Reaching the Advanced LIGO Detector Design Sensitivity

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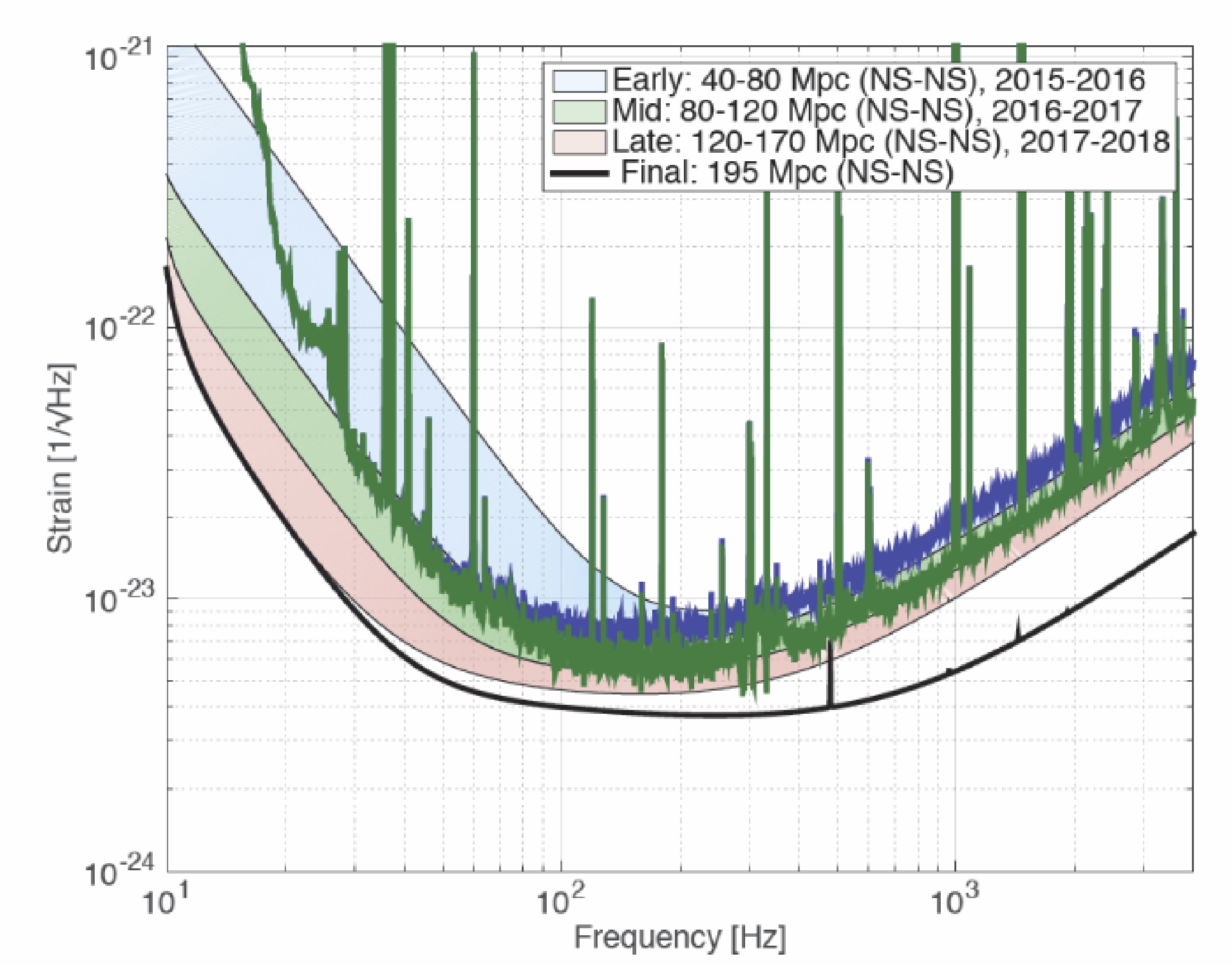
Plan

- Interleave commissioning with observation runs
  - Shorter runs at the beginning
- Work in stages
  - O1: ~3 months, we ~~could get~~ were lucky
  - O2: ~6 months run at ~100 Mpc
  - O3: long run at ~150 Mpc
- Commissioning:
  - After O1: Increase power to 50W+
  - After O2: Increase power to 100W+ (or squeezing)

Sensitivity Goals for Early Runs



O1

O2 projection with 50 W laser power

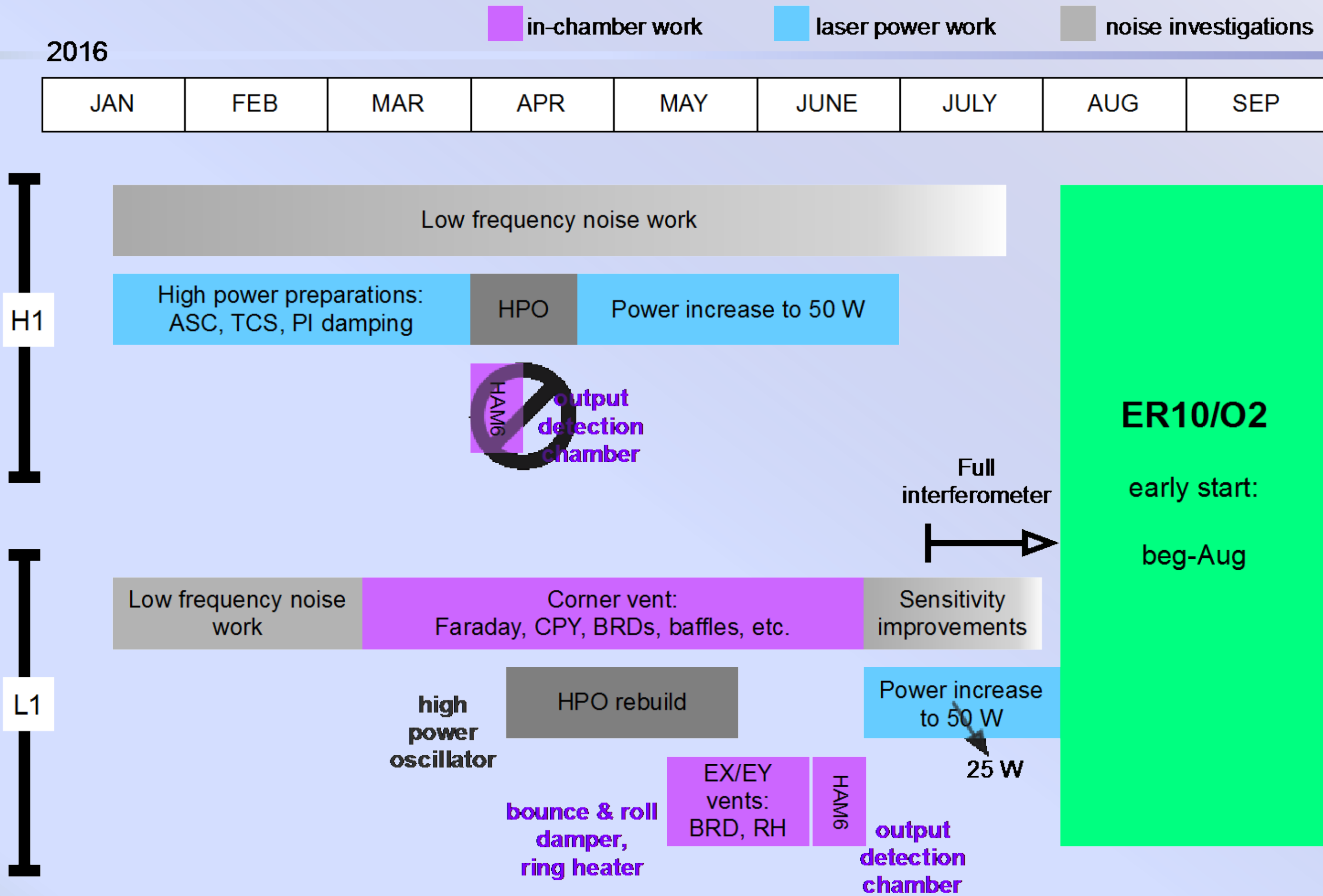
Major Challenges

- Understand and suppress low frequency noise
  - Alignment noise
  - Auxiliary degrees-of-freedom
  - Unknown noise sources and unknown coupling mechanism
- Increase power from ~25W (O1) to ~150W
  - Thermal lensing and thermal compensation
  - Control alignment instabilities w/o degrading noise
  - Control parametric instabilities

In Detail: Post O1 Commissioning

- Double the laser power: 25 W → 50 W
  - Requires activating High Power Oscillator stage
  - Currently at 40W at LHO
  - LLO: Plagued by laser problems
- Diagnose and reduce low-frequency noise
- Diagnose and reduce other instrumental artifacts
  - transient noises and spectral lines observed in O1
- Improve uptime
  - Work on robustness & stability

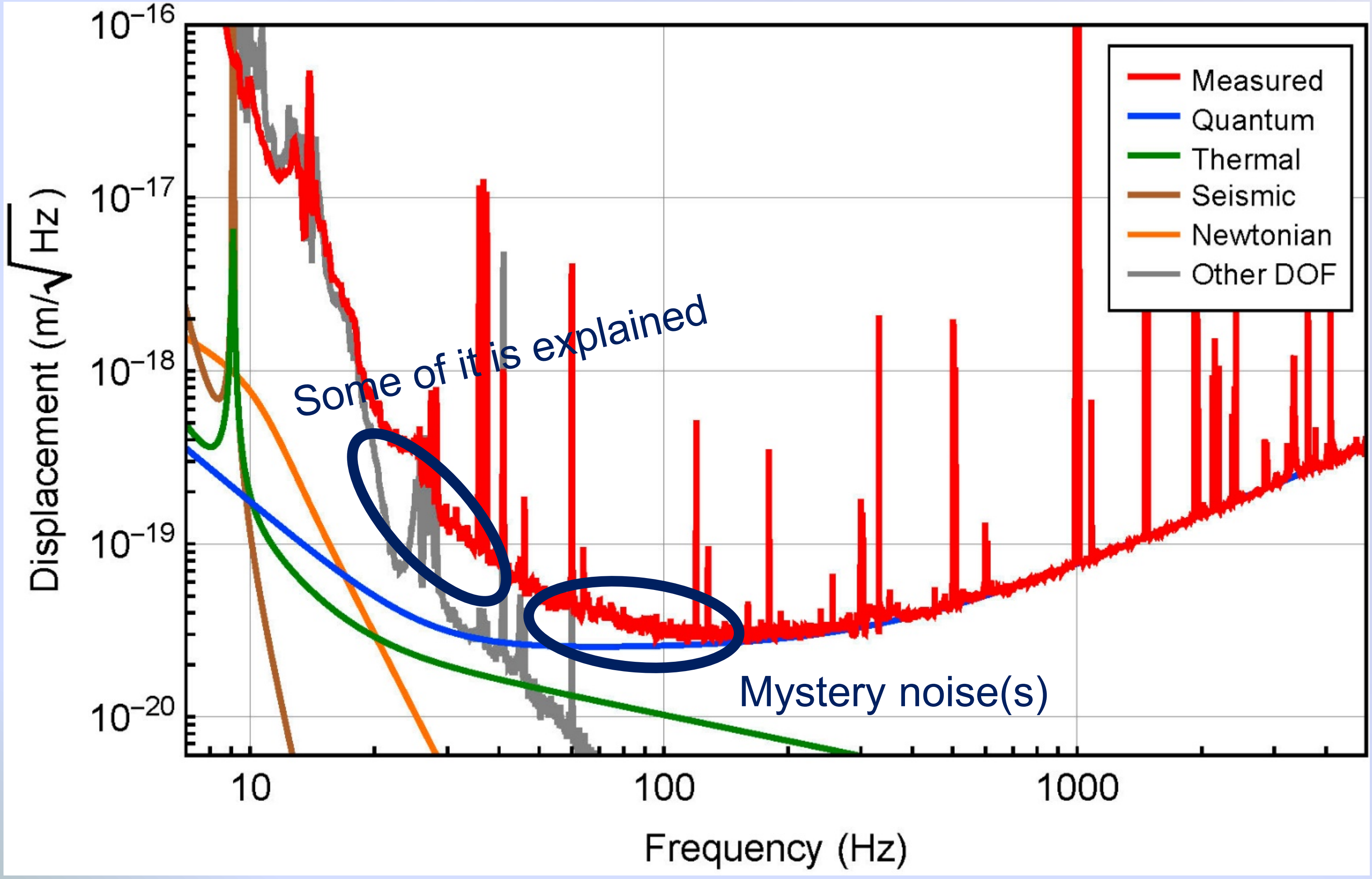
Timeline between O1 & O2



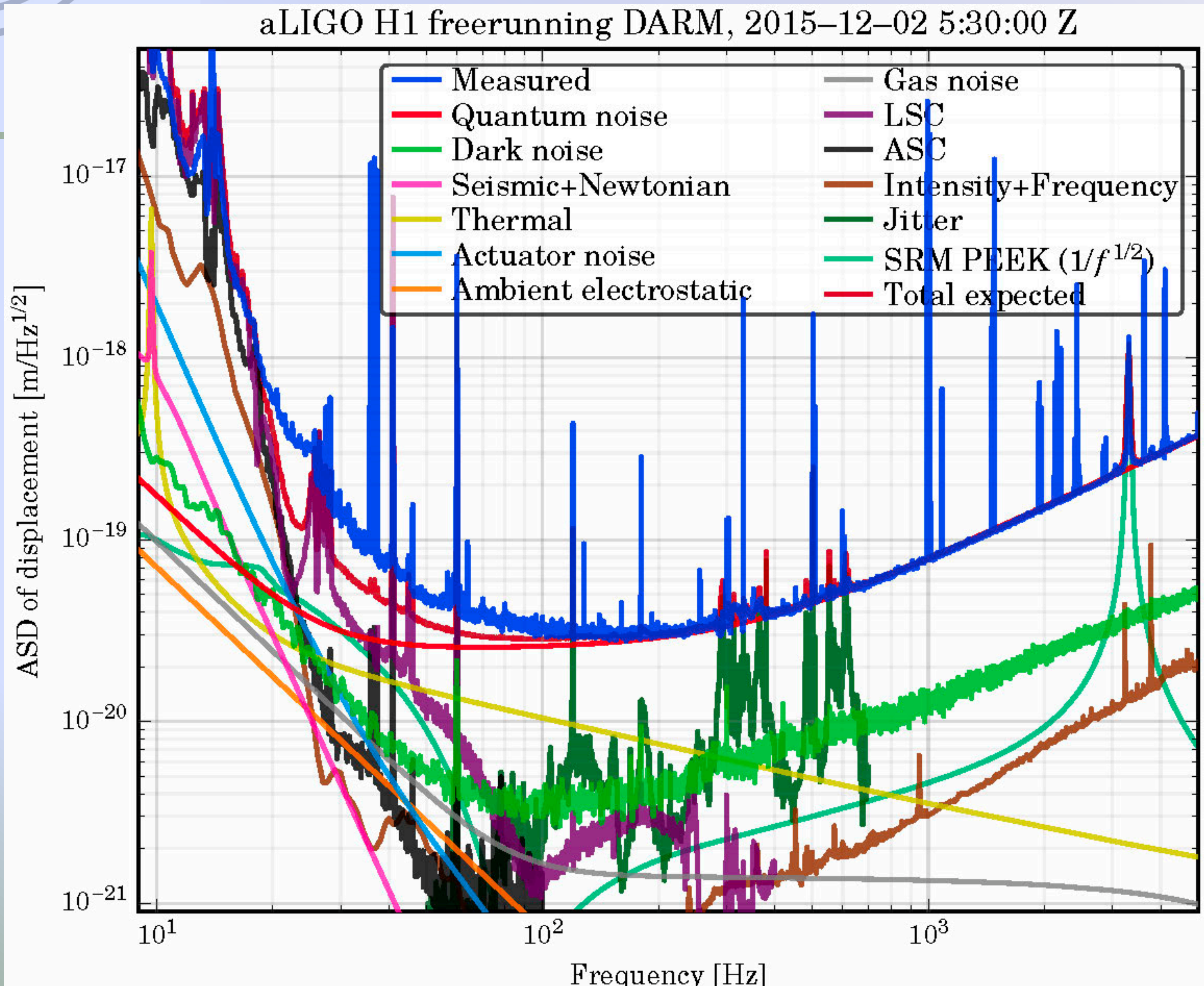
L1: In-vacuum work for O2

- Sensitivity
  - Faraday isolator, high QE photodetectors
  - Passive dampers for HAM seismic isolator components
  - Stray light baffles
- Laser Power Increase
  - Thermal compensation in signal recycling cavity
- Robustness
  - Passive tuned dampers for test mass suspension modes

Low Frequency Noise



Updated Noise Budget

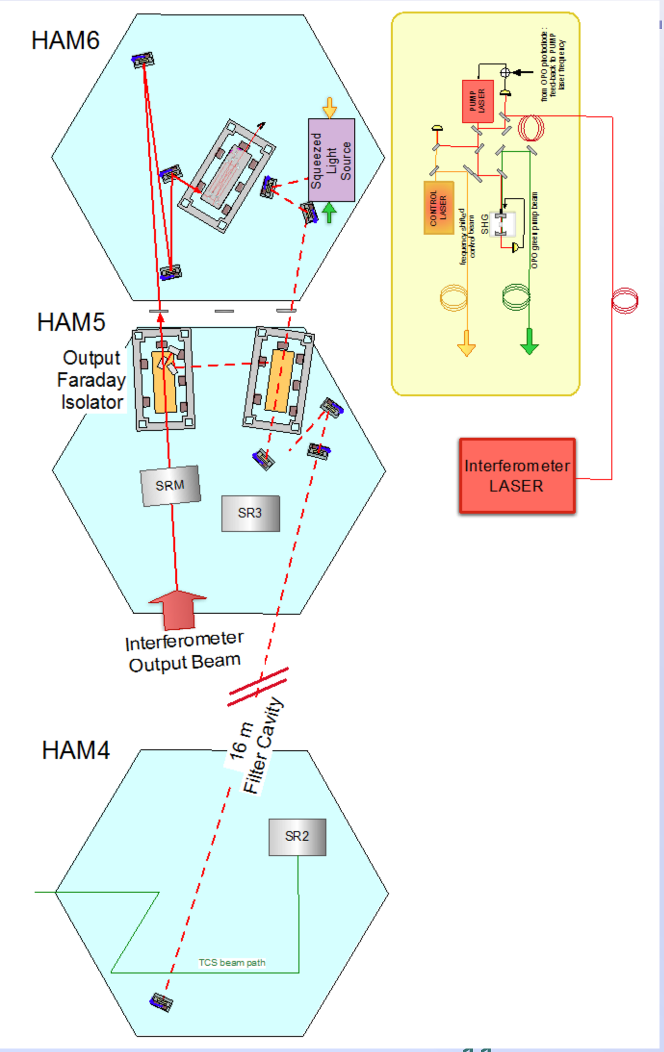


In Detail: Post O2 Commissioning

- Replace end test masses and end reaction masses
  - Fix 532nm coating error → should help with robust locking
  - Fix phase ripple that scatters light
  - Reduce squeezed film damping with new annular ERM
- Replace Compensation Plate on H1 (a la L1)
- Test mass Suspension mode dampers for H1
  - Dampers for triple suspensions in development
- Uptime → Robustness
  - Improve wind mitigation at LHO (tilt sensors, wind fences)
- Acoustic mode dampers for test masses
  - 3rd technique for Parametric Instability mitigation; still in development

Squeezed Light Injection: Post O2/O3

- Squeezed light source with in-vac OPO currently in development
  - Provide 3-5 dB of quantum noise reduction at high frequencies & corresponding increase in radiation pressure noise
  - Planning to make this an option for post-O2
- Addition of filter cavity would limit the low-frequency noise increase
  - Short filter cavity: ‘do no harm’
  - In development for testing at MIT-LASTI
  - Planning this as a post-O3 option



Summary

- Sensitivity of initial detectors was surpassed quickly
- Successful O1 run and first GW detection
  - There is now more incentive to run
- Explanation for low frequency noise is elusive
- High power operations hampered by laser problems
- Improvements in seismic
  - High wind & high μseis problem at LHO: tilt meters were installed
- Major vent at LLO: fix Faraday, ITM comp, BS baffle, etc.
- Ready for O2 in September of this year

Mystery Low Frequency Noise (1)

- What's known:
  - Possible explanation at lower end, but not at 80 Hz
  - Similar level between H1 and L1
  - L1 shows additional bumps (maybe due to scattering)
  - Relatively stationary
  - To reach above 100Mpc NS inspiral range we need both
    - Reduce this noise and
    - Higher laser power to reduce shot noise
- Unknown:
  - What causes it
  - Single or multiple sources
  - Exact spectral shape (not enough exposed, but not flat)

Mystery Low Frequency Noise (2)

- It ain't:
  - ETM/ITM coating thermal or SUS thermal
  - Just scattering (too stationary)
  - Suspension drive electronics
  - Electric charge
  - Sensing noise
  - Laser noise (frequency, intensity, RFAM)
  - Beam jitter
  - Angular control noise
  - Up-conversion
  - Beamsplitter motion
  - OMC related
  - PEM related such as acoustic, seismic, magnetic, …

Mystery Low Frequency Noise (3)

- Still out there:
  - Scattering (not completely ruled out)
  - Squeezed film damping
  - Mechanical interference
  - Anything in the SRC such as ITM/BS AR coatings