
# Low-frequency Cutoff in Advanced LIGO

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# Review goals for AdLIGO's low-frequency performance

*Written up in LIGO-T020034*

- Astrophysical source potential & impact
- Interferometer design trade-offs
- Signal processing possibilities
- Upgrade options
- Recommendations

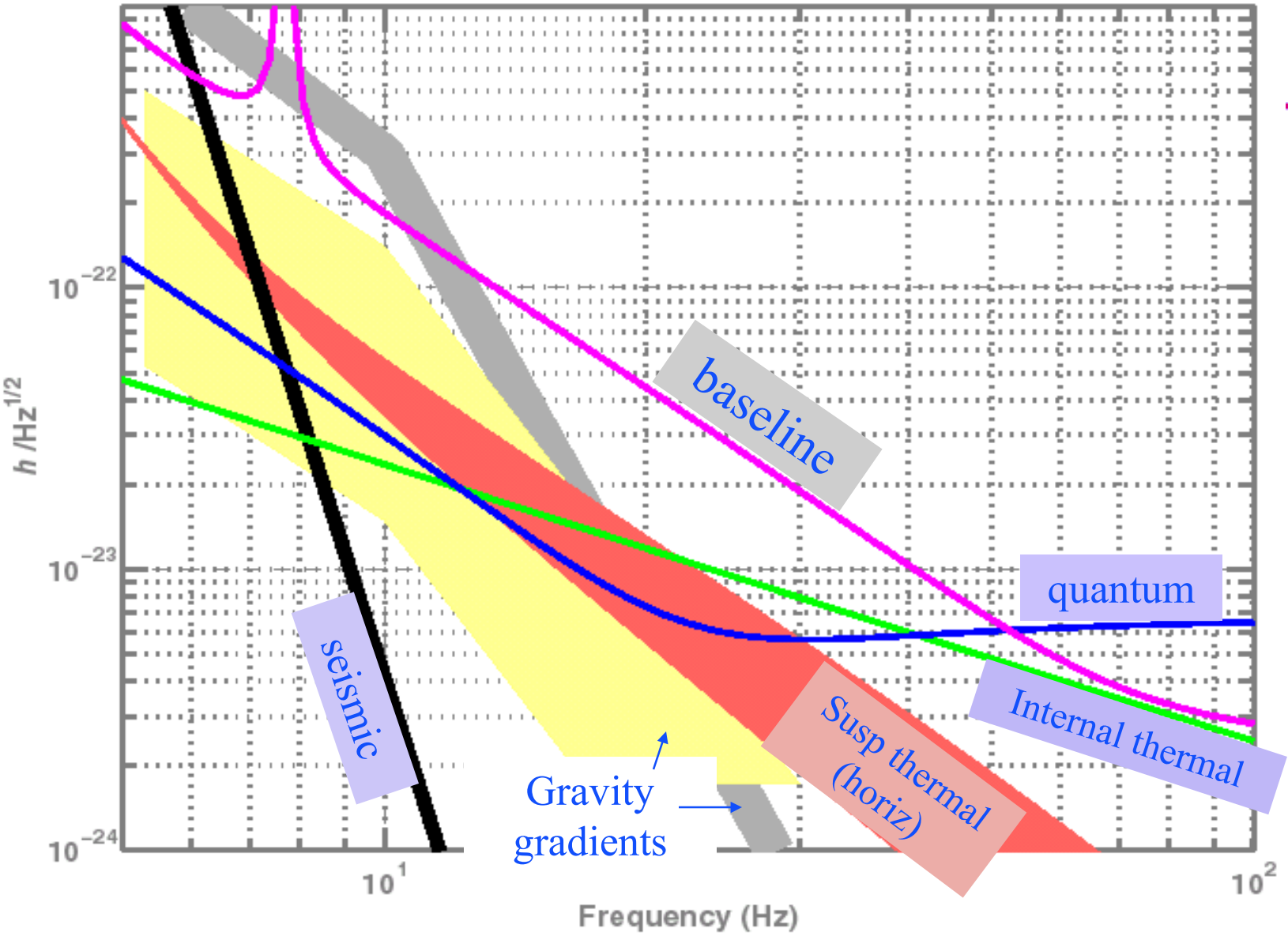

# Impact of 10-15 Hz cutoff on astrophysical source detection

- Binary inspiral and stochastic background sensitivity:
  - » Less than few percent impact for $f_c$ up to 15 Hz
- Other potential sources--GW theorist community polled for comments:
  - » Massive binary inspirals (BH/BH)
  - » Core collapse of massive stars
  - » Low frequency pulsars
- General conclusions:
  - » Not enough information to rule out or 'rule in' any sources with $f_c$
  - » No anticipated sources are excluded or included as $f_c$ is varied in this interval


# Interferometer design: fixed components

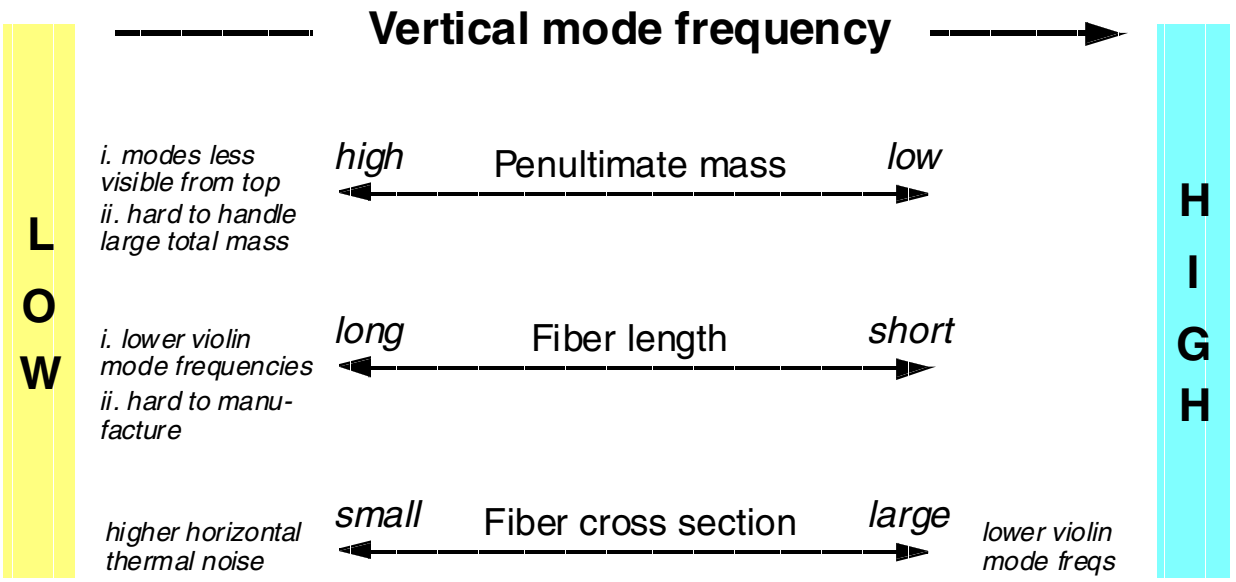
- Active isolation system, with displacement noise performance as described in the SEI DRD
- Quad test mass suspensions, with fused silica fibers for last stage; room temperature
- Signal- and power-recycled FPMI; fixed transmission signal mirror, phase tunable
- Sapphire test masses, 40 kg
- Laser power: up to 125 W at input

# Limiting noise levels



# Suspension vertical thermal noise: design trade-offs

- Vertical peak exceeds horizontal thermal noise over a 2-3 Hz band (assuming 0.001 v-h coupling)




# A variable cross section fiber

- Thick at the ends
  - » Minimizes the horizontal damping/thermal noise, via cancellation of linear thermal expansion by Young's modulus temperature dependence
- Thin in the middle
  - » High stress, to lower vertical mode and increase violin modes
- Cancellation effect still needs to be demonstrated
- Production and strength of variable cross section fibers must be proven

# Low Frequency Technical Noise

*Is it realistic to have sensitivity down to 10 Hz? Below 10 Hz?*

- Technical radiation pressure
- Frequency noise
- Scattered light
- Local damping noise:
  - » Active damping noise:
    - – $(3 \times 10^{-4})(10/Q)(10^{-10}$ m/rtHz) = $3 \times 10^{-17}$ m/rtHz at 10 Hz
    - – Falls as ~$1/f^7$
  - » Solved only by eddy current damping?
- Glitches in highly stressed fibers


# Signal processing

*Why not just remove the line from the data, as has been done for the violin modes?*

- Kalman filtering applied to 40m data (Mukherjee & Finn)
  - » 40 dB reduction, over a bandwidth of ~1 Hz
  - » Limited by non-linear coupling not included in the model
- For the AdLIGO vertical mode, with a 0.001 v-h coupling
  - » 60 dB suppression needed to bring vertical mode signal below horizontal thermal noise
  - » 2-3 Hz bandwidth


# Recommendations

- Lack of support for a sub-10 Hz v-mode requirement:
  - » No clear source impact
  - » Possibility of removal of vertical mode from data
  - » Obscuration of sub-15 Hz region by gravitational gradients
- Vertical mode frequency: 12 Hz or lower
  - » 11-13 Hz region dominated by vertical mode; line removal may allow it to be recovered
  - » Sub-10 Hz mode still desirable, if attainable without excessive risk
- Horizontal thermal noise: $10^{-19}$ m/rtHz at 10 Hz
- Violin mode fundamental: 400 Hz or higher
- Technical noise: controlled to allow observations to 10 Hz
- Suspension design impact:
  - » fiber design can continue to be explored, remain open for some time
  - » Penultimate mass must be chosen now, but doesn't have to be heaviest imaginable