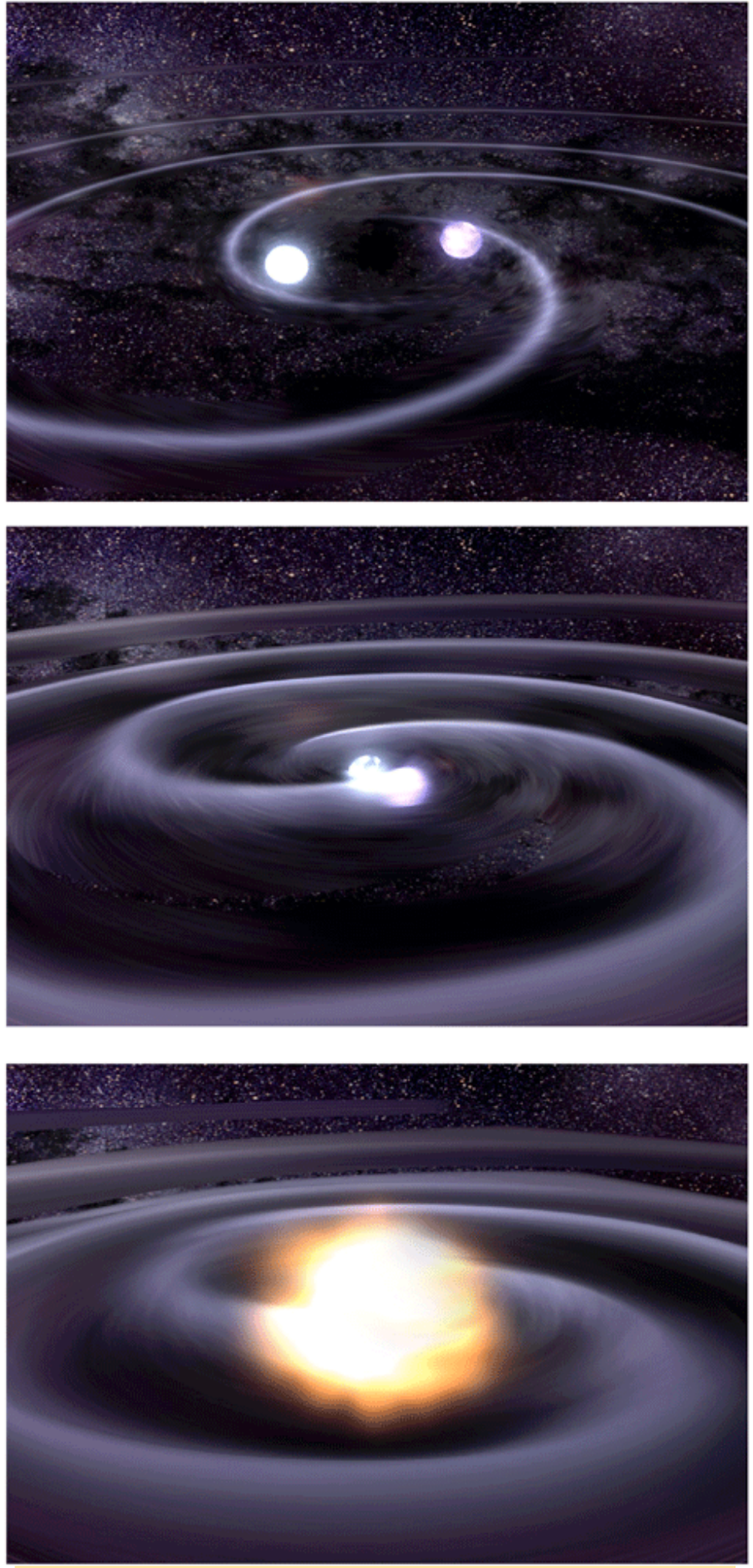


NASA/Dana Berry, Sky Works Digital

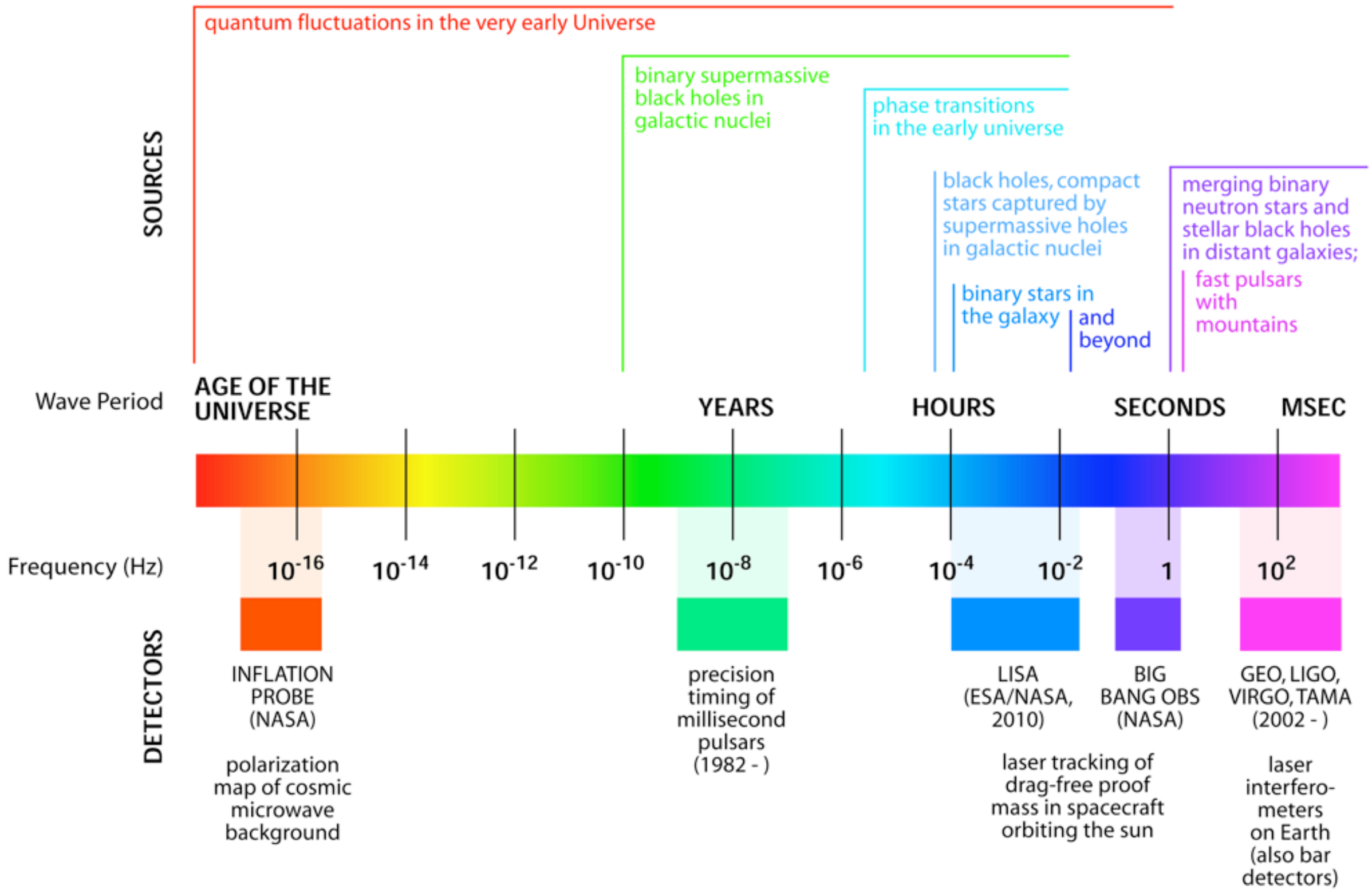
Near Term Upgrades

Rana Adhikari 2009

G0900460-v1

http://www.srl.caltech.edu/lisa/graphics/LISA_science.html

THE GRAVITATIONAL WAVE SPECTRUM



http://www.srl.caltech.edu/lisa/graphics/LISA_science.html

Beyond Einstein Roadmap

NS/NS
Broadband
NS/NS no
BHBH
High Freq

iLIGO

Enhanced

Advanced

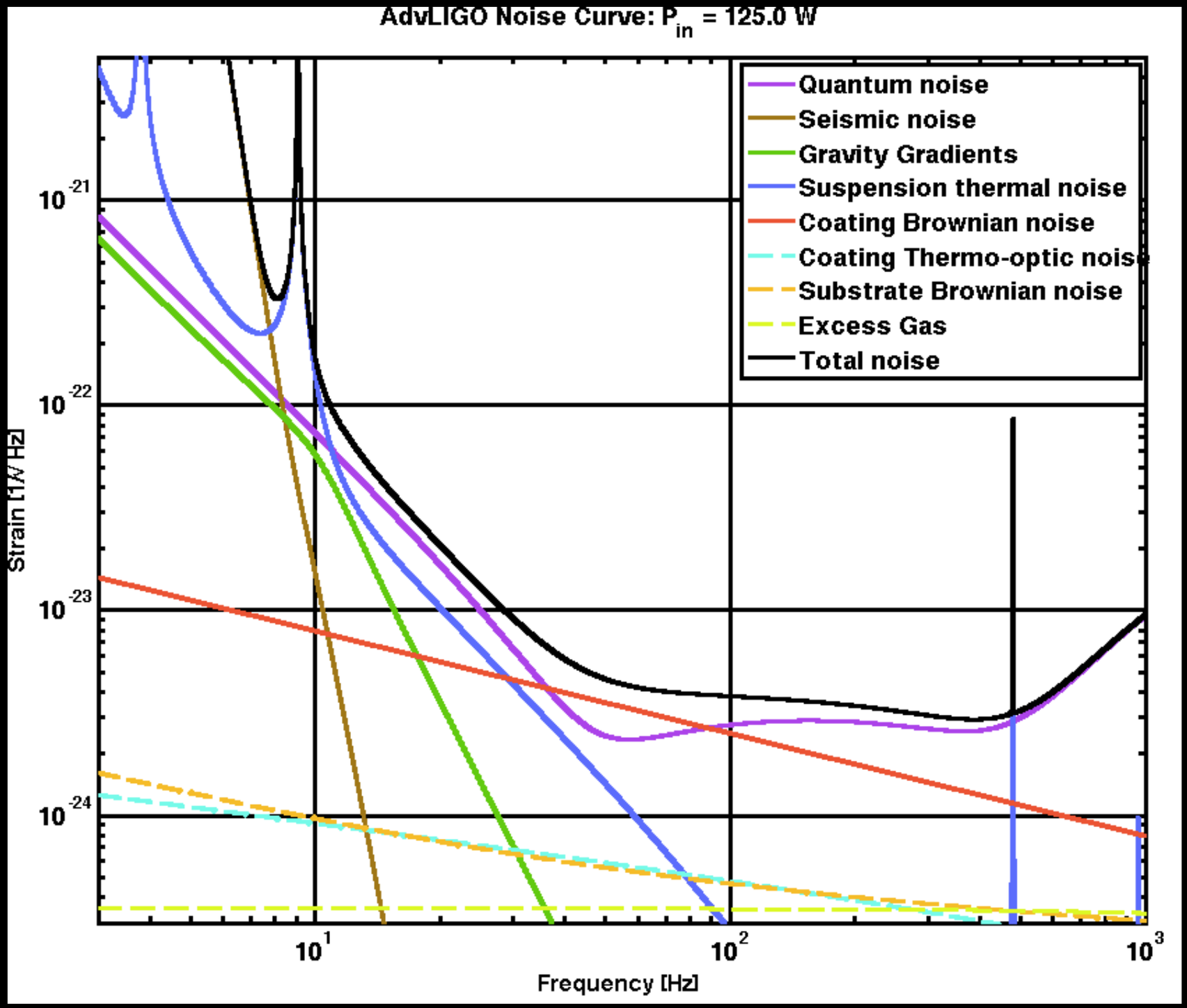
10^{-21}
10^{-22}
10^{-23}
10^{-24}

Strain [1/√Hz]

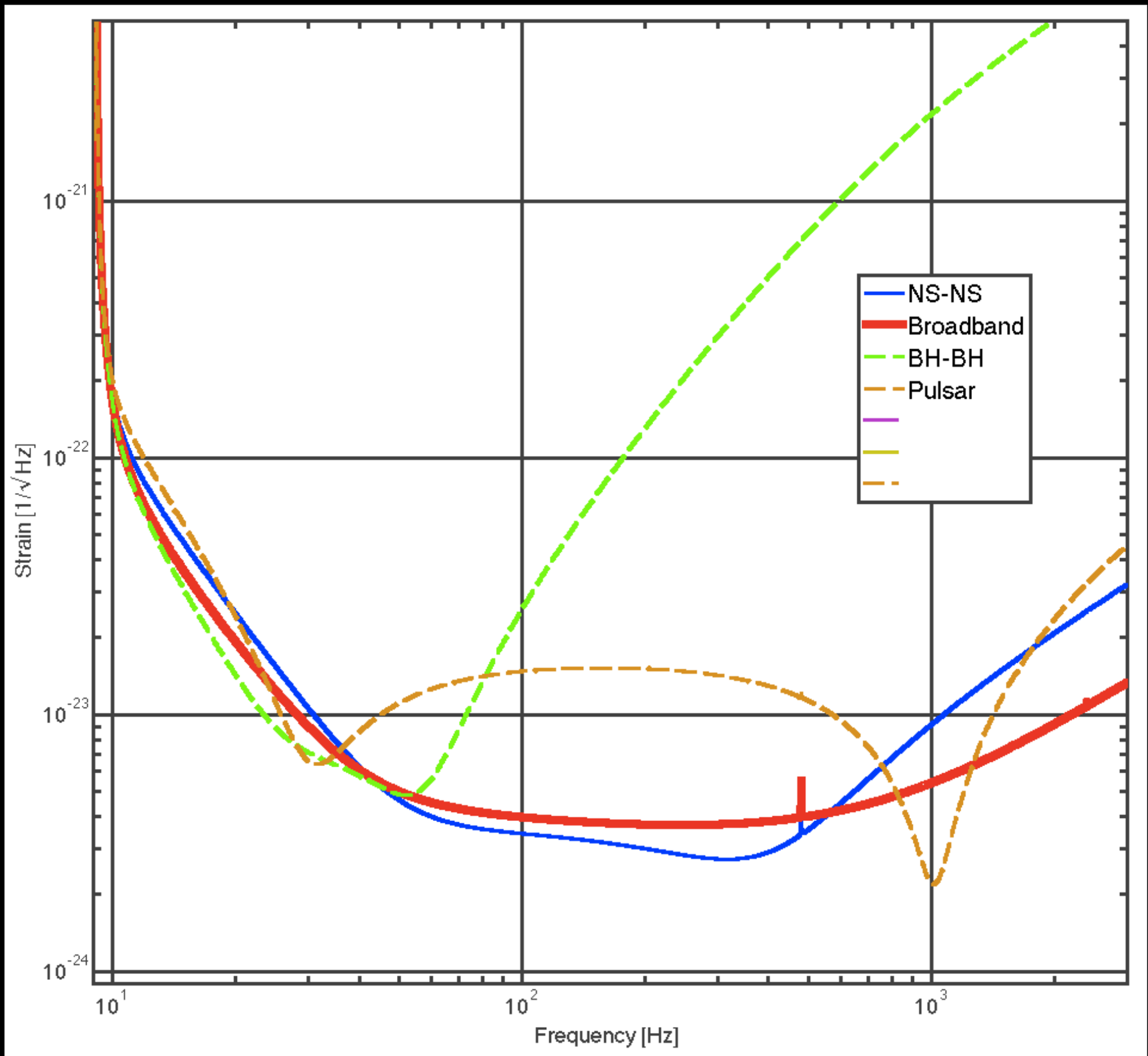
10^{1}
10^{2}
10^{3}

Frequency [Hz]

Noise Limits

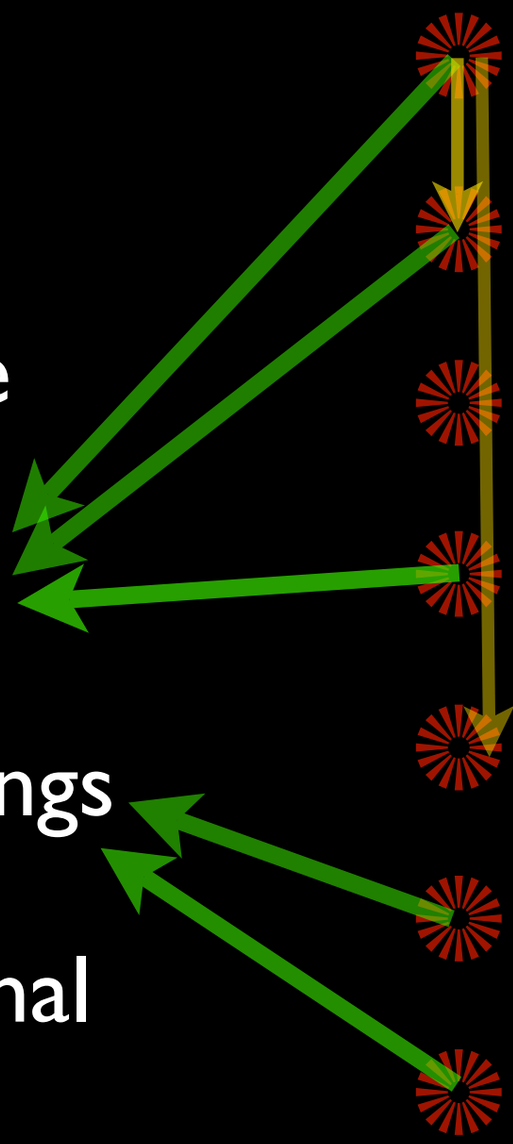


Tunings


NS-NS
Broadband
BH-BH
Pulsar
Strain [1/√Hz]
Frequency [Hz]
10^-21
10^-22
10^-23
10^-24
10^1
10^2
10^3

Low F v. High F

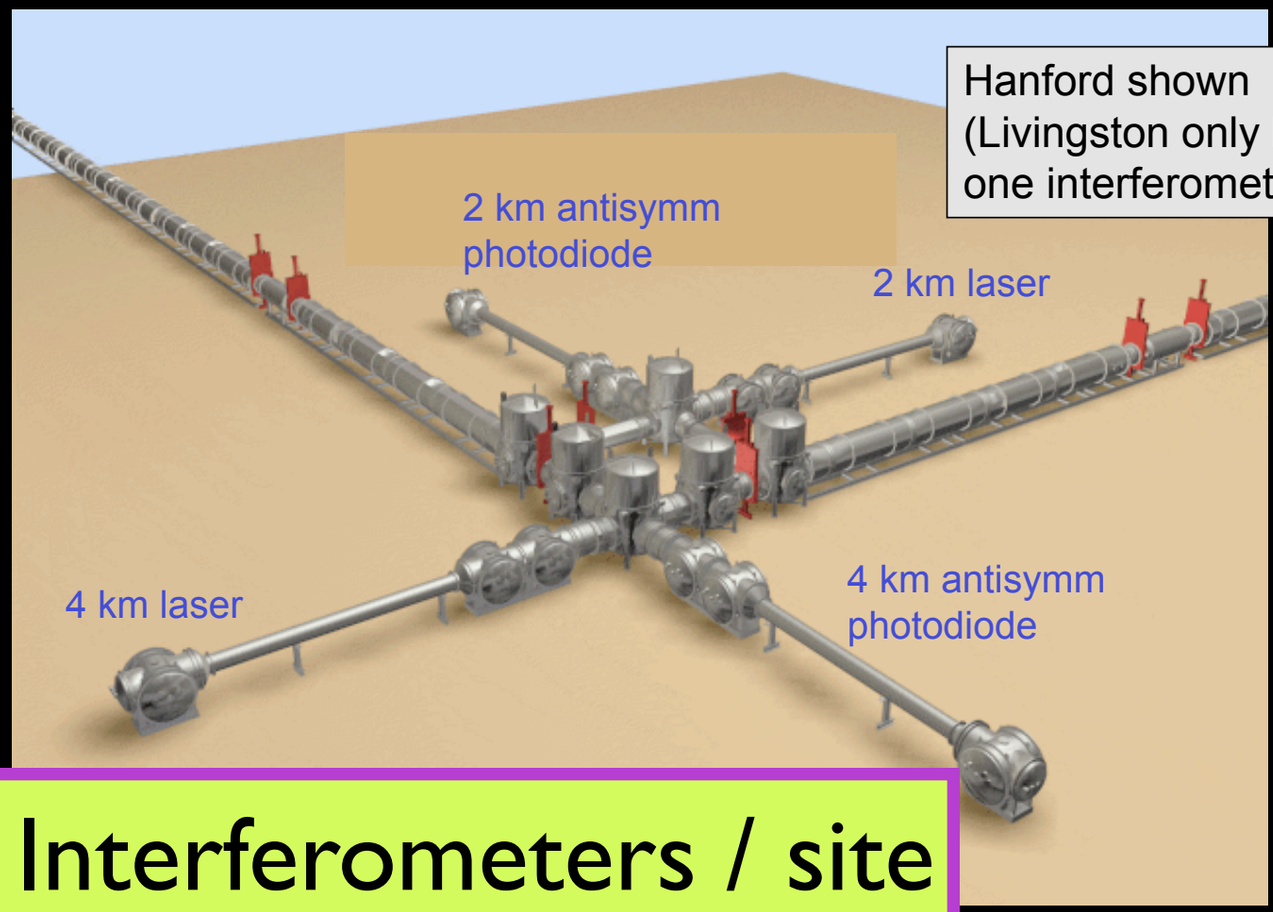
- Seismic Noise
- Newtonian Noise
- Angular Controls
- Low Noise Coatings
- Suspension Thermal



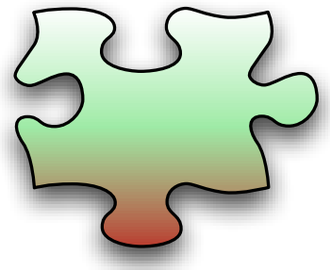
- High Circulating Power
- Radiation Pressure
- Squeezed Light
- High BW Angle Control
- Thermal Compensation
- Low Absorption
- Low Scatter

What to do?

- AdvLIGO/Virgo
  ~ 2014-2017
- Need Adv+ IFO R&D
  now, before 3G.
- Need coincidence for
  both low f & high f.
- H1/H2 + L1/L2 + V1/V2



2 Interferometers / site



Test Masses:
fused silica,
34 cm diam x 20 cm thick,
40 kg

ETM

4 km

ITM

CP

ITM

ETM

BS

Input
Mode
Cleaner

Laser

Φ_m

FI

125 W

T= 3%
PRM

5.7 kW

815 kW

T=1.4%

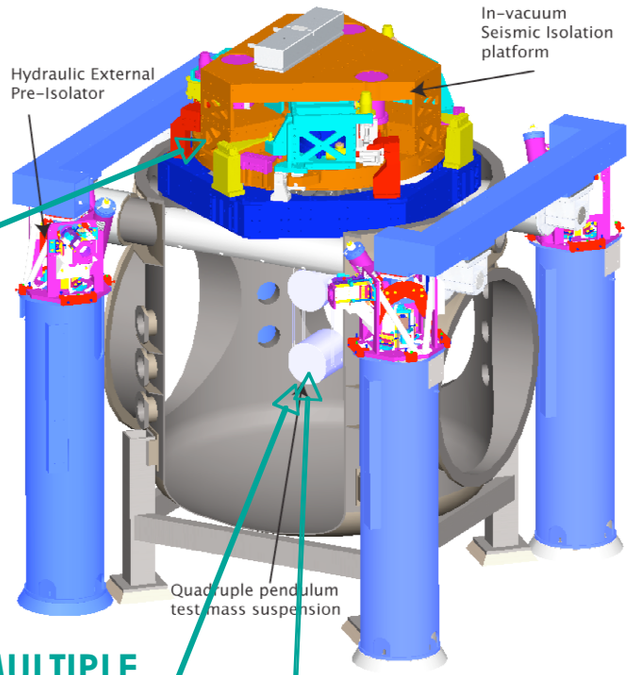
T= 20%
SRM

FI

PD

GW readout

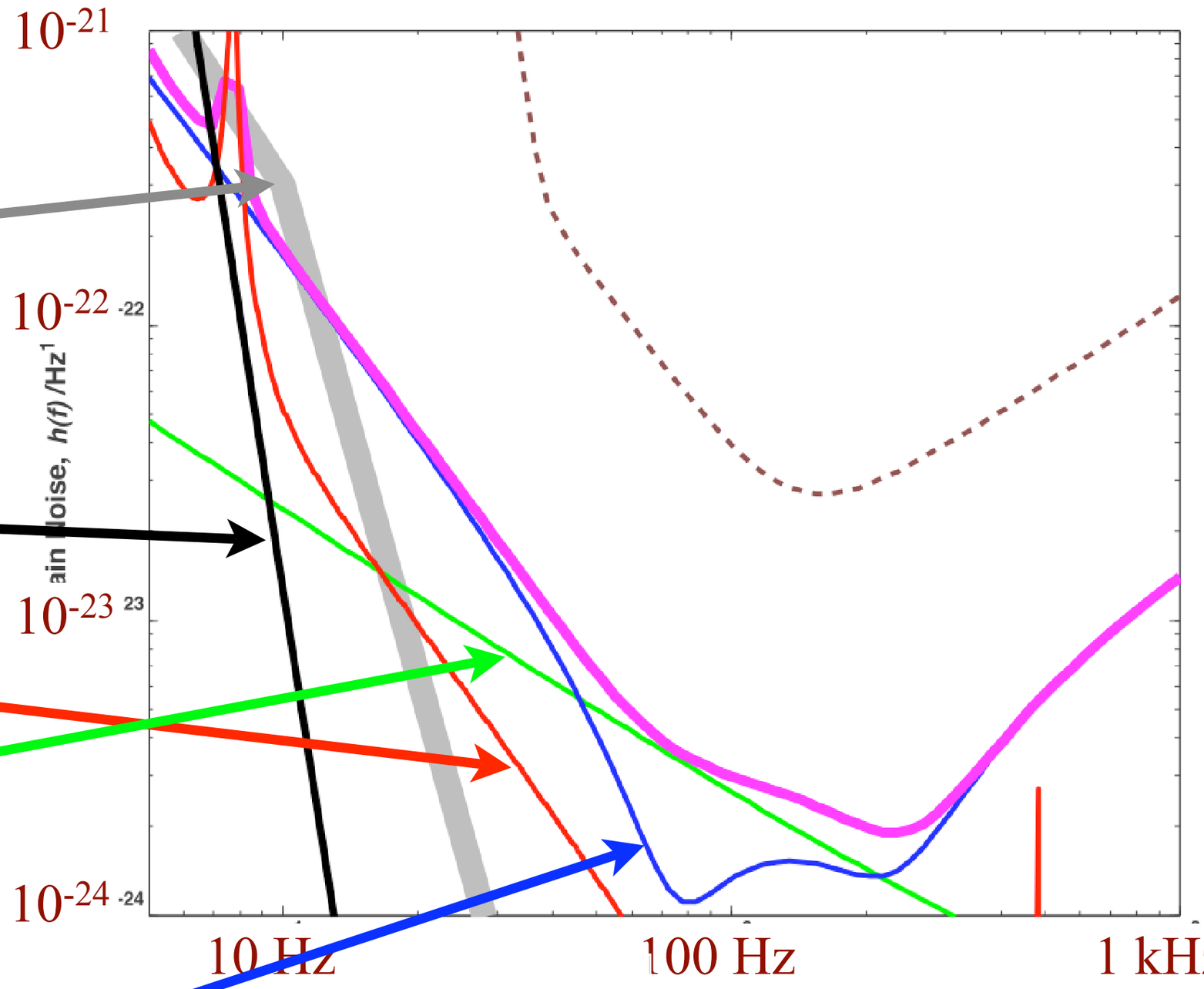
Output
Mode
Cleaner



ACTIVE
SEISMIC
ISOLATION

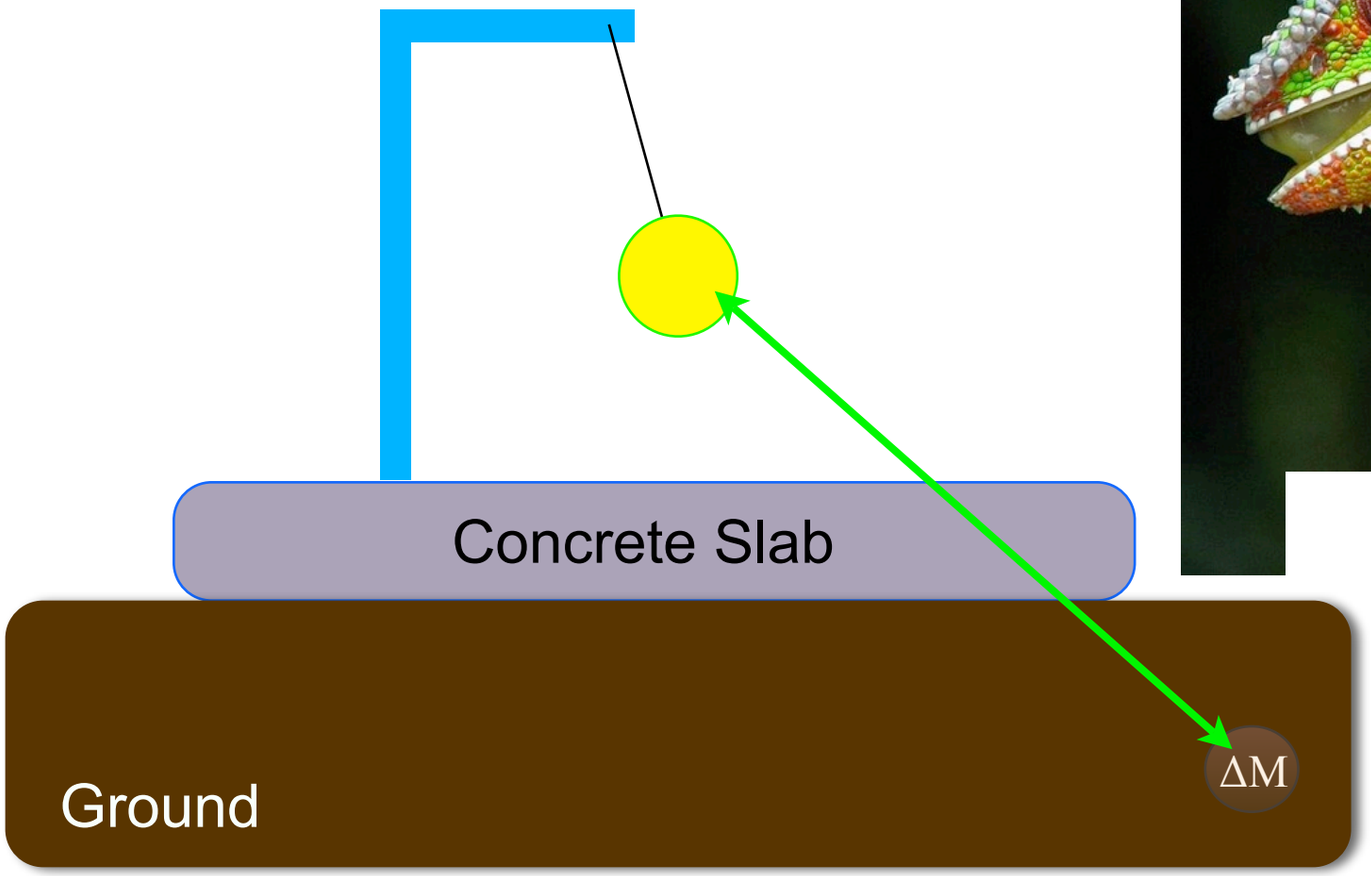
FUSED SILICA, MULTIPLE
PENDULUM SUSPENSION

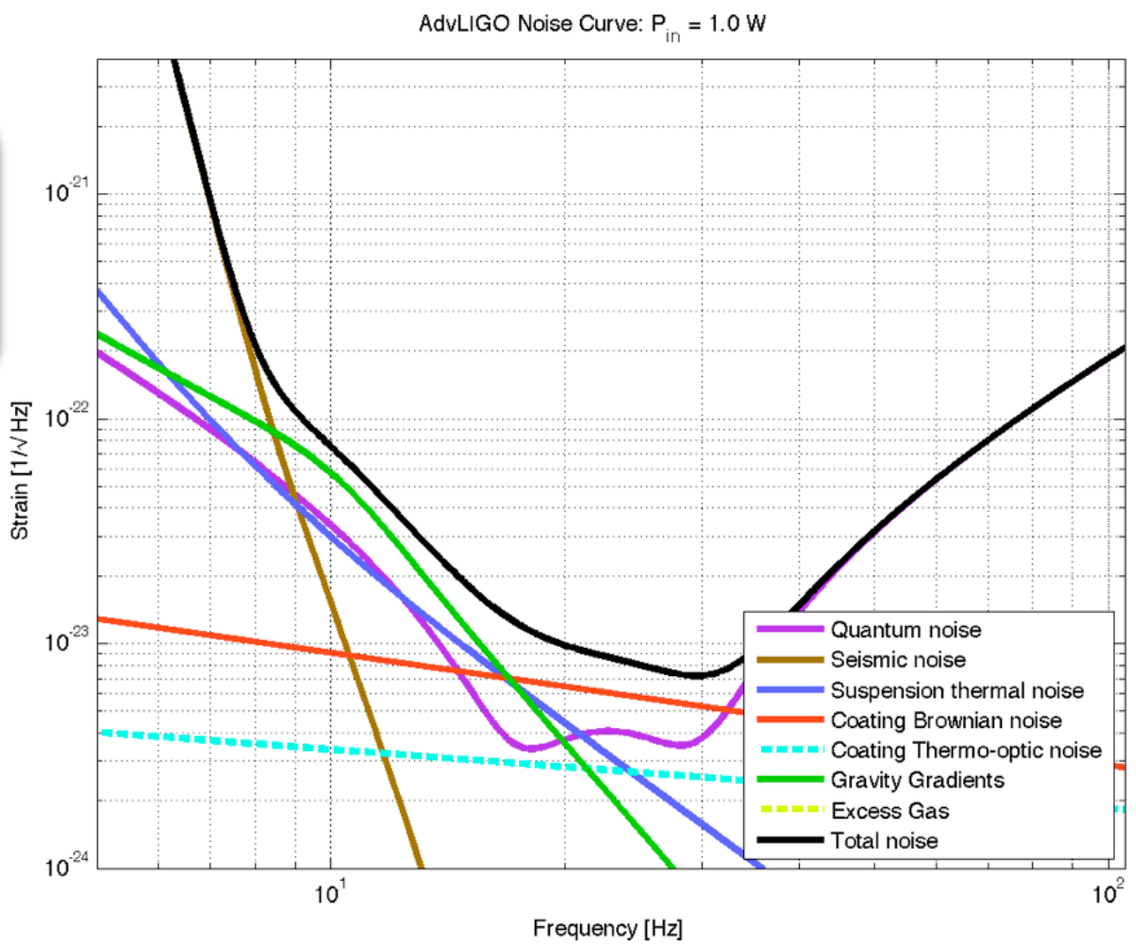
- Newtonian background, estimate for LIGO sites
- Seismic 'cutoff' at 10 Hz
- Suspension thermal noise
- Test mass thermal noise
- Unified quantum noise dominates at most frequencies for full power, broadband tuning



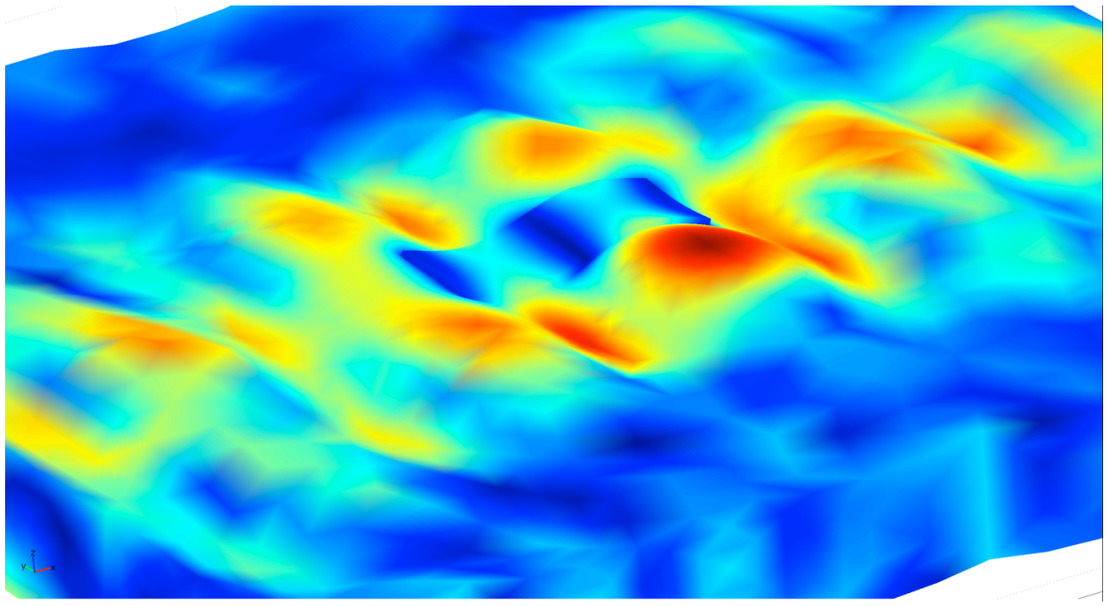
Newtonian Gravity Noise

$$x(f) = G\,\Delta M(f) / (f^2\, r^2)$$

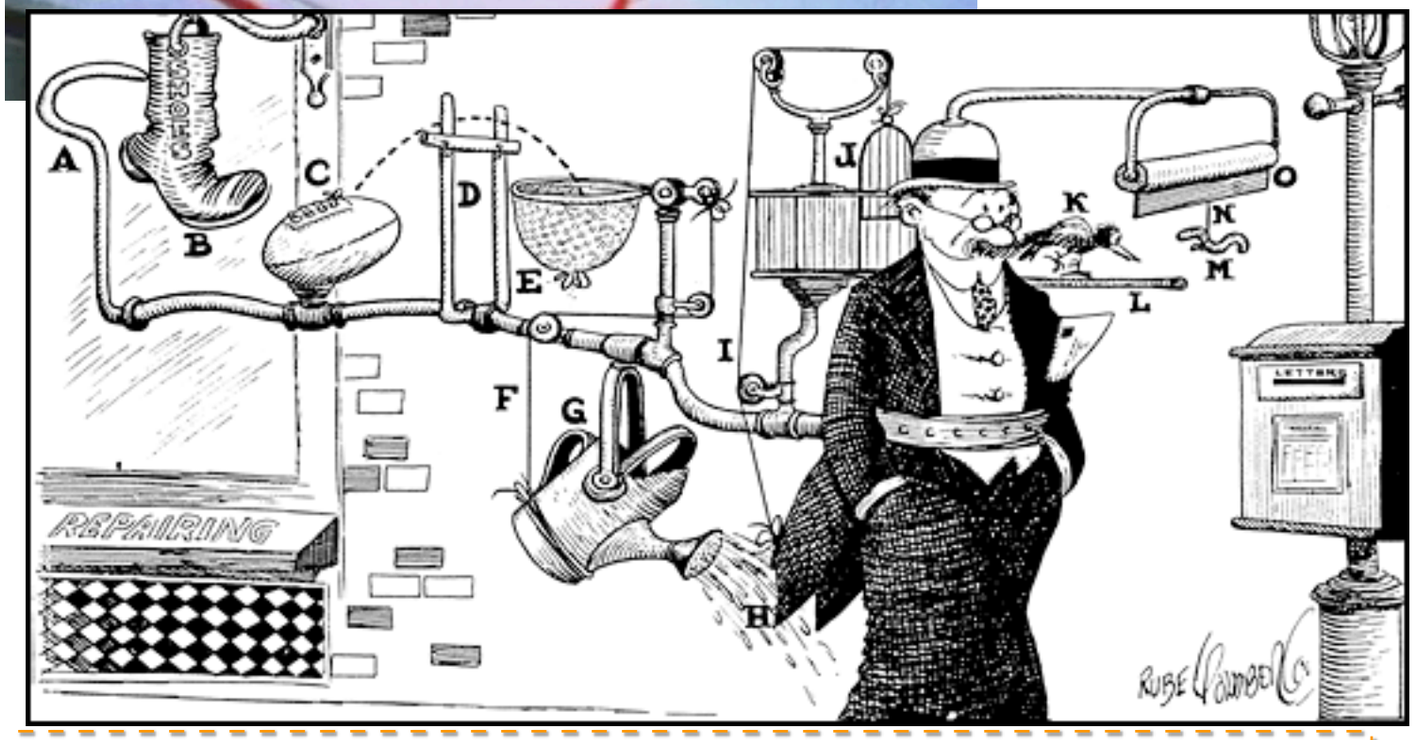




- **Noise Sources**
  - Surface Waves
  - Air Pressure Fluctuations
  - Subsurface density Fluctuation

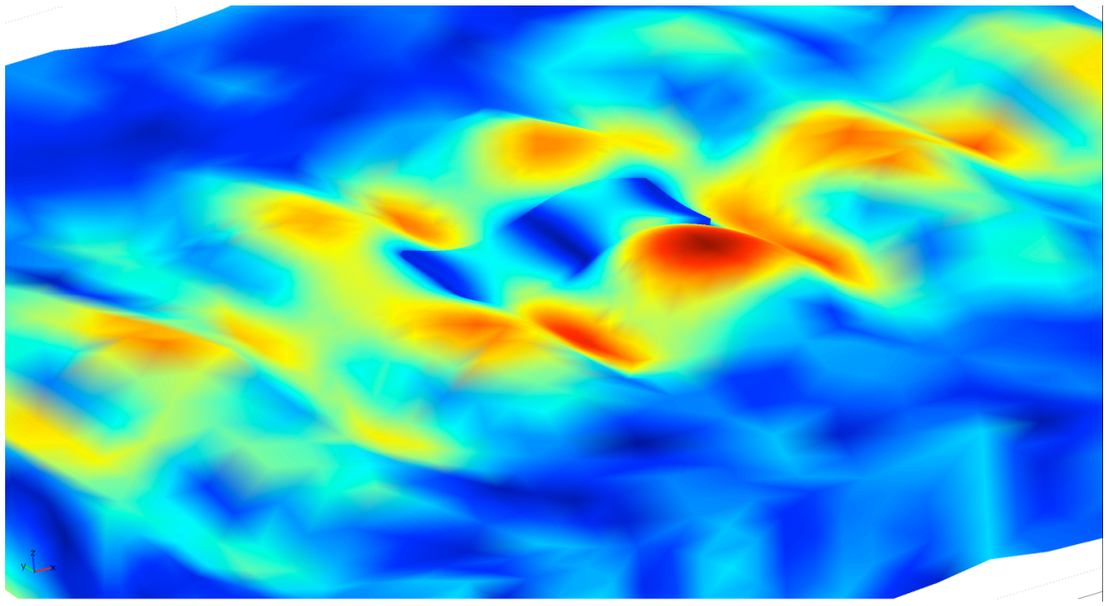


FEA of Concrete Slab

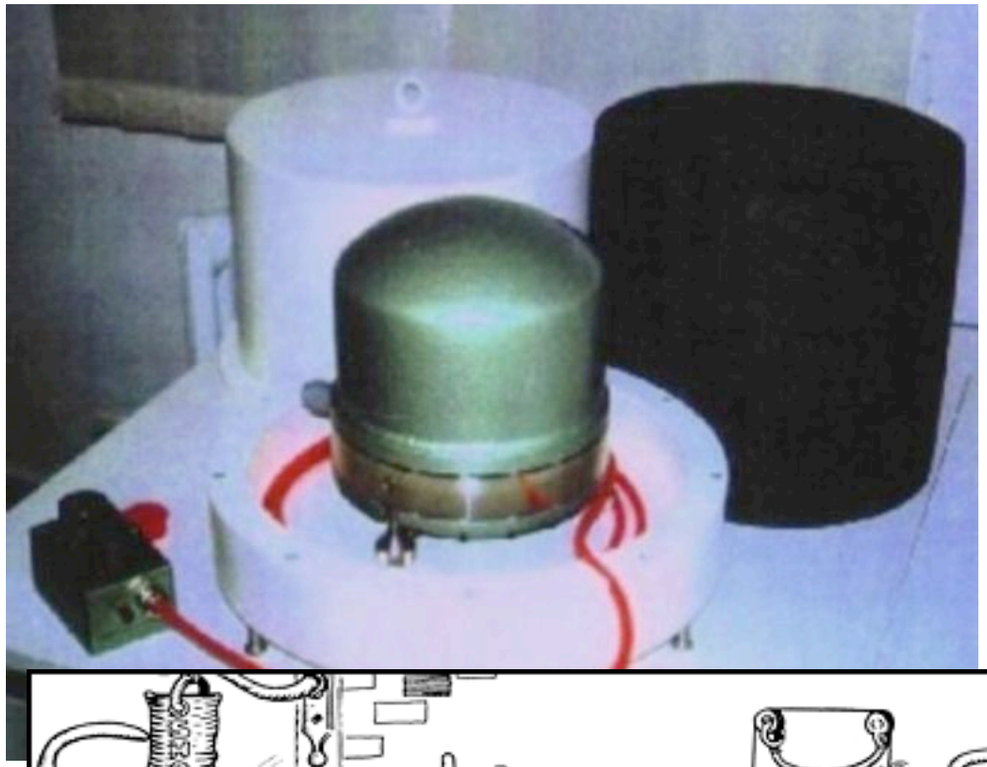


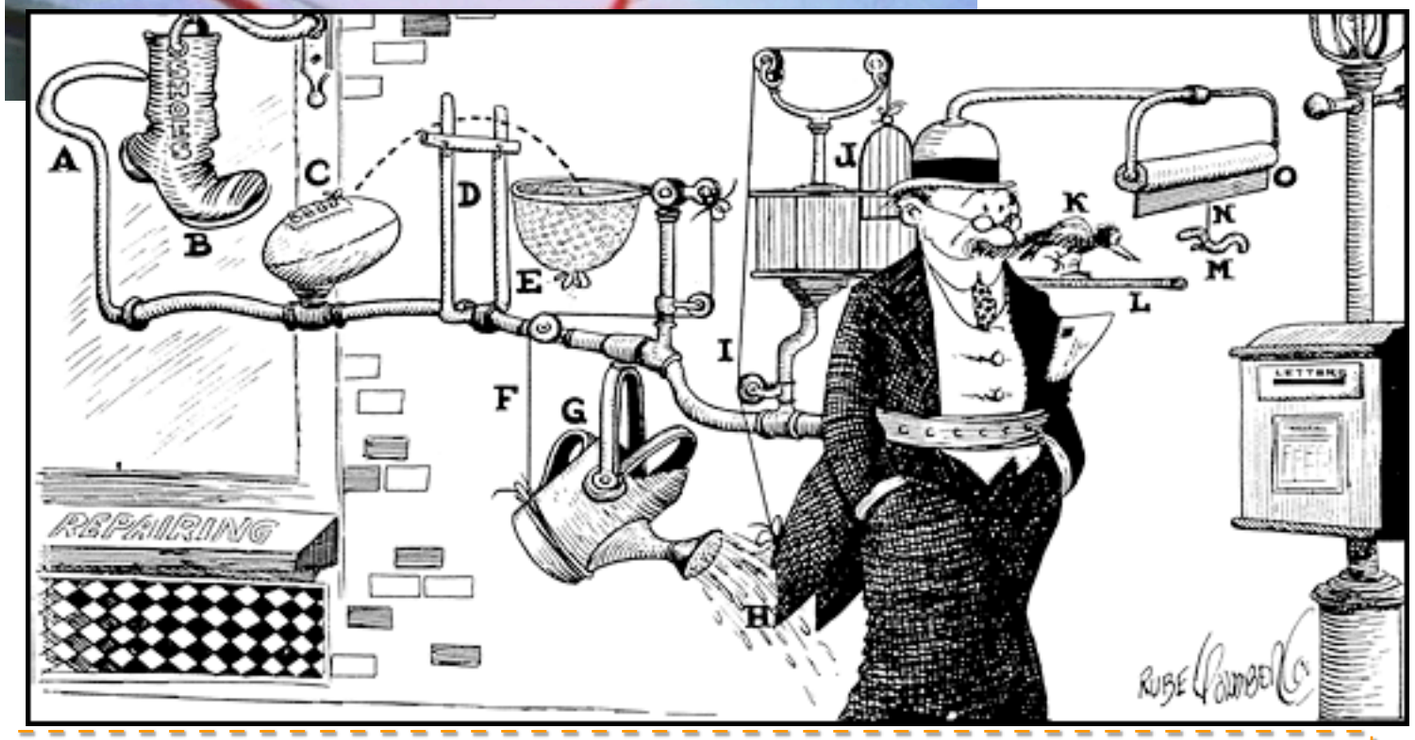
- **Noise Cancellation**
  - Accelerometers measure ground motion
  - Adaptive algorithm estimates GG noise
  - Subtraction done through software

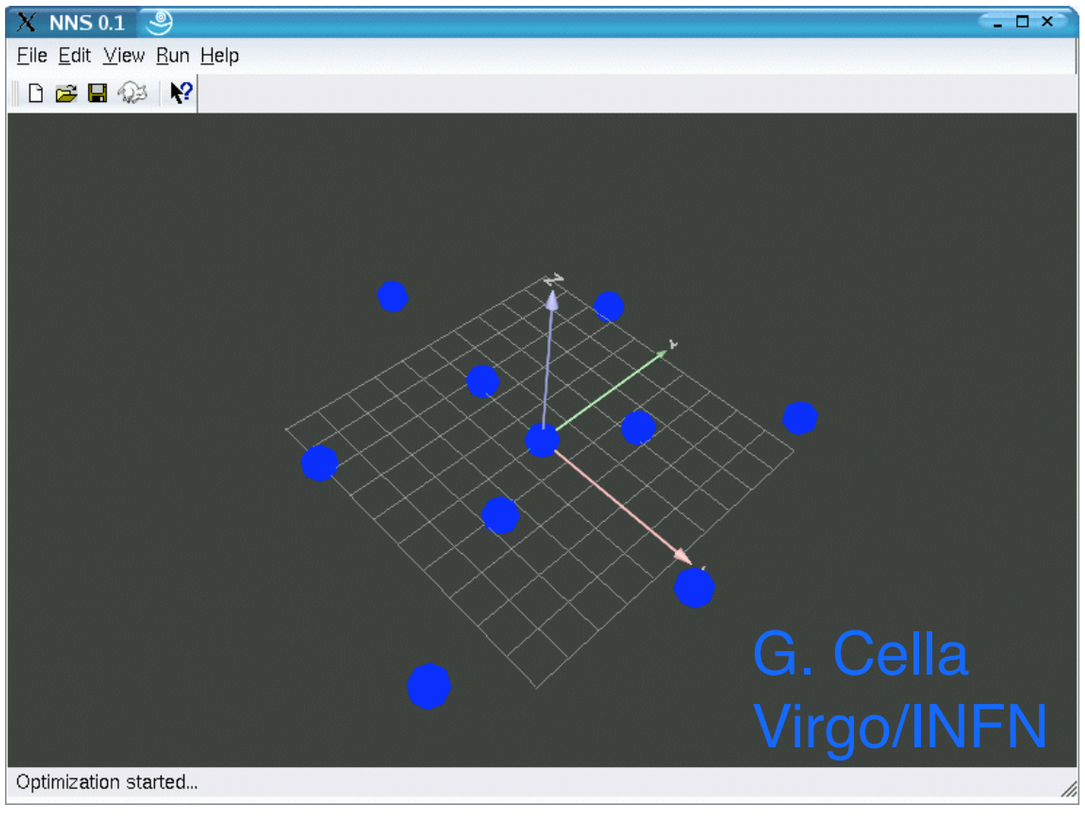
G. Cella
Virgo/INFN



FEA of Concrete Slab







- **Noise Cancellation**
  - Accelerometers measure ground motion
  - Adaptive algorithm estimates GG noise
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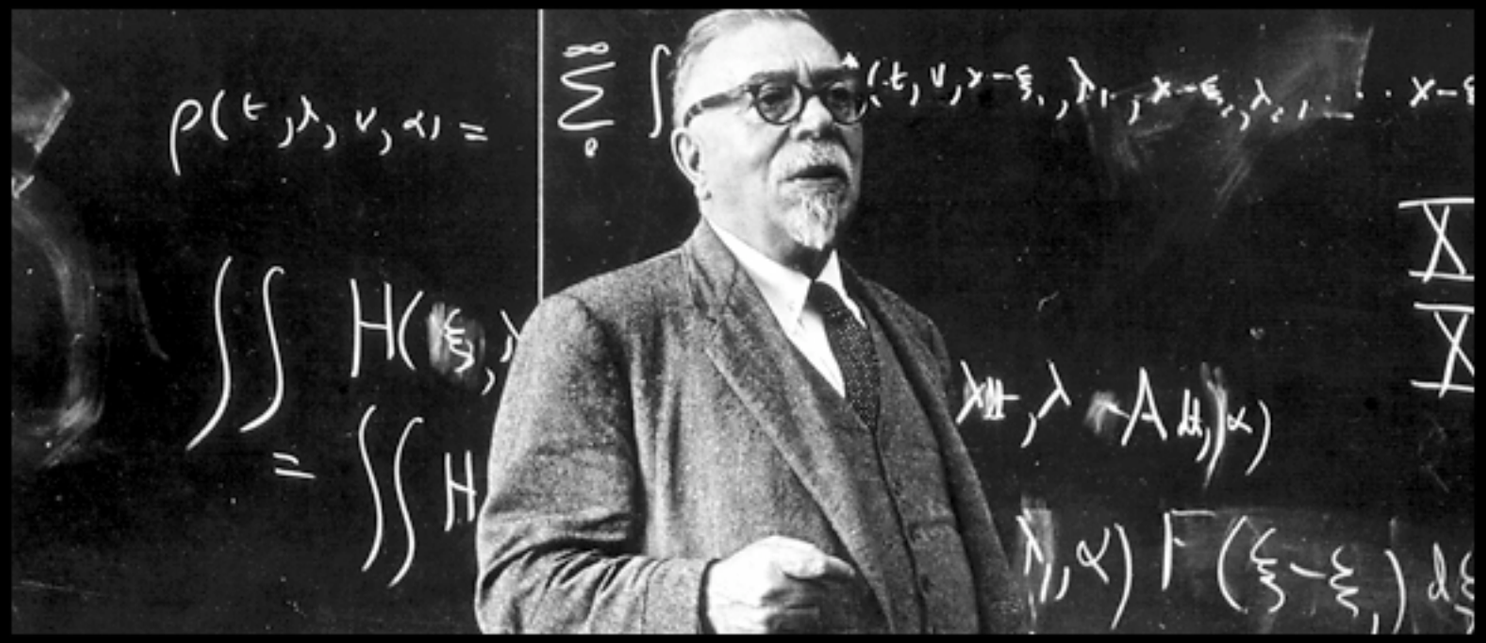
Wiener Filter



Norbert Wiener, MIT

$$x[n] = \sum_{i=0}^{N} a_i w[n-i]$$

Block Toeplitz

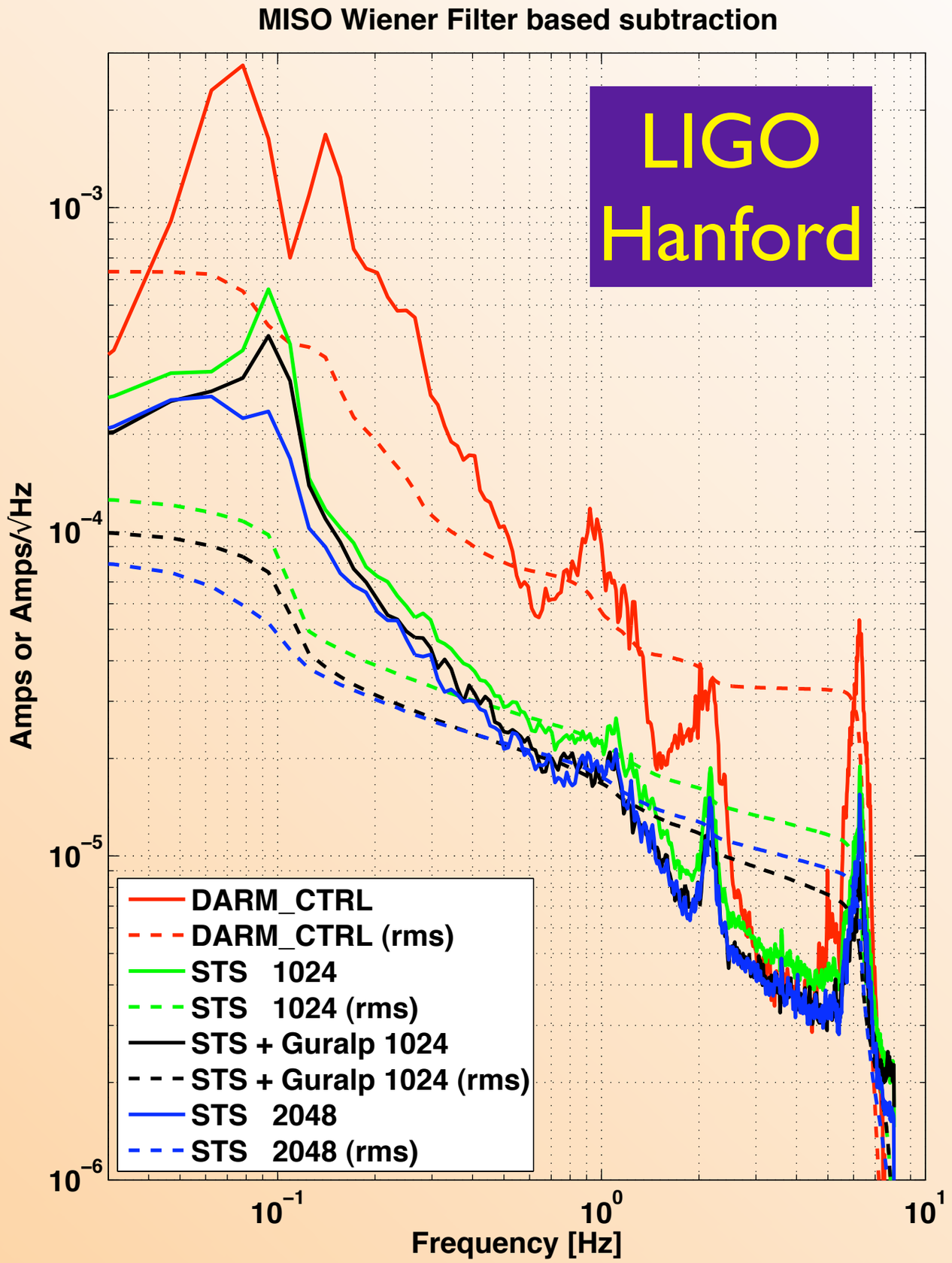
$$\begin{bmatrix} R_w[0] & R_w[1] & \cdots & R_w[N] \\ R_w[1] & R_w[0] & \cdots & R_w[N-1] \\ \vdots & \vdots & \ddots & \vdots \\ R_w[N] & R_w[N-1] & \cdots & R_w[0] \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ \vdots \\ a_N \end{bmatrix} = \begin{bmatrix} R_{sw}[0] \\ R_{sw}[1] \\ \vdots \\ R_{sw}[N] \end{bmatrix}$$

Input Signal (PEM) Covariance Matrix

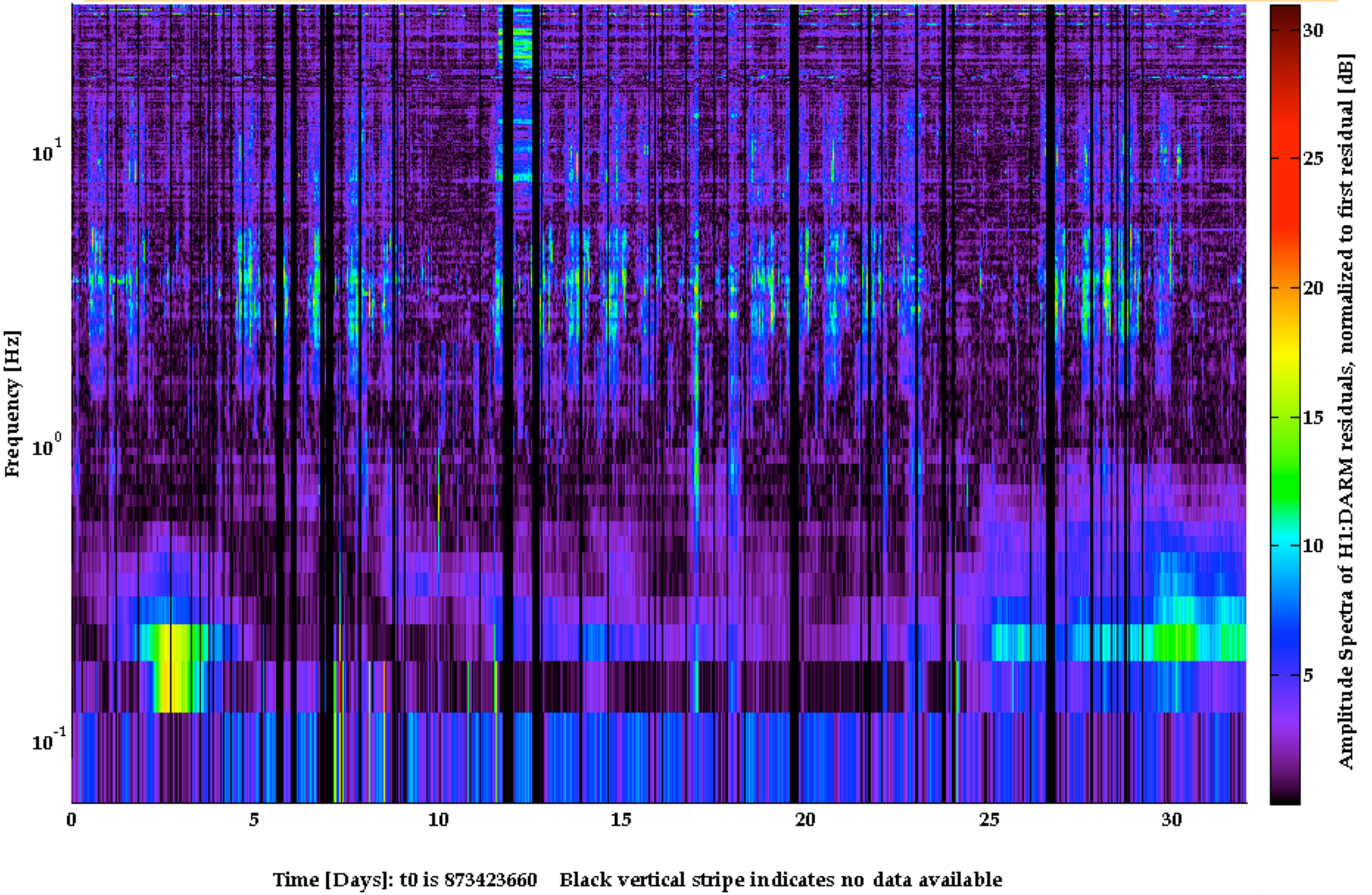
Cross Correlation Matrix

Wiener FF for L- Control

- ***Simulated*** reduction of mirror control force
- >5x reduction in RMS *in addition* to the Active Isolation (HEPI)
- Using ground seismometers only.
- *No knowledge* of transfer functions required.



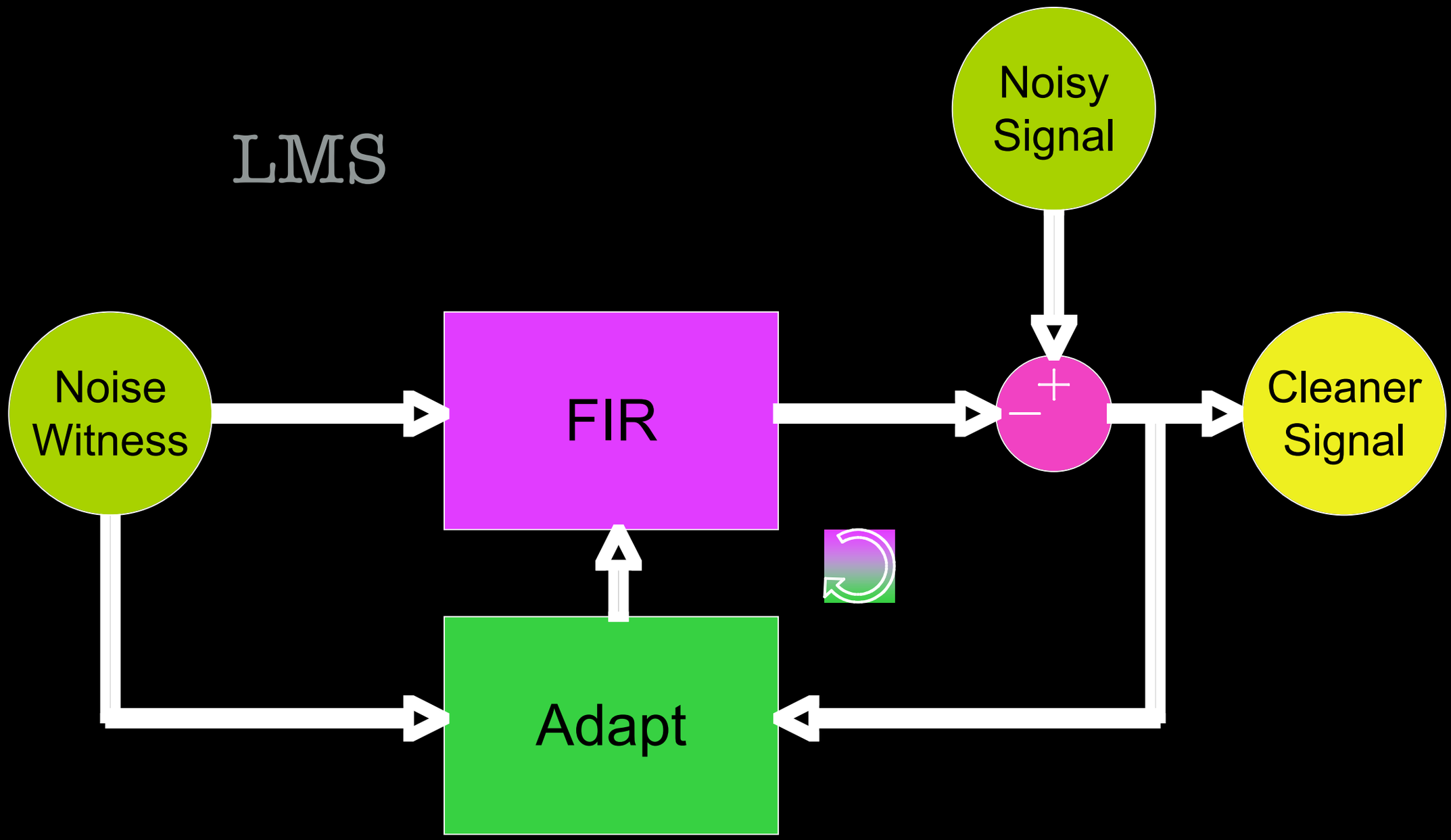
Wiener Performance



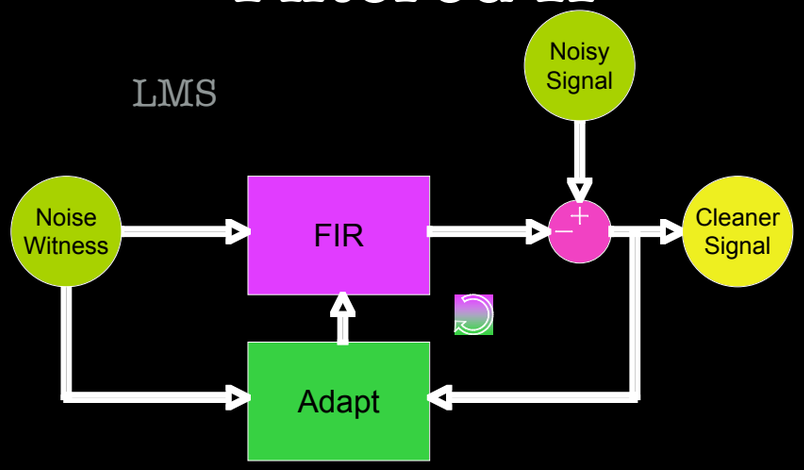
JENNE DRIGGERS, CIT

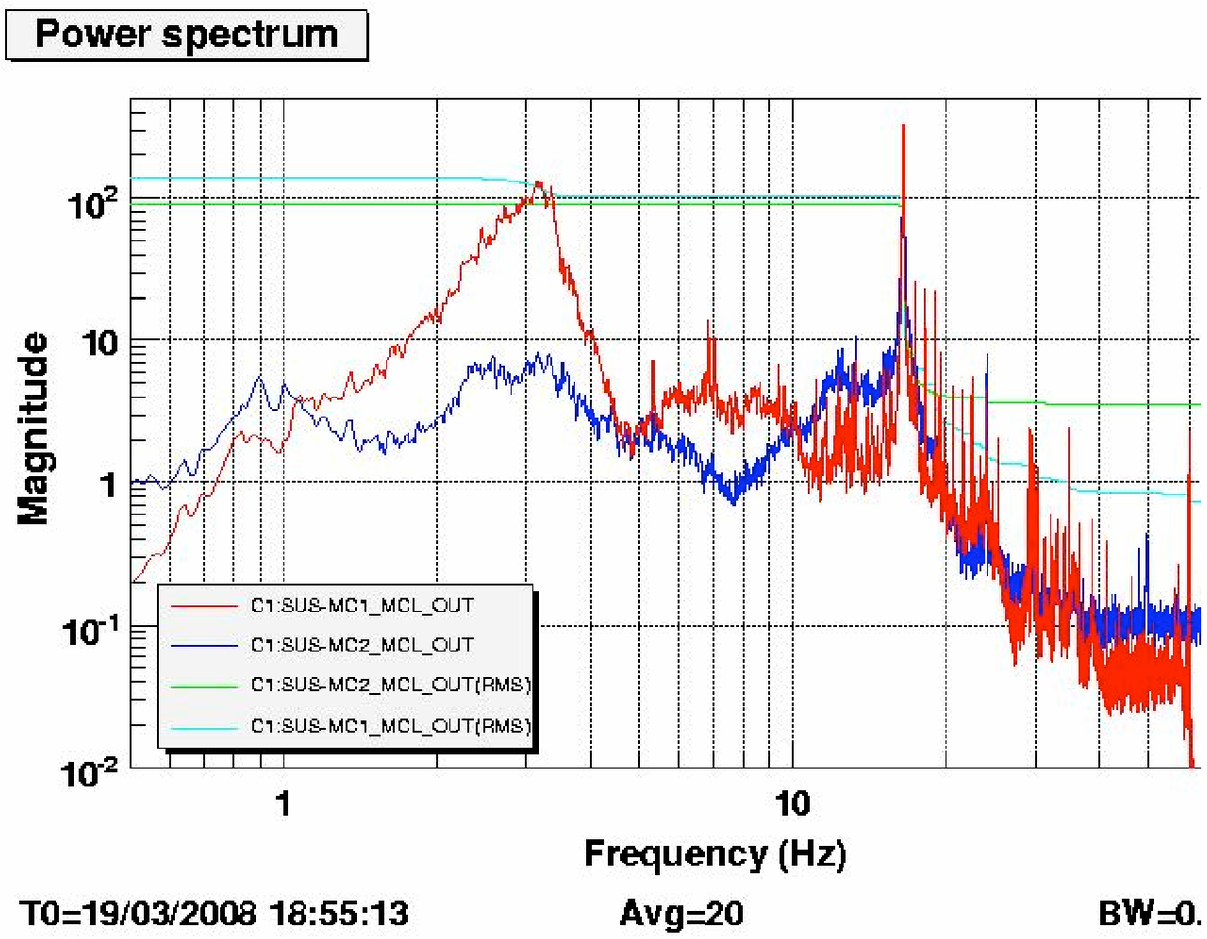
From LMS to Filtered-X

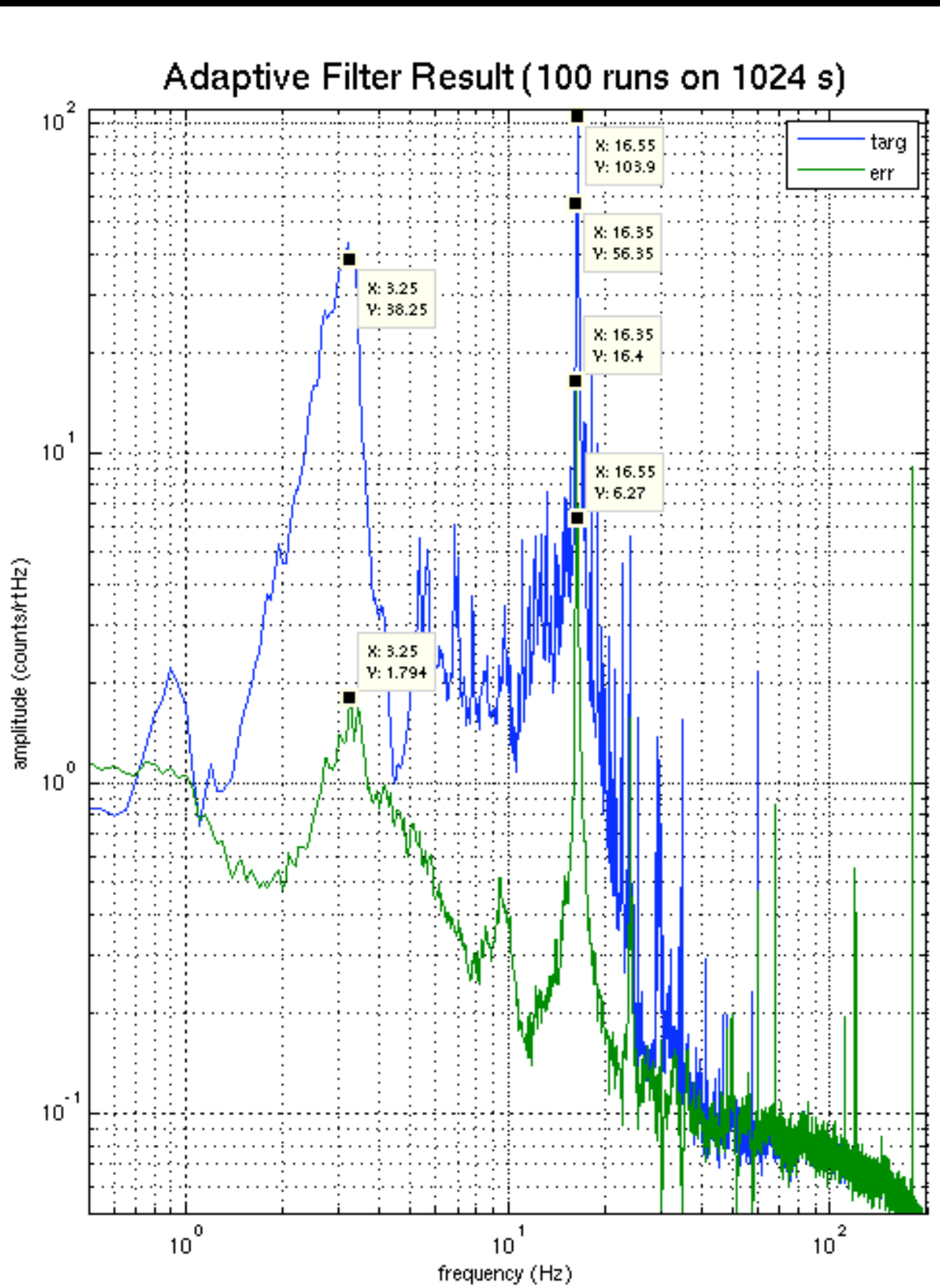
LMS



From LMS to Filtered-X







Adaptive FF running online at CIT 40m prototype

Coating Possibilites

- Standard approach: find a lower loss material
  - Reached a plateau? Is $\phi \sim 10^{-5}$ possible?
- Use less layers (lower Finesse, higher loss)
- Use thinner layers ($\lambda \approx$ 404-532 nm)
- Optimize periodic pattern (e.g. 1/8-3/8 layers) to minimize high loss material's volume
- Optimize Brownian w/ the ABC scheme (*see Yanbei Chen's talk*)
- ABC scheme w/ multi-color arm cavity readout

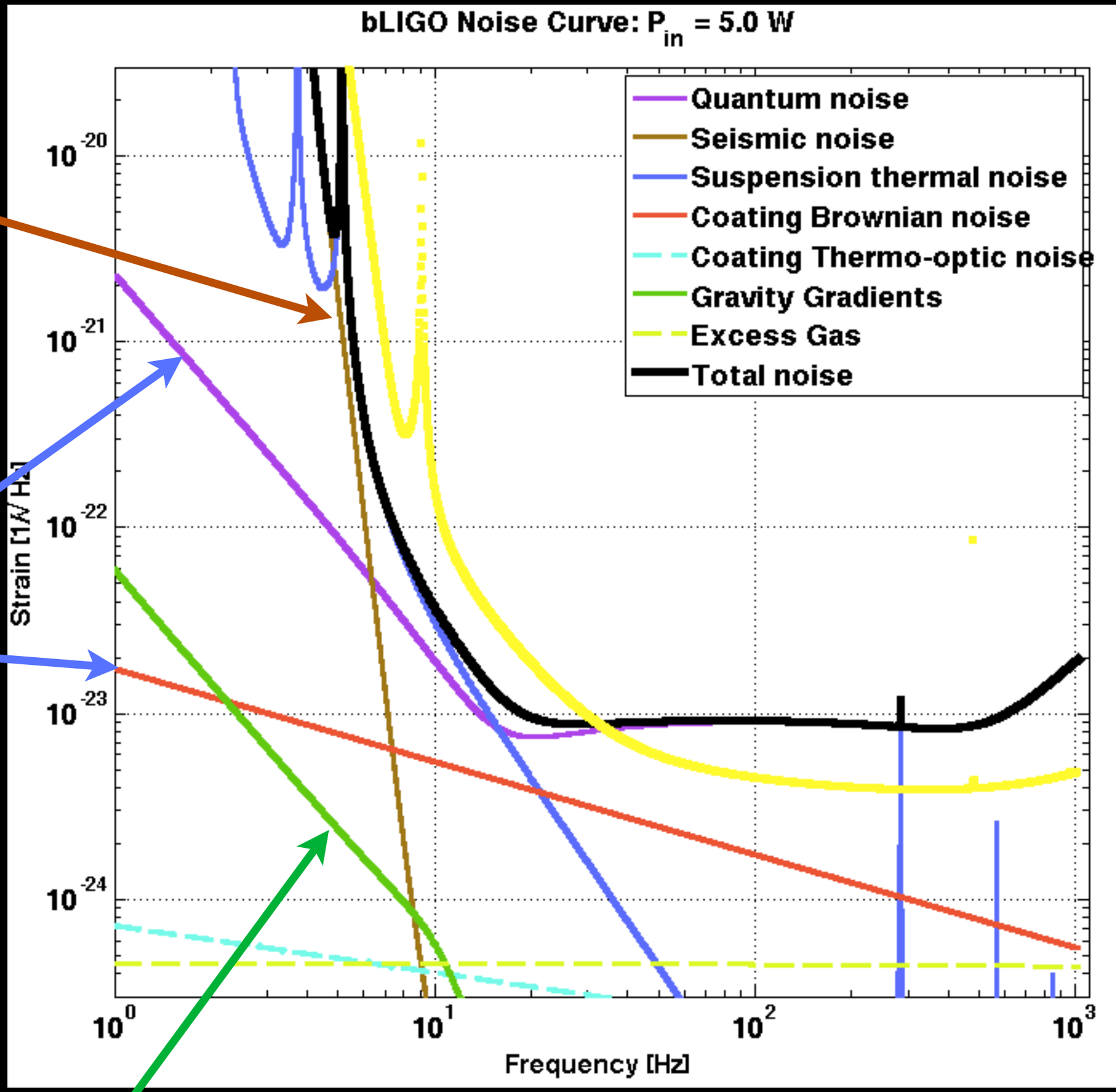
Red v. Blue


CONFIDENCE
It lets you wield any [redacted] color lightsaber you like.

x30 Seismic FF

405 nm laser

- Absorption
- EO Components
- High QE PDs



x10 Newtonain Subtraction