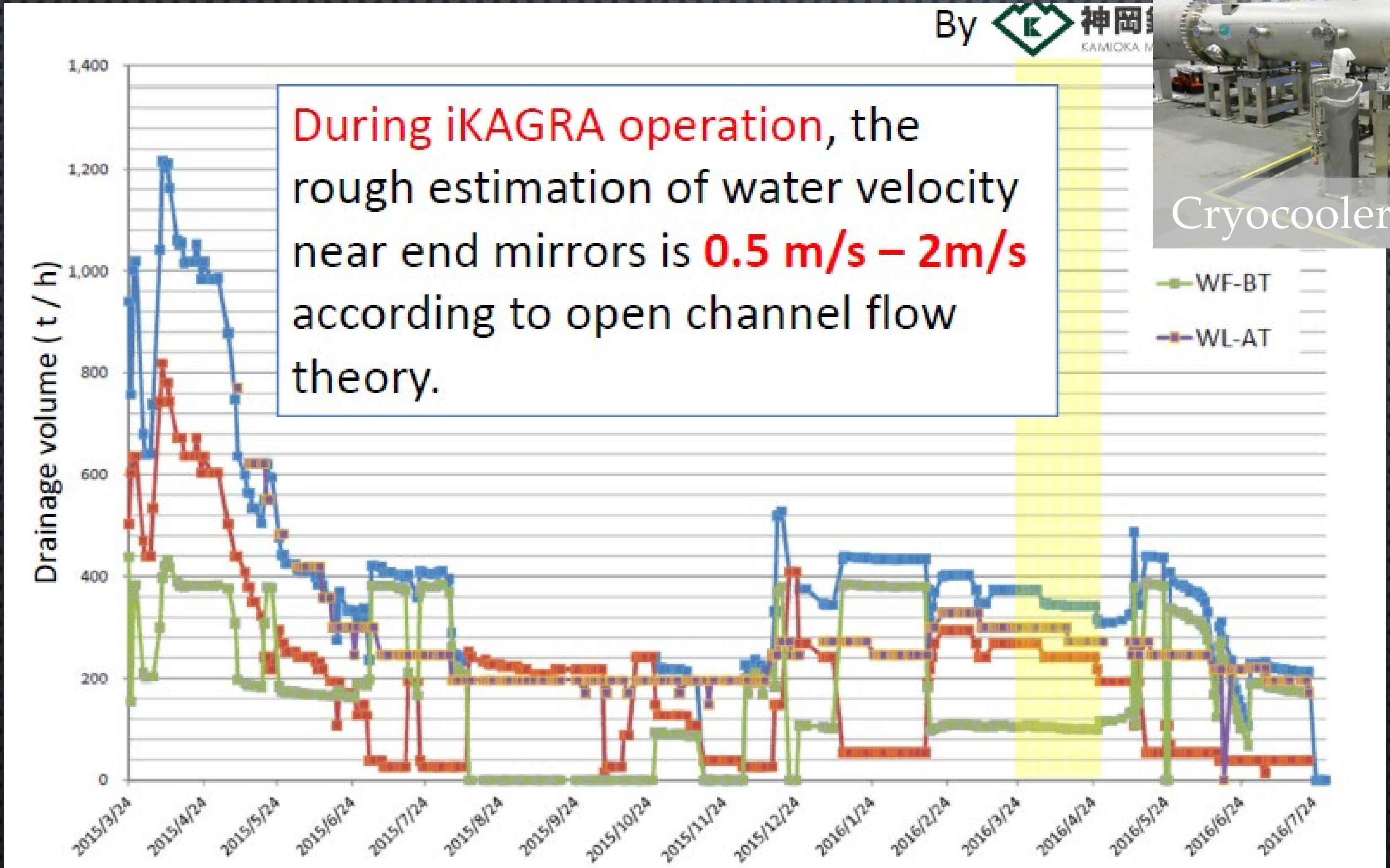


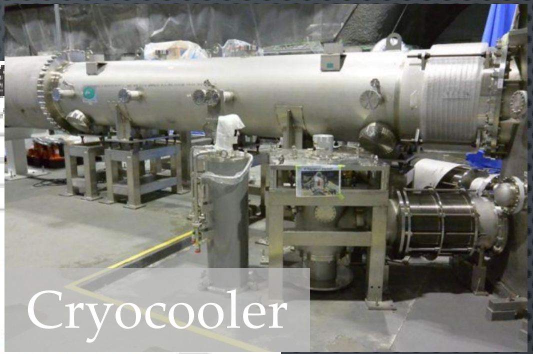




Janssens et al, PRD 106, 042008 (2022)

UNDERGROUND NOISE SOURCES





Vacuum pumps

https://dcc.ligo.org/LIGO-G1601857

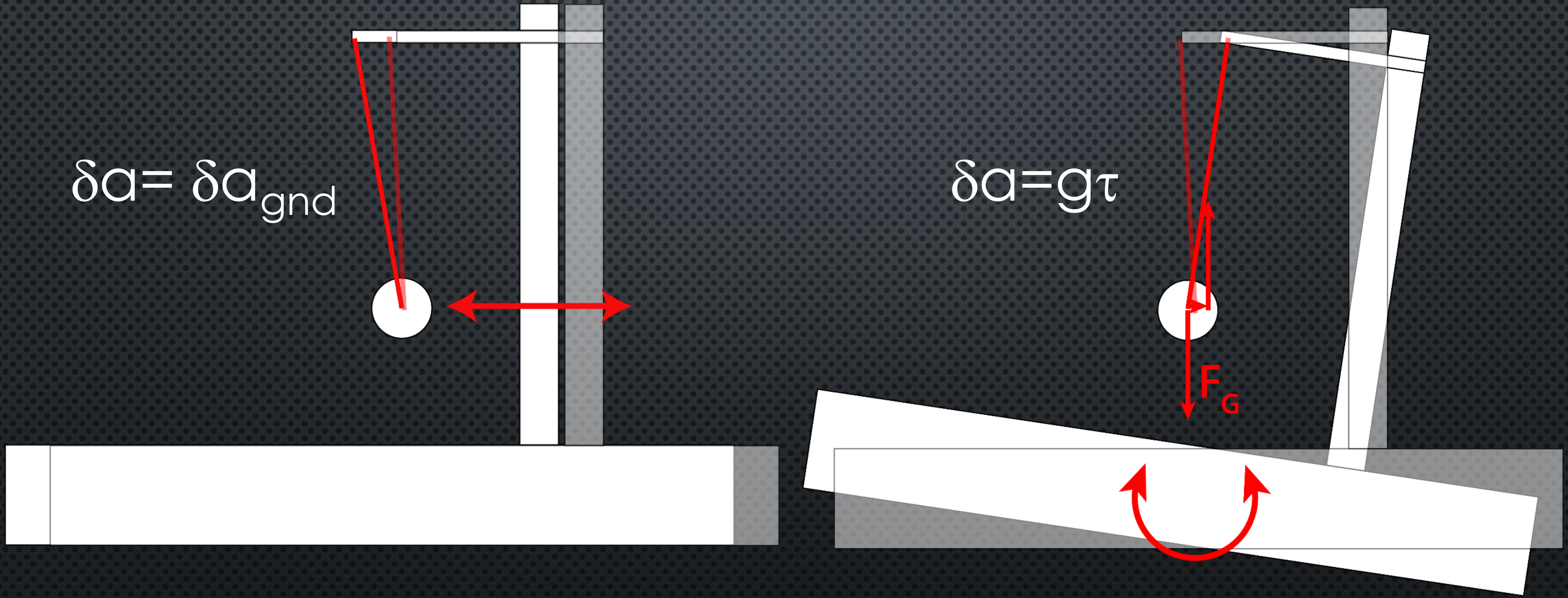
GSSI

TILT-TO-HORIZONTAL COUPLING

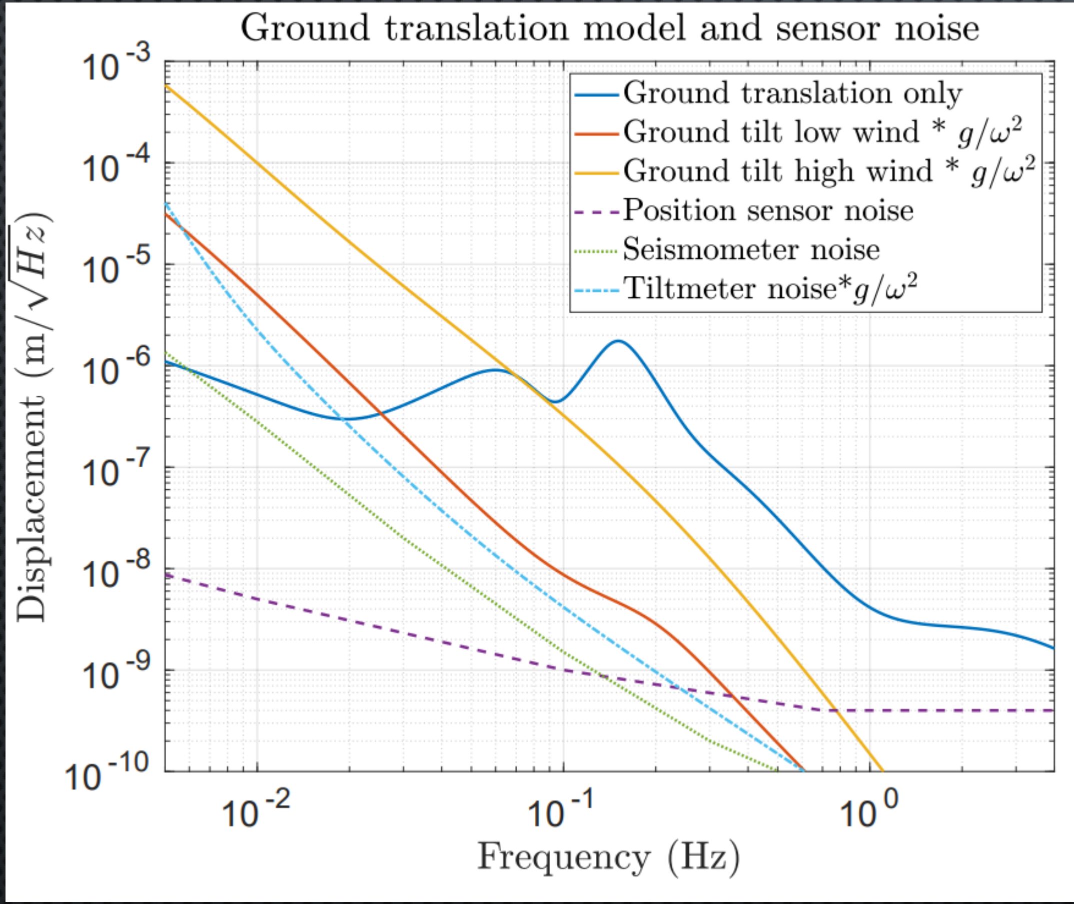
EINSTEIN TELESCOPE

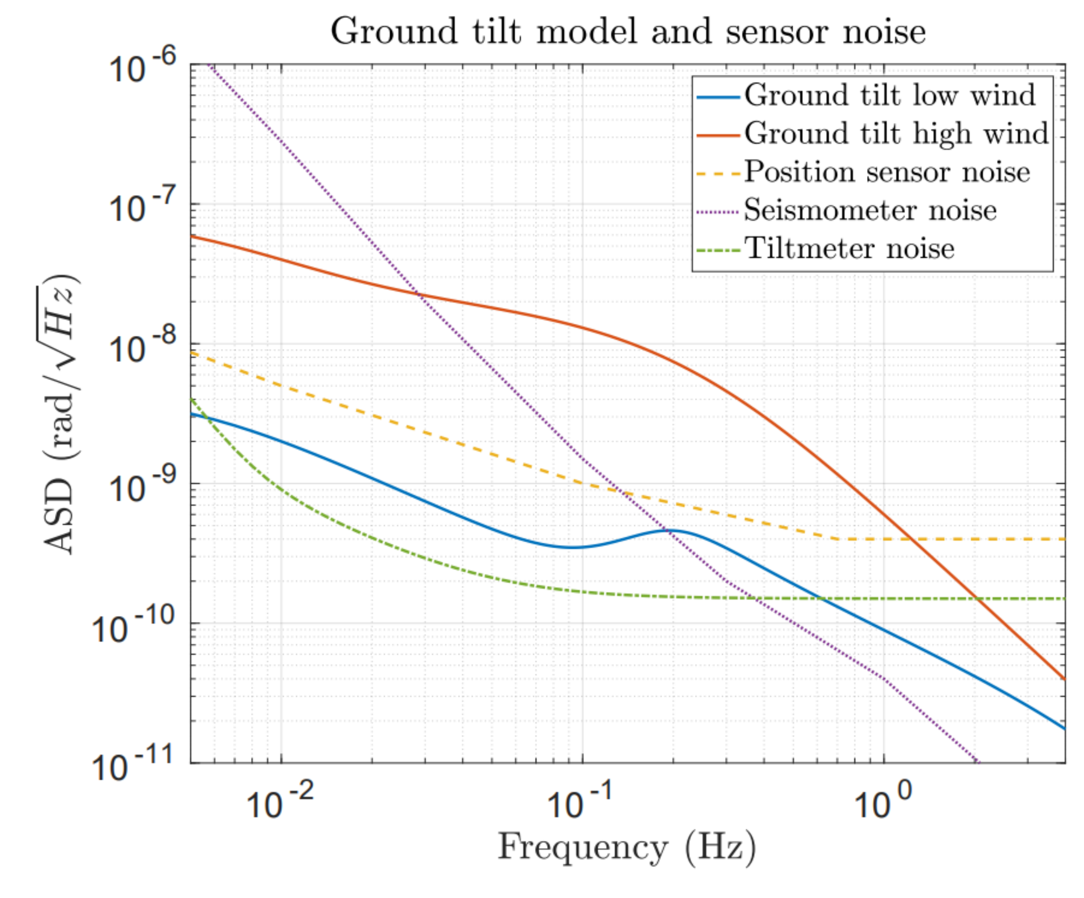
$\delta a = \delta a_{gnd}$

$\delta a = g\tau$



THE RELEVANCE OF GROUND TILT

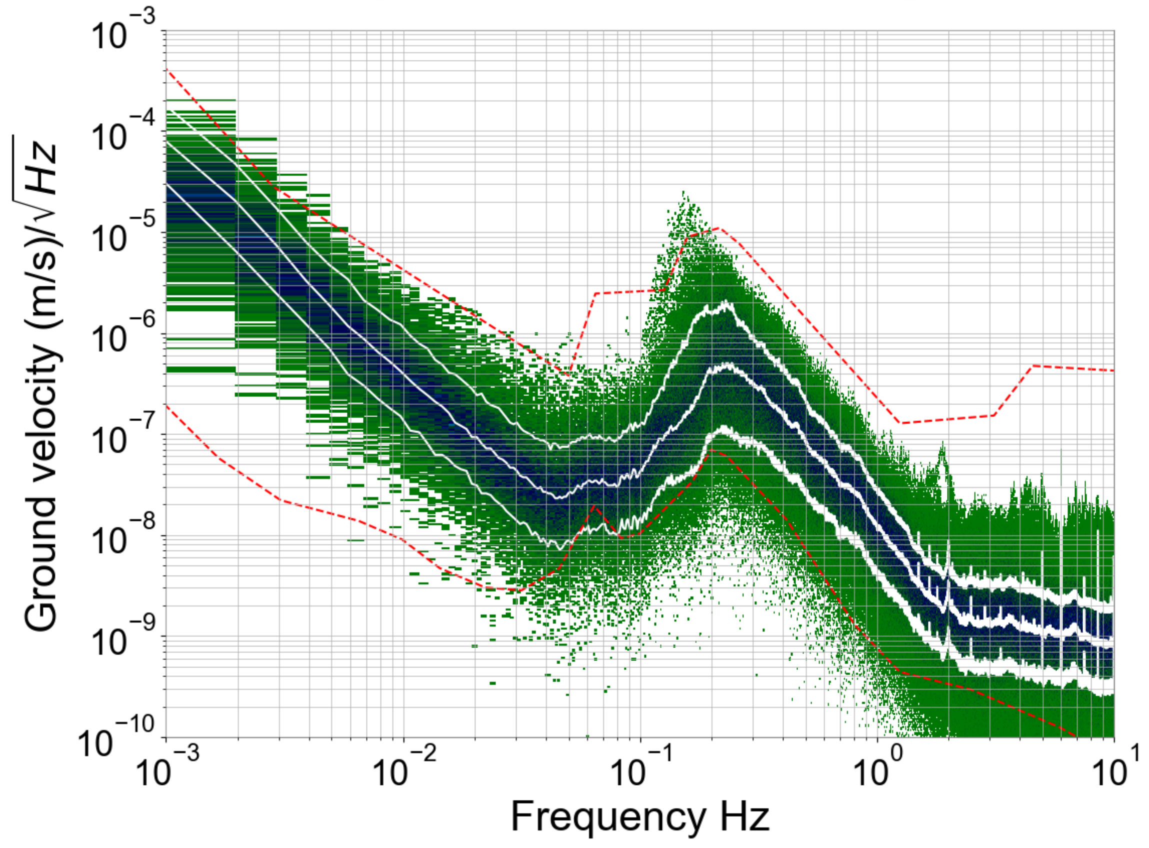




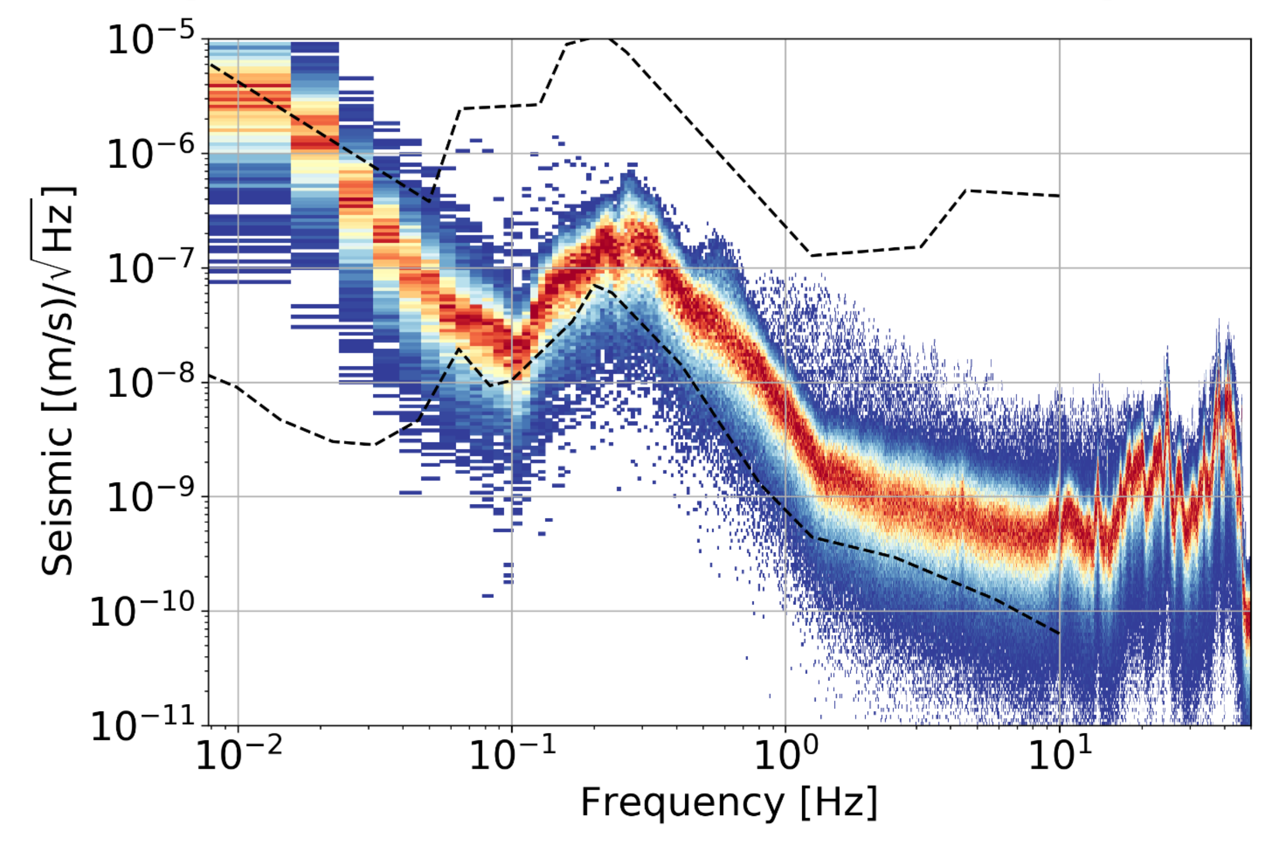
Ross et al, CQG 37 185018 (2020)

UNDERGROUND SEISMIC NOISE

KAGRA (CENTRAL STATION)



LNGS (AT GINGERINO SITE: IV_GIGS)



PLANS FOR ANM<>SUS PARALLEL SESSION

1st session

Brief tutorials/demonstrations of simulation tools (Finesse, Lightsaber, SpicyPy).

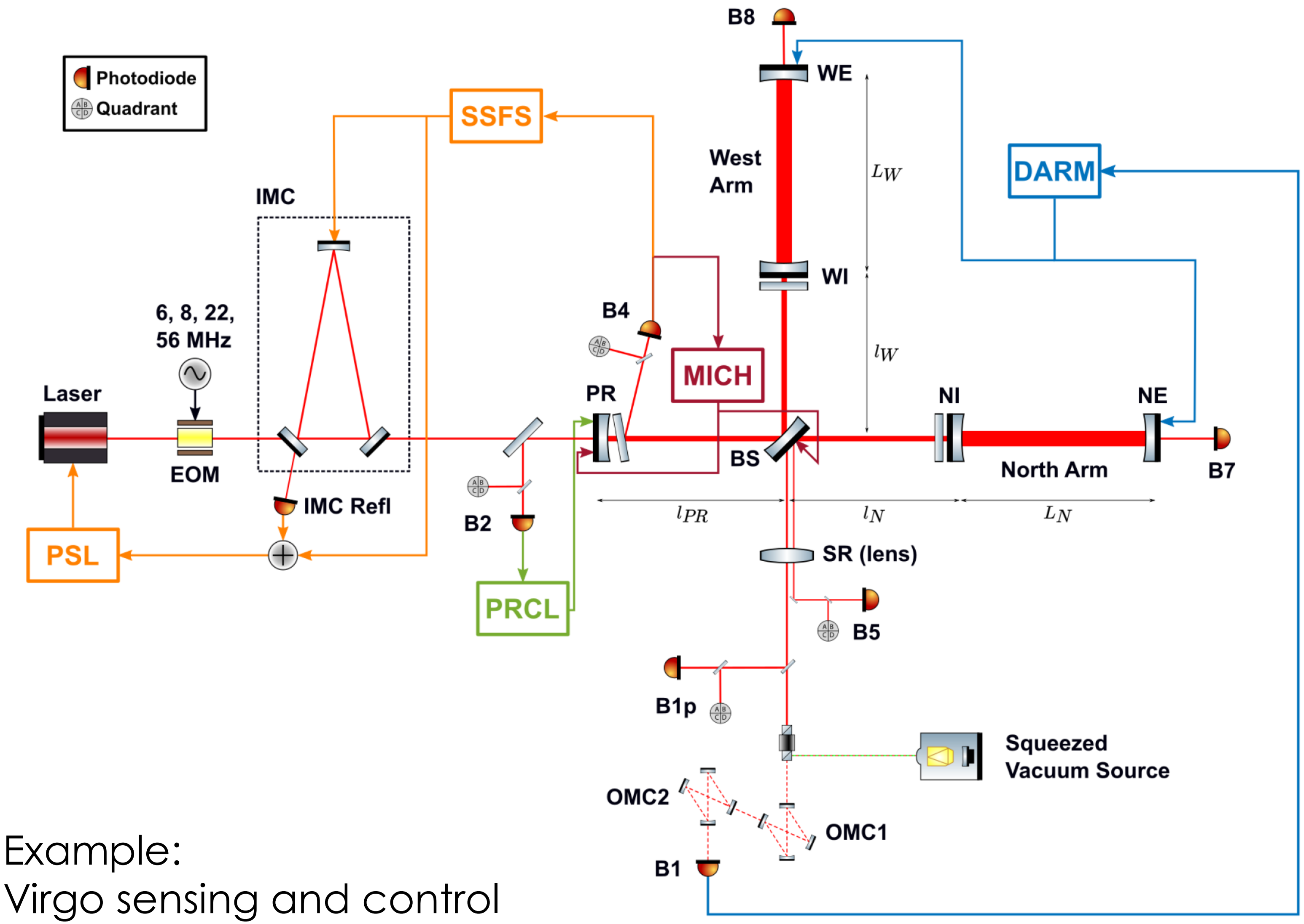
2nd and 3rd sessions

Defining a first simplified model of the lower ET-LF suspension stages and its noise inputs and actuation scheme in the context of angular controls. Calculate the requirement of rms angular motion of arm-cavity mirrors for ET-LF.

4th session

Simulation of the arm-cavity angular controls of ET-LF.

A SMALL PART OF A COMPLEX SYSTEM

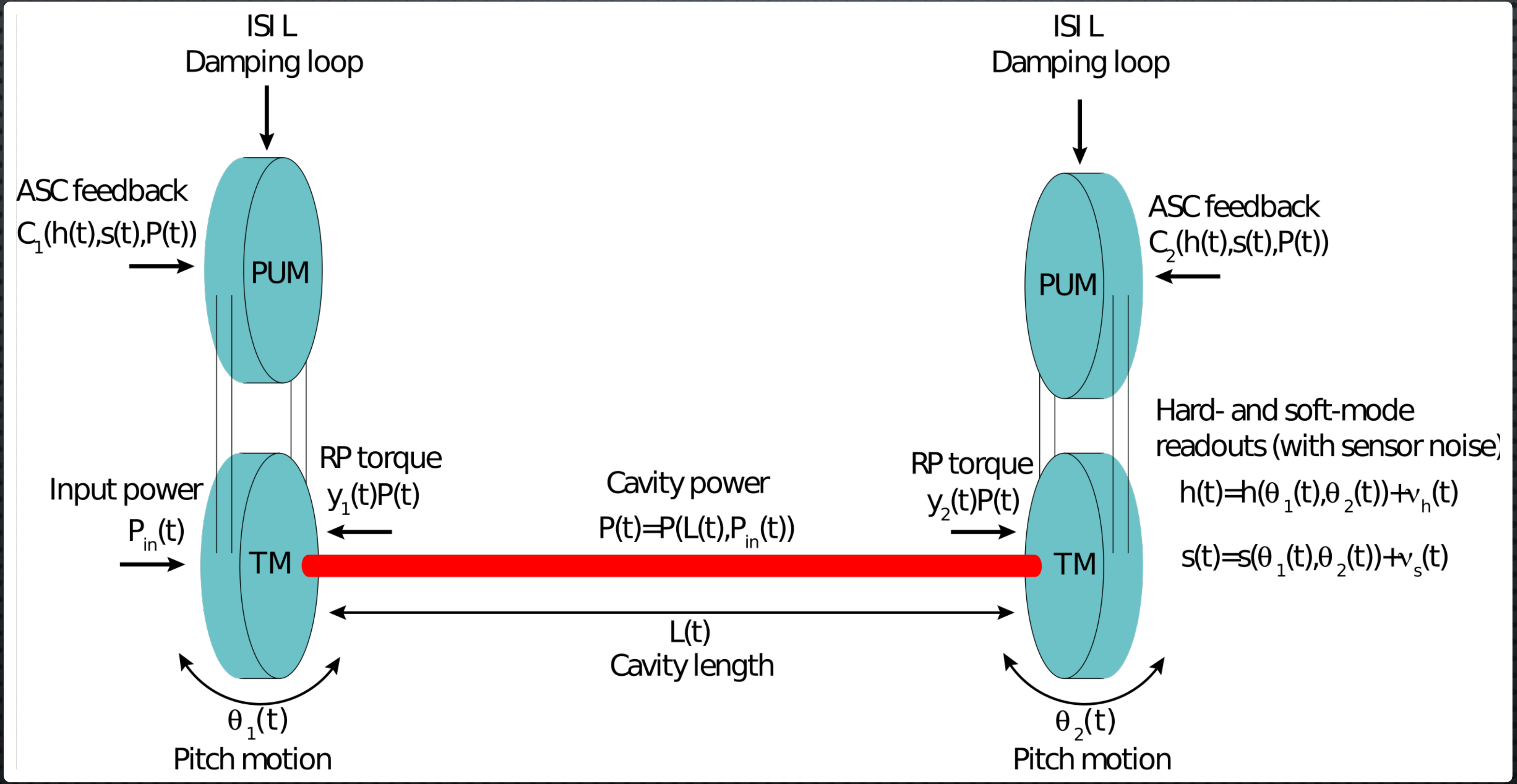


Example:
Virgo sensing and control

Allocca et al, Galaxies 8, 85 (2020)

LIGO: ARM-CAVITY ANGULAR CONTROL

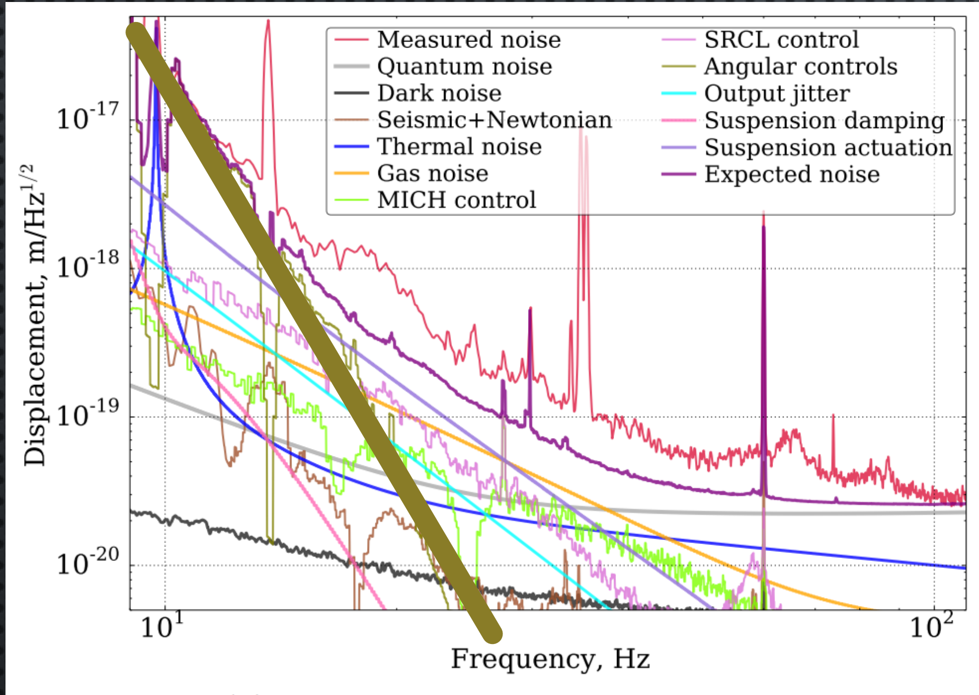
Goal: simulate the equivalent of this system for ET-LF



Andric, Galaxies 2021, 9(2021)

ET: RELEVANT DESIGN ASPECTS

LIGO angular controls noise (2016)



(a) LIGO Livingston Observatory

Why should the problem be less severe in ET-LF?

- Larger test masses
- Lower arm-cavity power (smaller optomechanical resonance frequencies)

Why might there still be a problem?

- Observation band moves close to the oceanic microseismic peak
- Some of the noise injected by controls in the observation band might be considered fundamental, e.g., DAC noise
- …

STEPS OF THE ANALYSIS

Final suspension stages

- Response: actuator torque for pitch control [Nm] to test-mass pitch motion [rad]
- Response: radiation-pressure torque [Nm] to test-mass pitch motion
- Noise input: suspension-resonance damping
- Noise input: top-stage platform motion

Arm cavity

- Response: pitch motion of test masses [rad] to beam-spot motion on test masses [m]
- Response: cavity-length fluctuations [m] to power fluctuations [W]
- Noise input: laser-power fluctuations [W]
- Noise input: sensing of pitch motion [eff. rad]