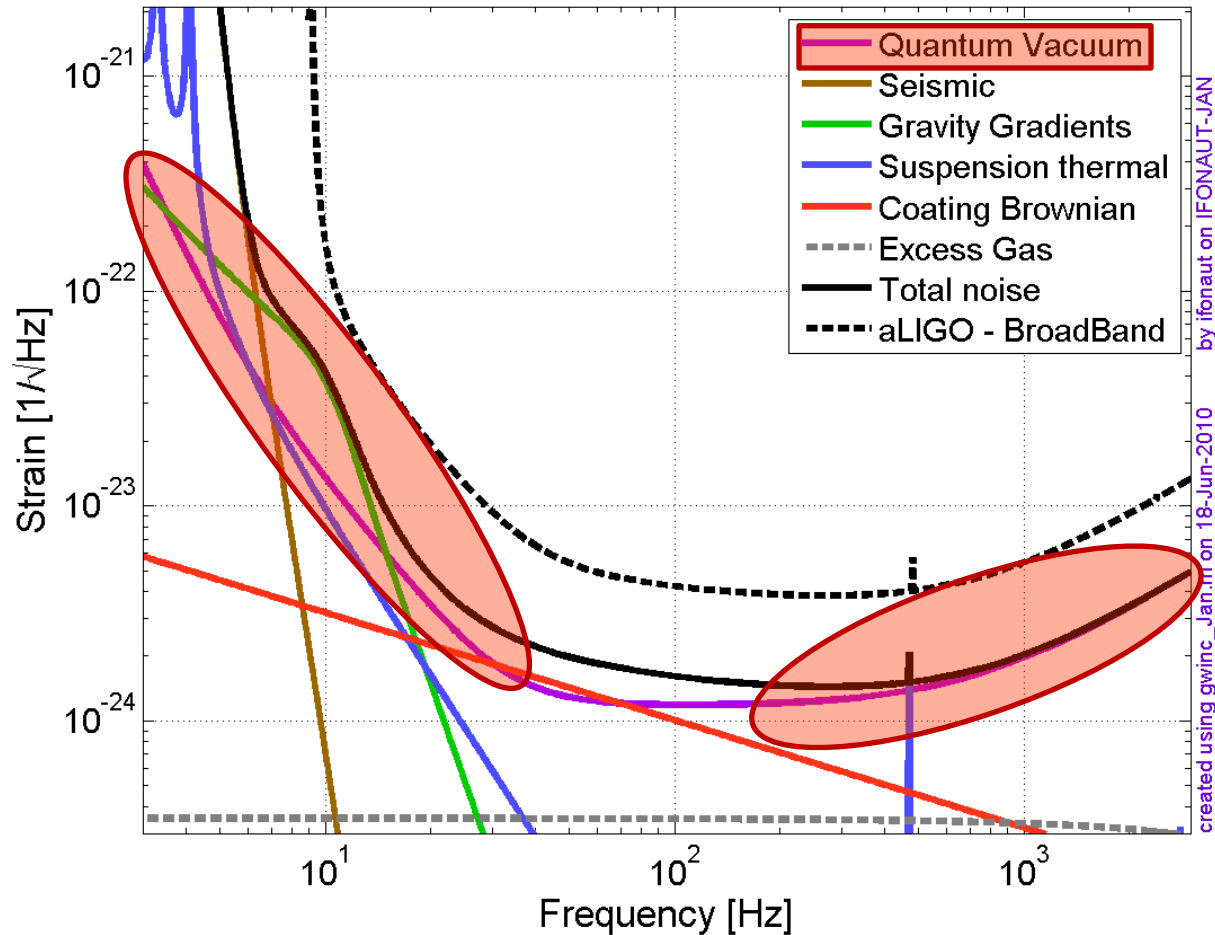


# Lecture on Fundamental Noise Sources in GW Detectors

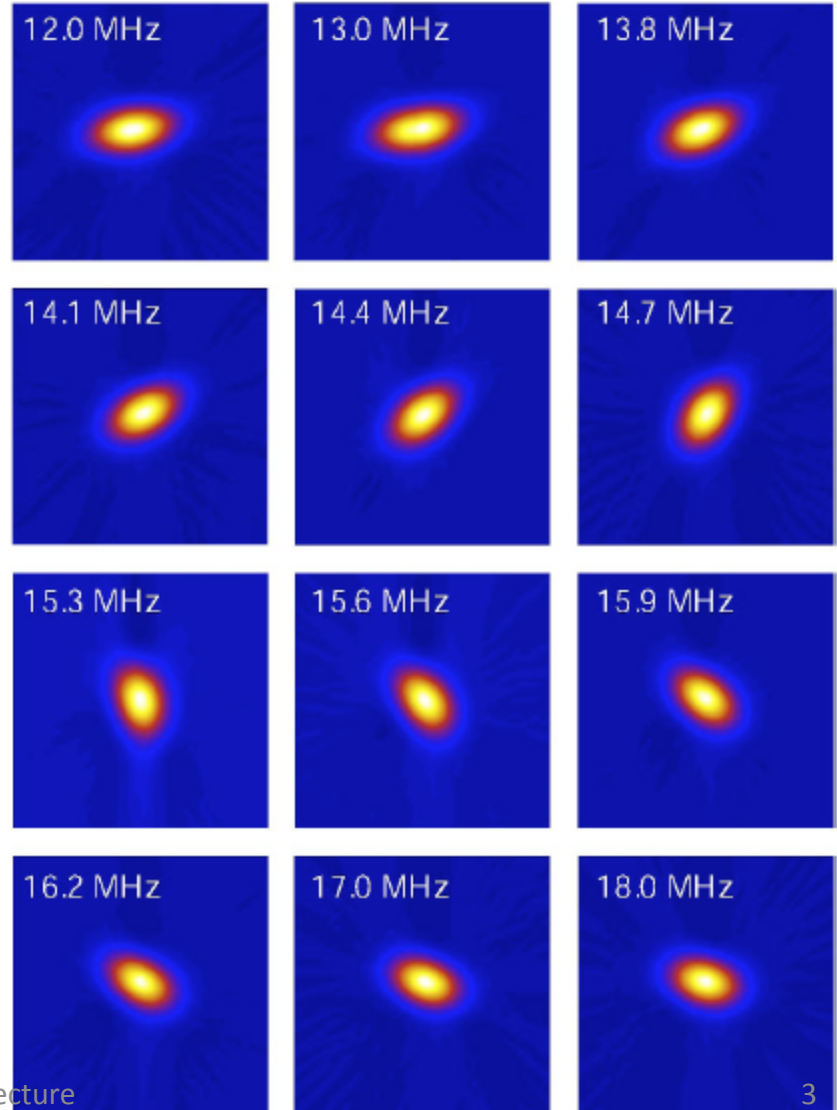
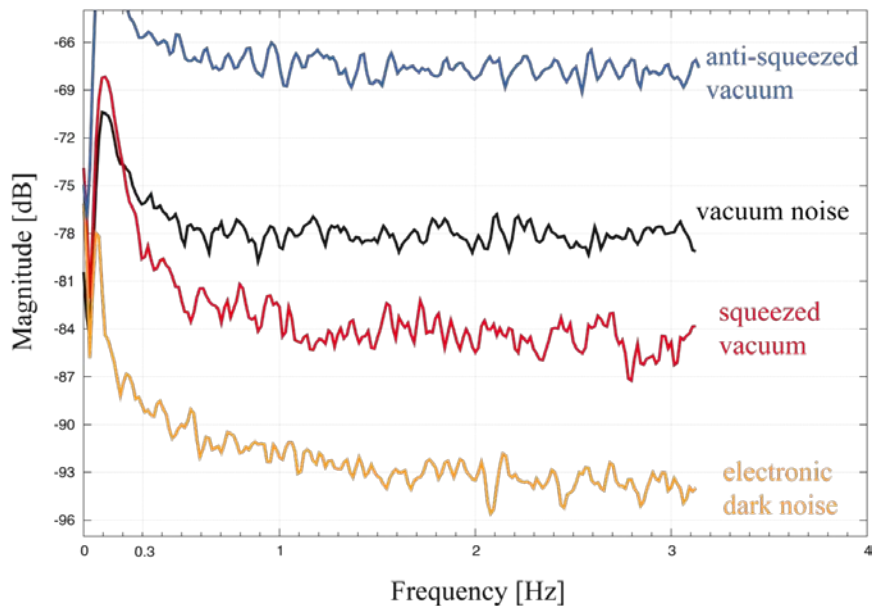
Jan

# (Futuristic) Noise Model



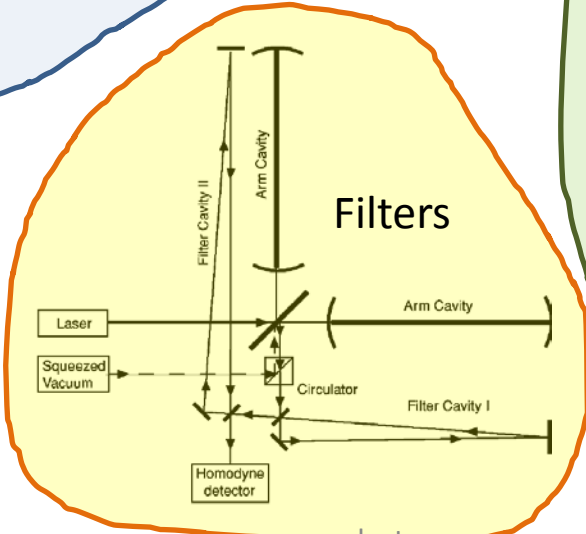
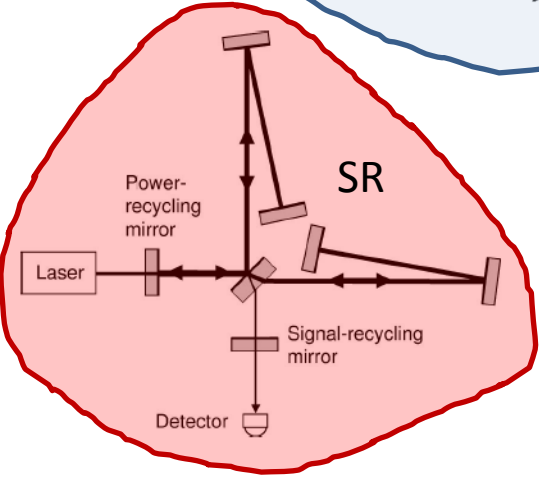
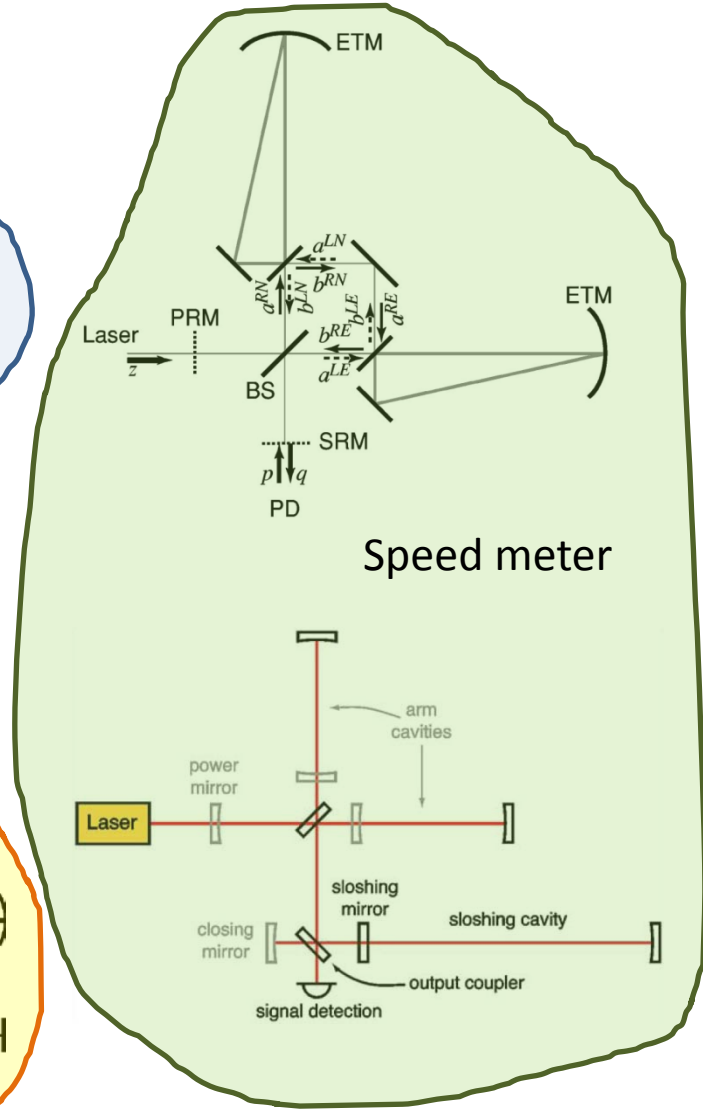
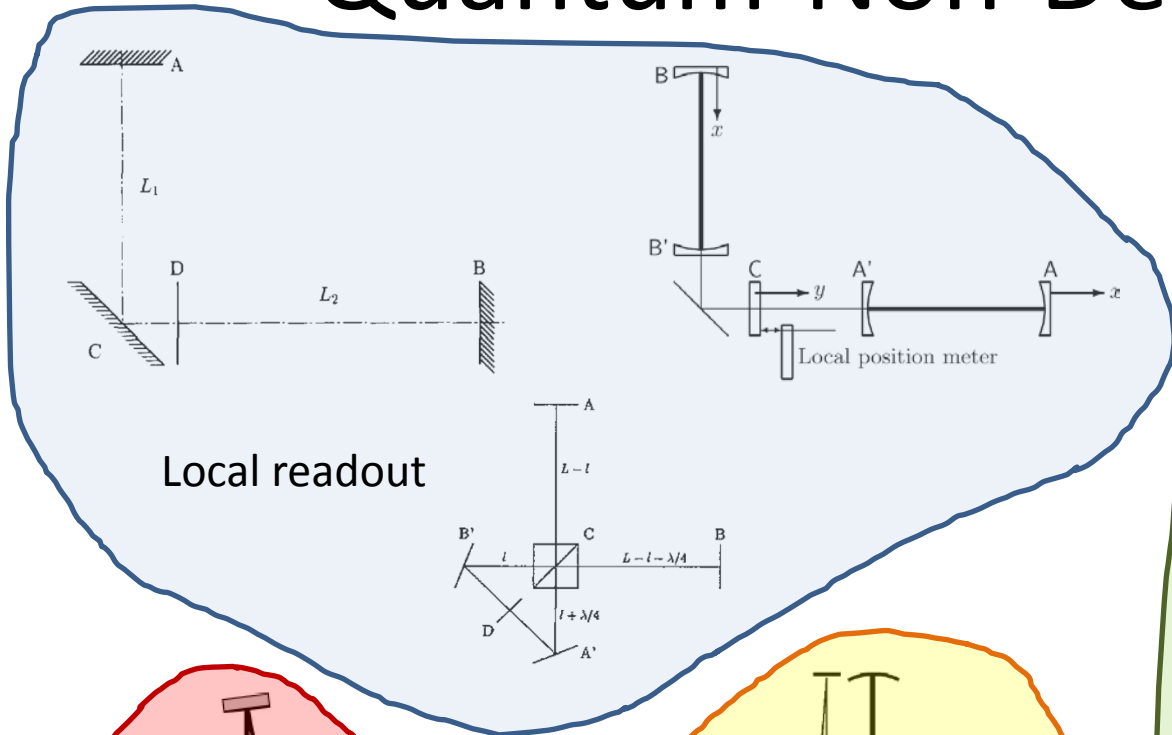
# Squeezed Vacuum Noise

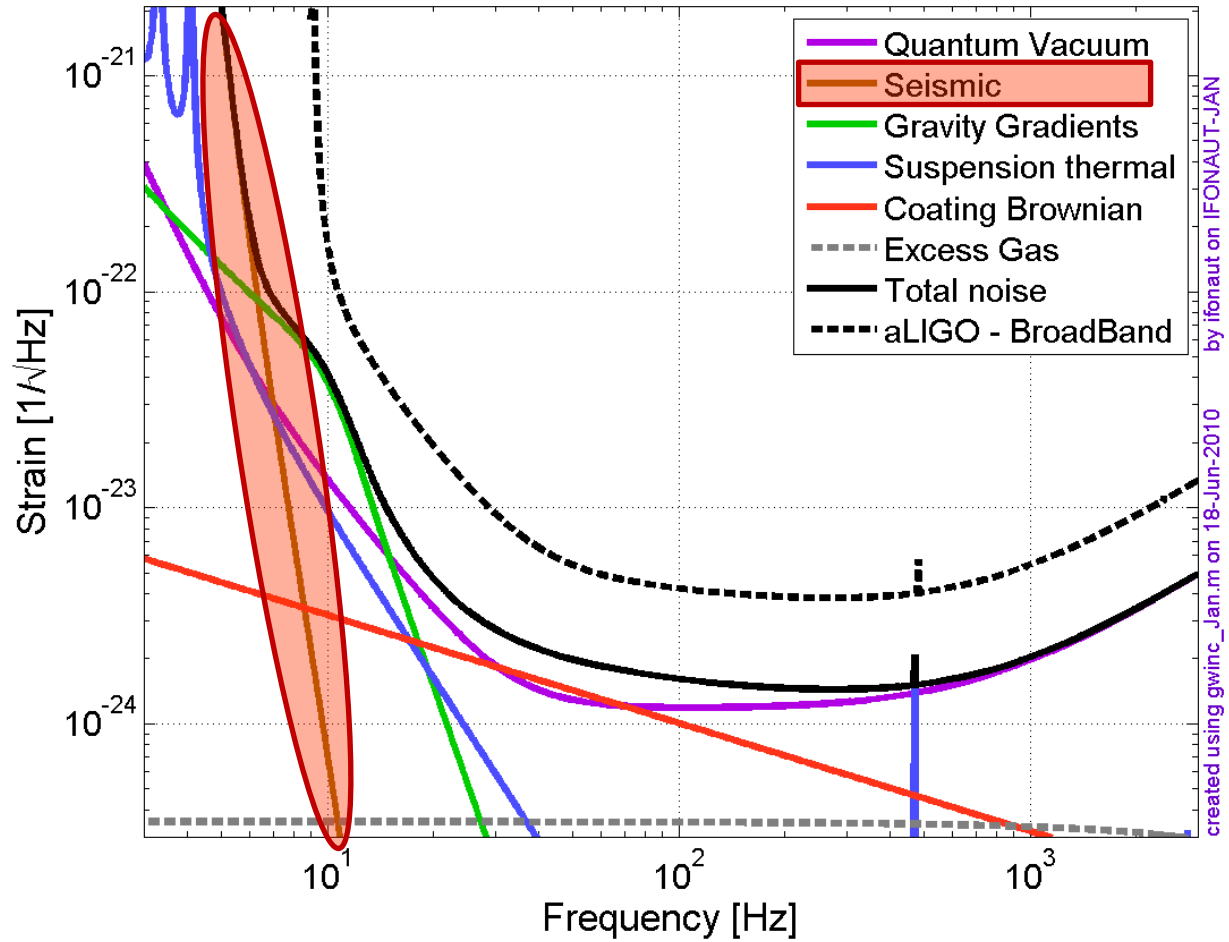
Khalaidowski, Vahlbruch (AEI)



Chelkowski, Vahlbruch,  
Hage, Franzen, Lastzka,  
Danzmann, Schnabel (2005)

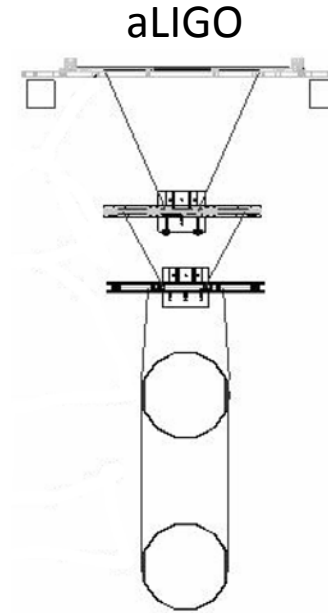
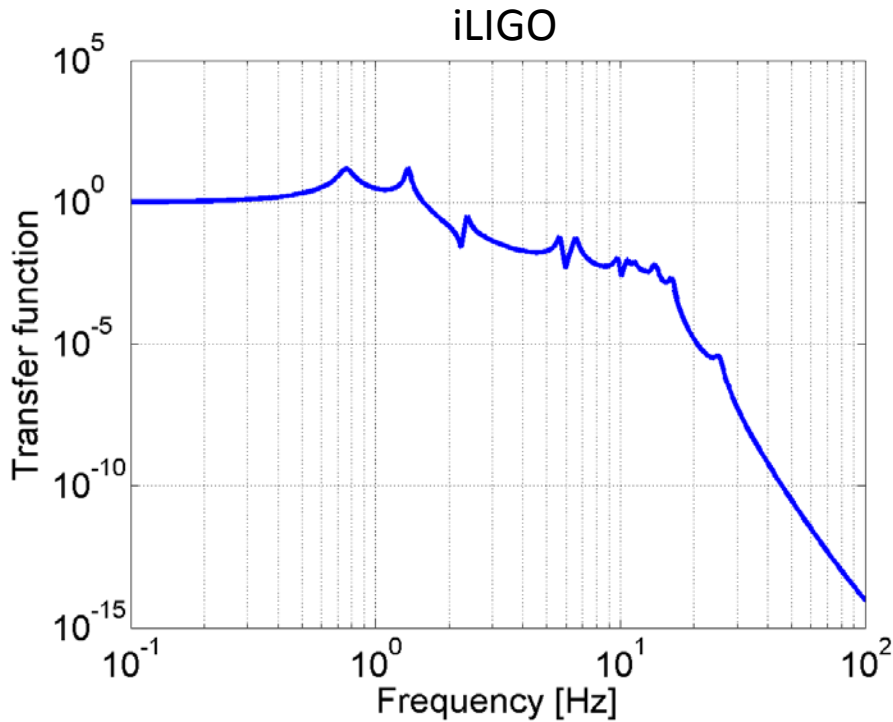
# Quantum-Non-Demolition





by ifonaut on IFONAUT-JAN  
created using gwinc\_Jan.m on 18-Jun-2010

# Seismic Isolation



Wavelength of light ~ 1 micron  
(typical quiet-time ground motion)

÷ 10,000



Atomic diameter  $10^{-10}$  m

÷ 100,000

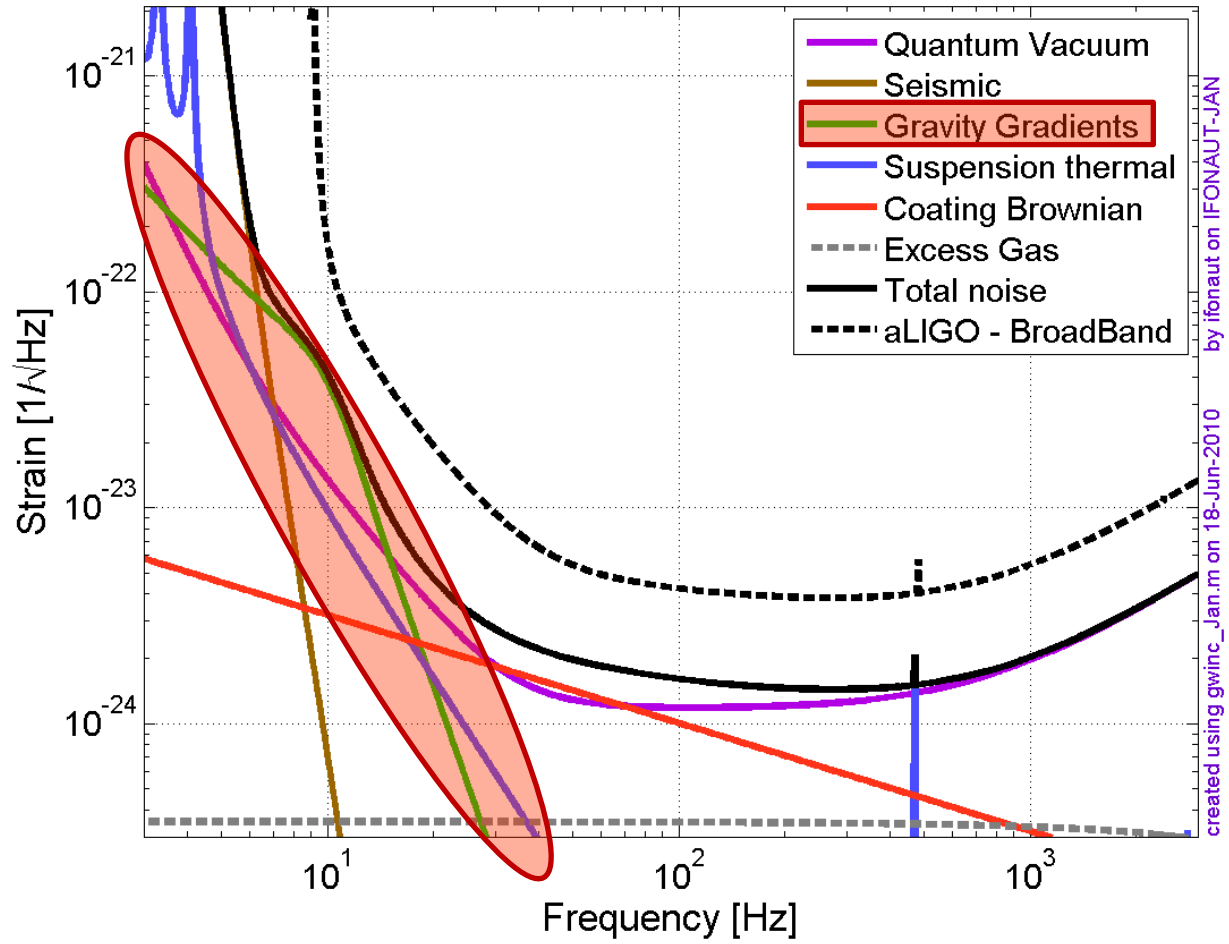


Nuclear diameter  $10^{-15}$  m

÷ 1,000

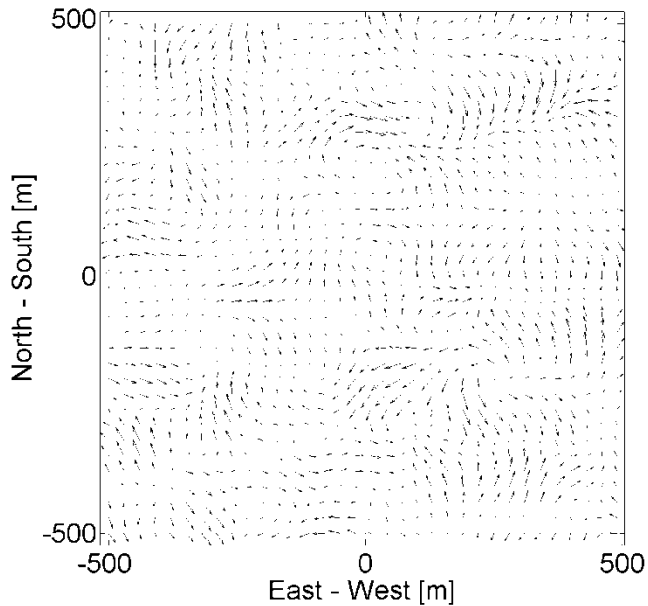


LIGO sensitivity  $10^{-18}$  m



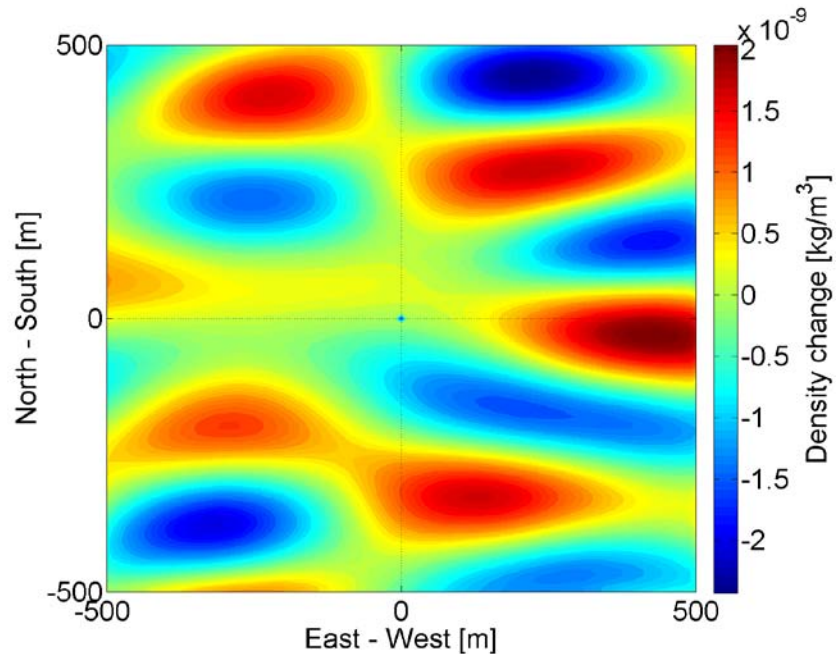
# Newtonian Noise

Seismic field



Seismic field causes density perturbations.

Density perturbation

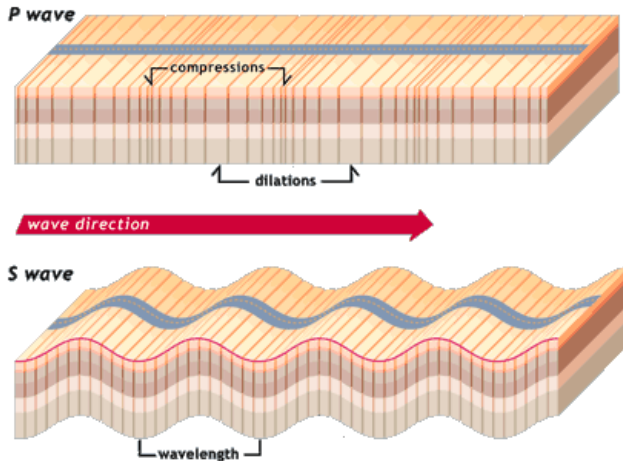


Density perturbations cause gravity perturbations.



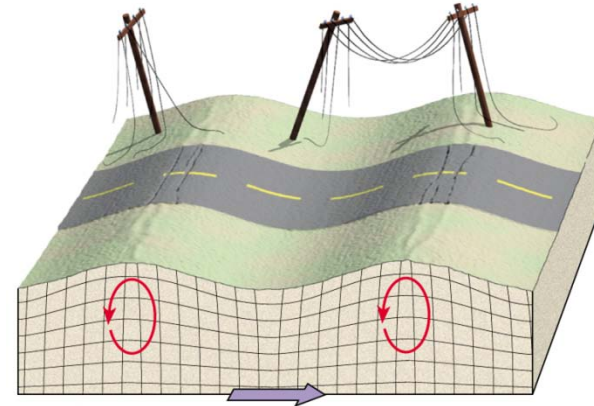
# Seismic Waves

## Body waves



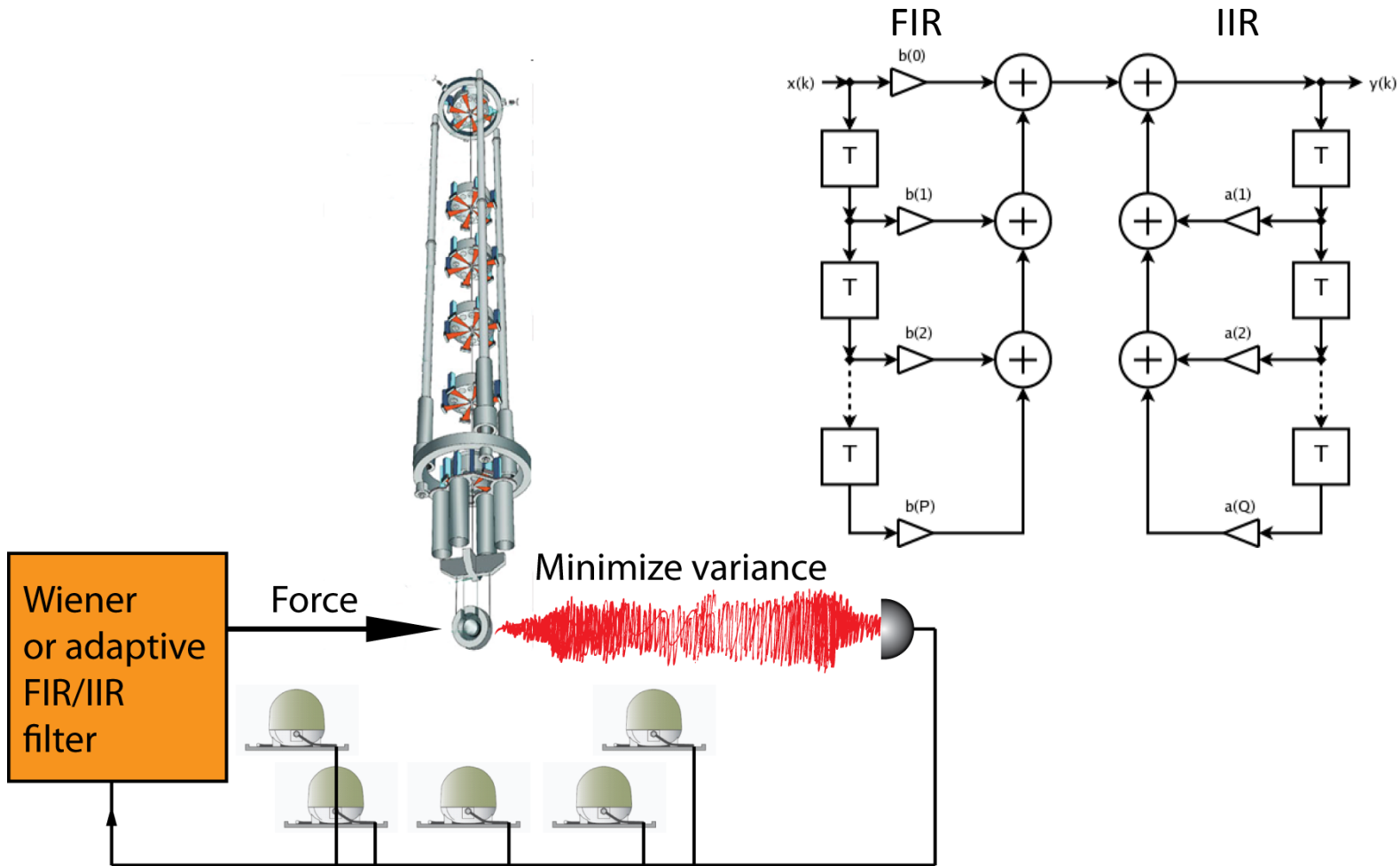
- Body waves propagate in three dimensions
- P = pressure, S = shear
- P wave is fastest
- P wave is longitudinal, S wave is transversal

## Rayleigh waves



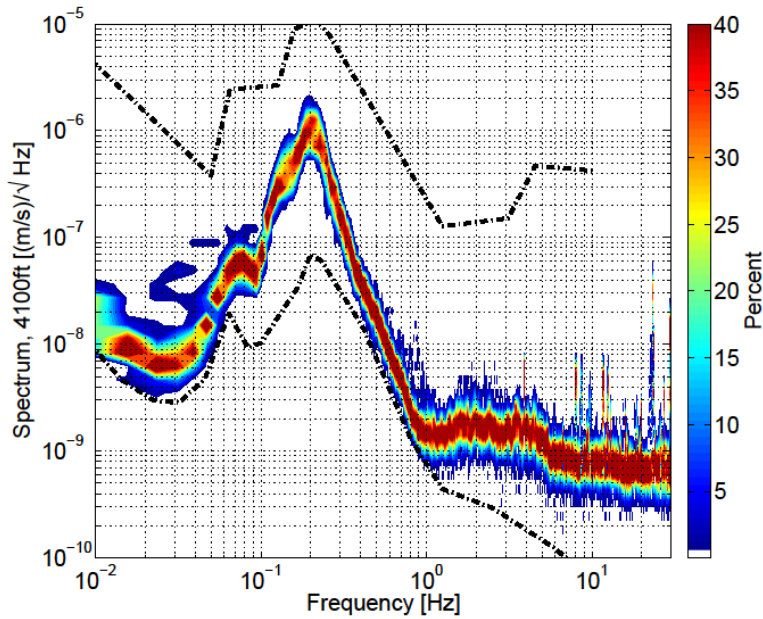
- Rayleigh waves propagate on surfaces
- Rayleigh-wave amplitude decays exponentially with increasing depth
- Rayleigh wave is a superposition of P and S

# Ears and Eyes

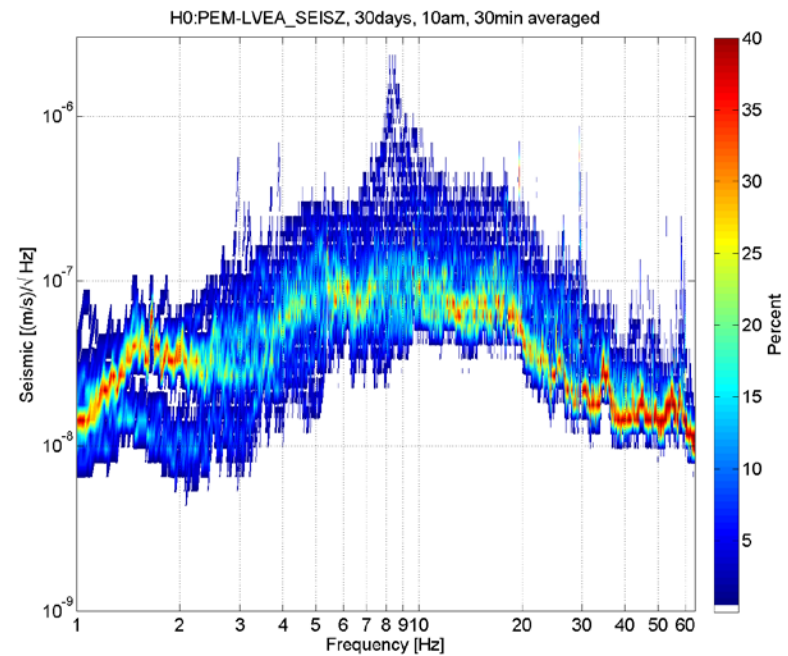


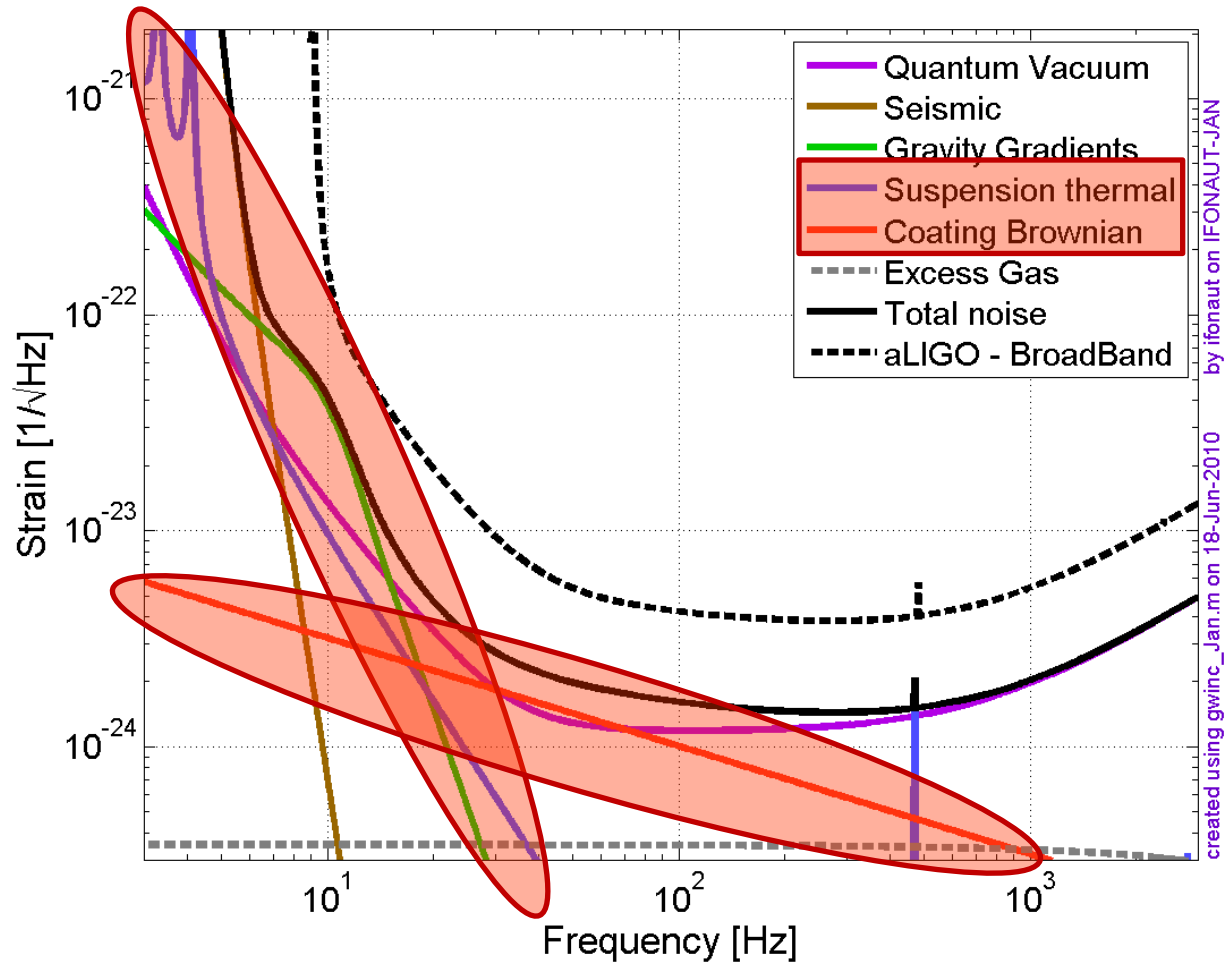
# Seismic Noise

4100ft below surface

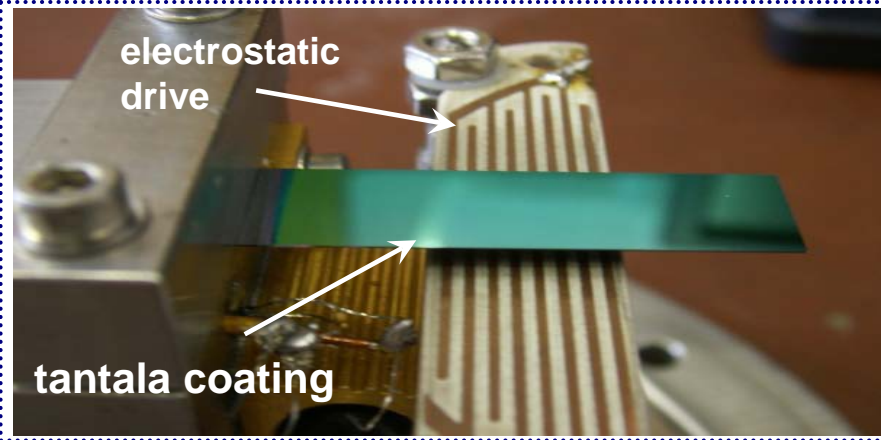


LIGO Hanford





# Coating Brownian

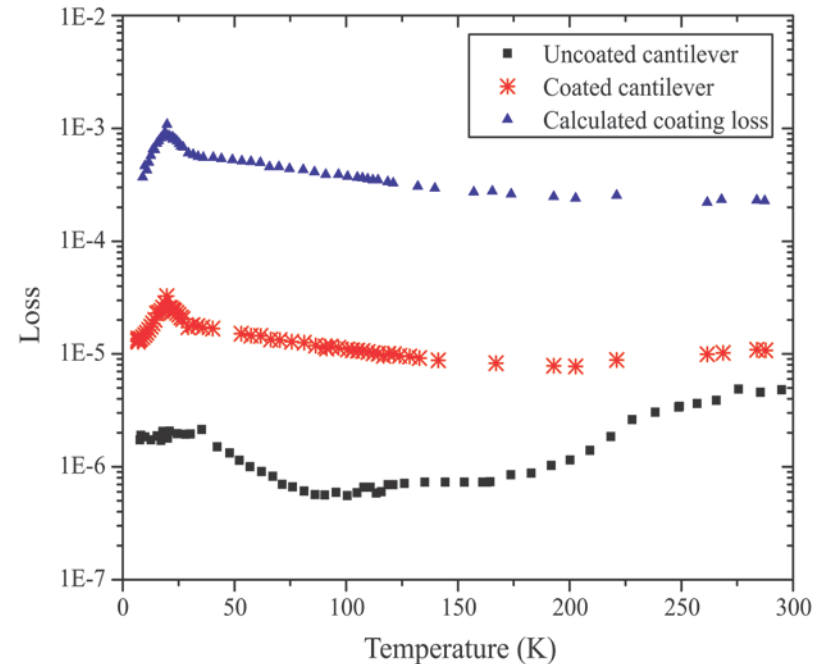
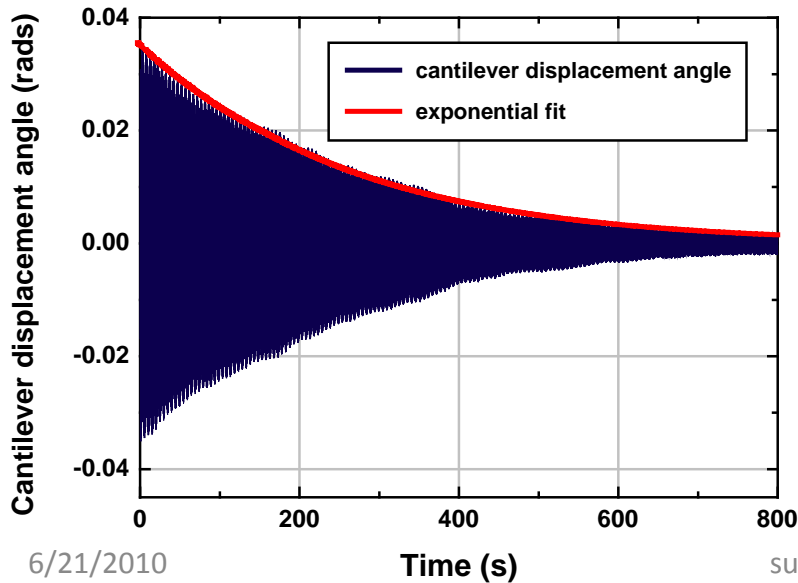


fused silica      tantala

↓                      ↓

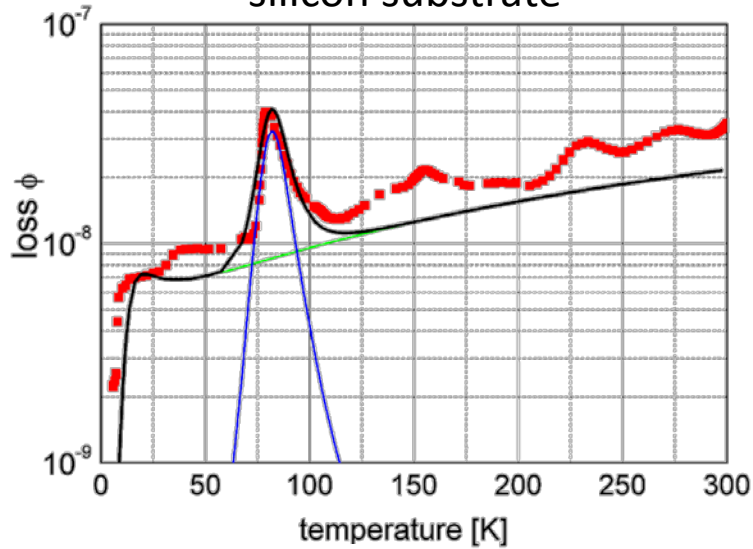
$\text{SiO}_2 - \text{Ta}_2\text{O}_5$  sequence of coating layers

coated cantilever in clamp



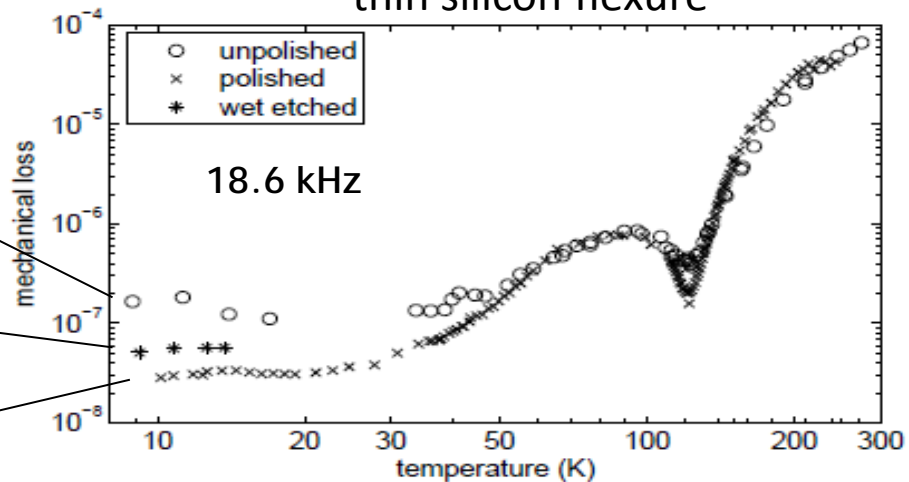
# Suspension Thermal

silicon substrate

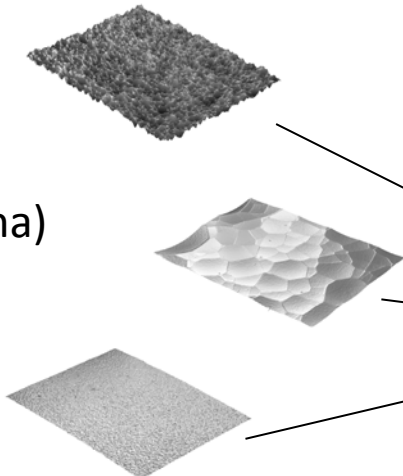


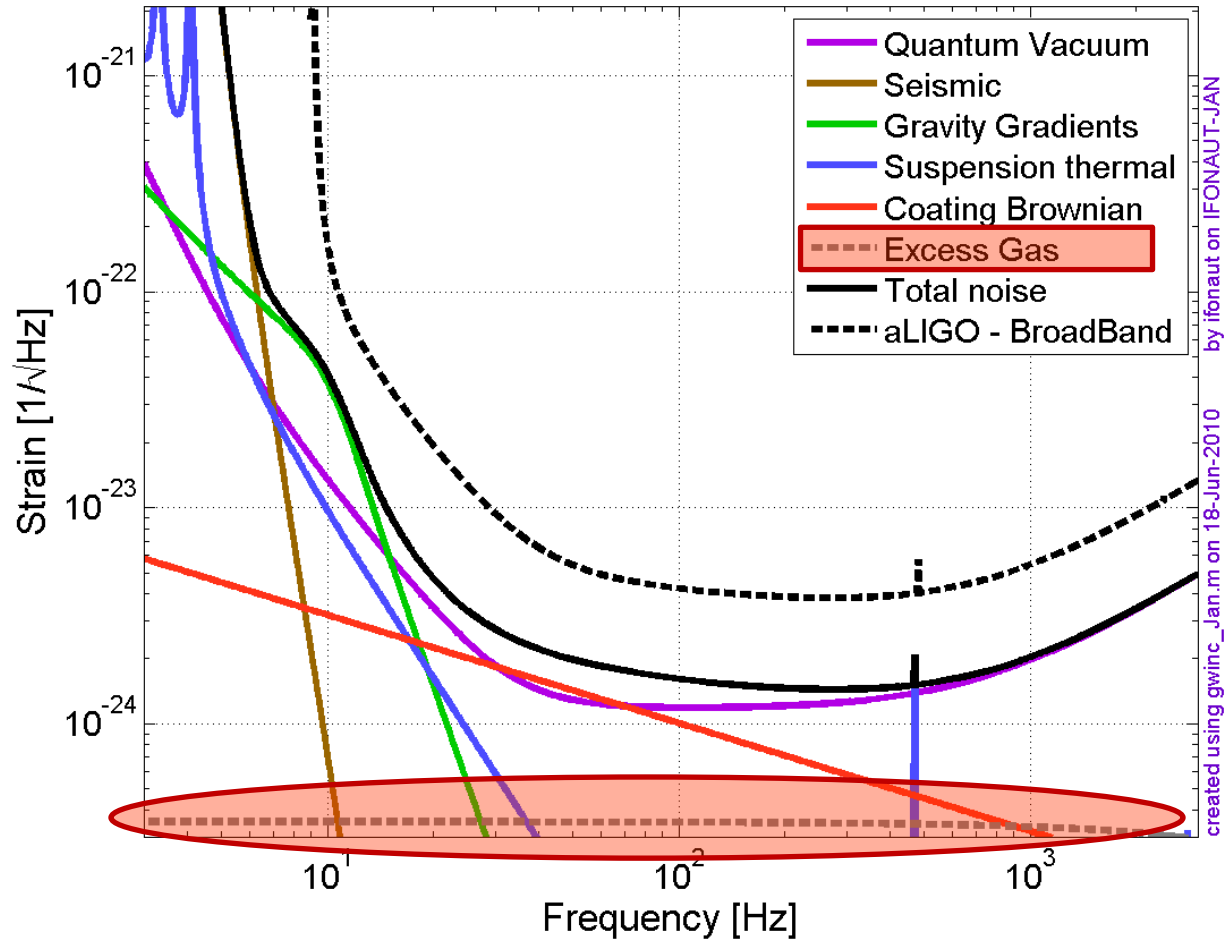
$$\phi = \phi_{bulk} \left( 1 + k \frac{S}{V} \right)$$

thin silicon flexure



Nawrodt,  
Schwarz (Jena)





by ifonaut on IFONAUT-JAN  
 created using gwinc\_Jan.m on 18-Jun-2010

# Vacuum @ LIGO

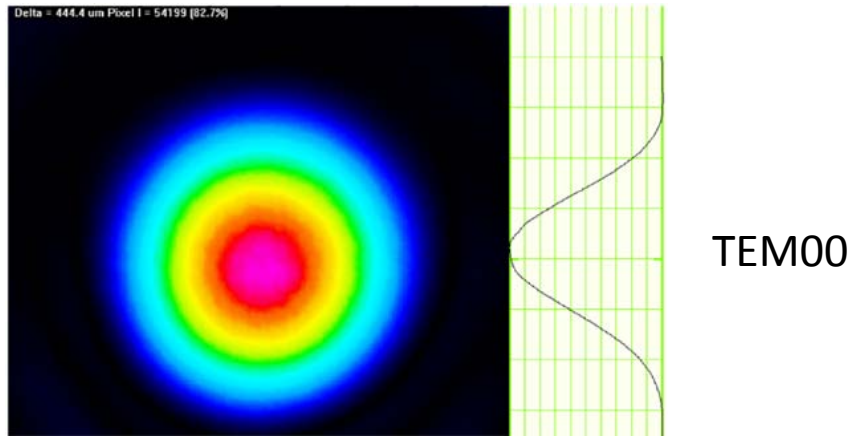


Pressure  $\sim 10^{-8}$  torr  
 $3 \times 10^{14}$  particles/m<sup>3</sup>





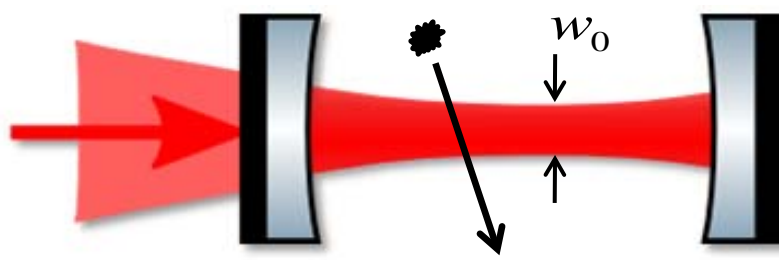
# Gas Scattering



Weak scattering from residual gas causes additional phase noise of the laser.

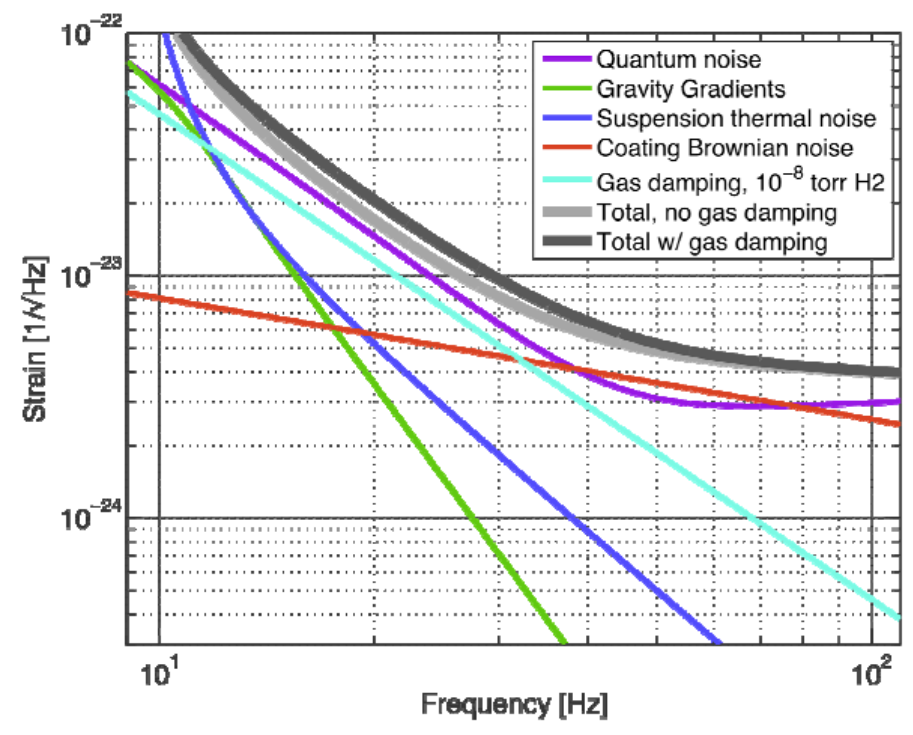
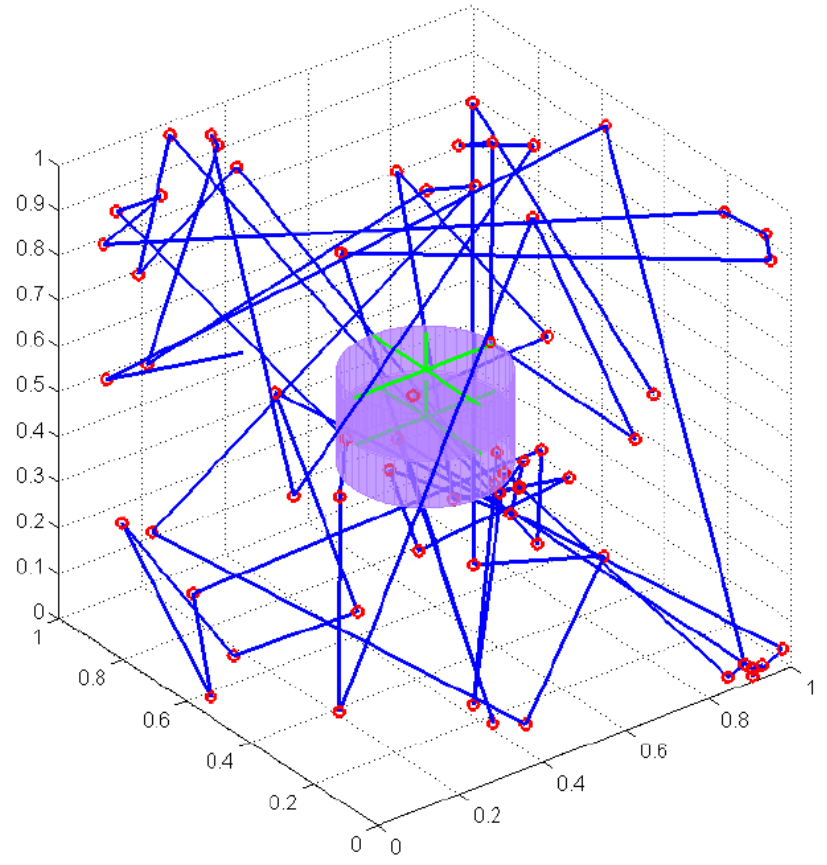
Scattering is proportional to polarizability of gas molecule.

$$\text{Phase noise} \propto 1 / \sqrt{w_0}$$



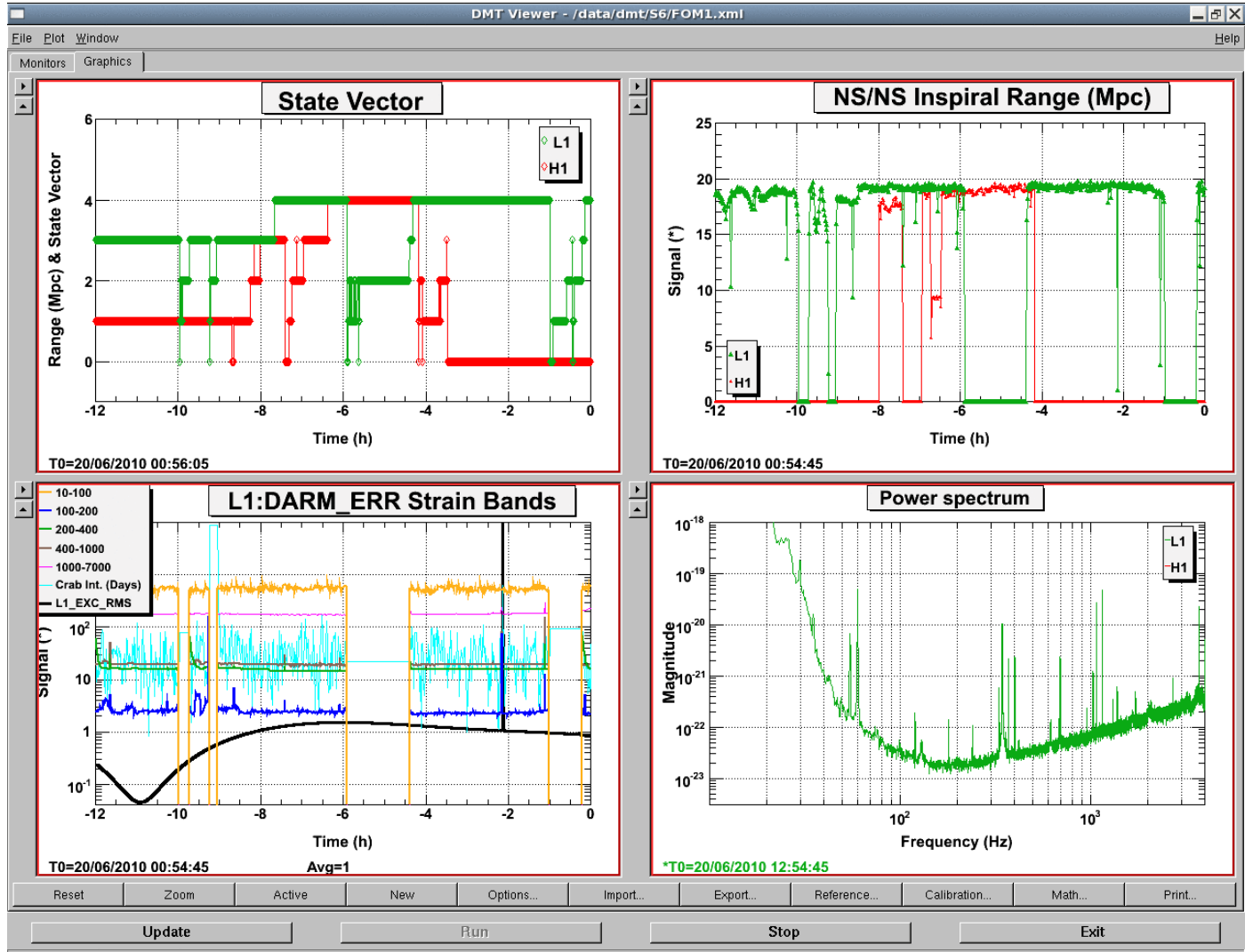
$$\text{Thermal velocity} \propto \sqrt{T}$$

# Gas Damping



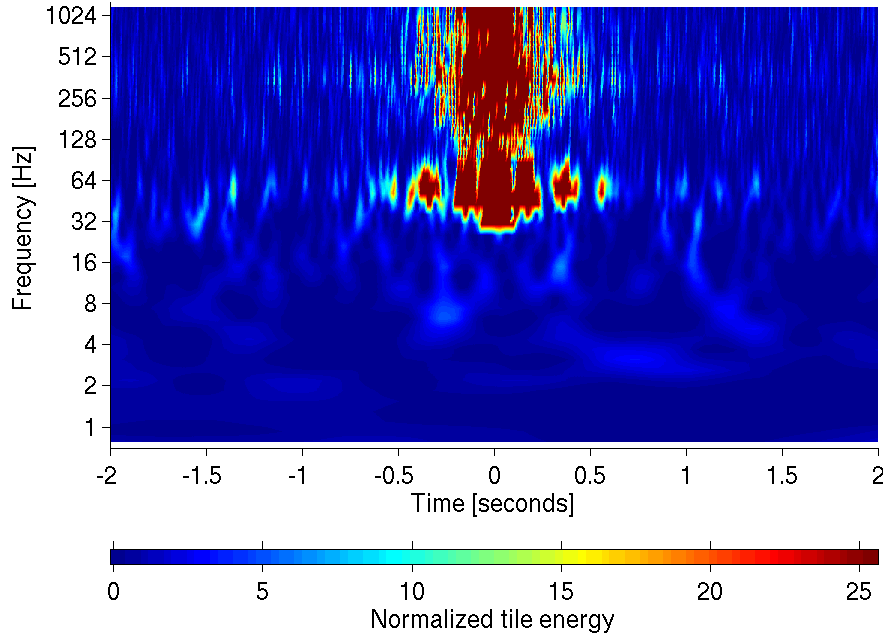
Evans, Fritschel, Weiss (2010)

# Stationarity...

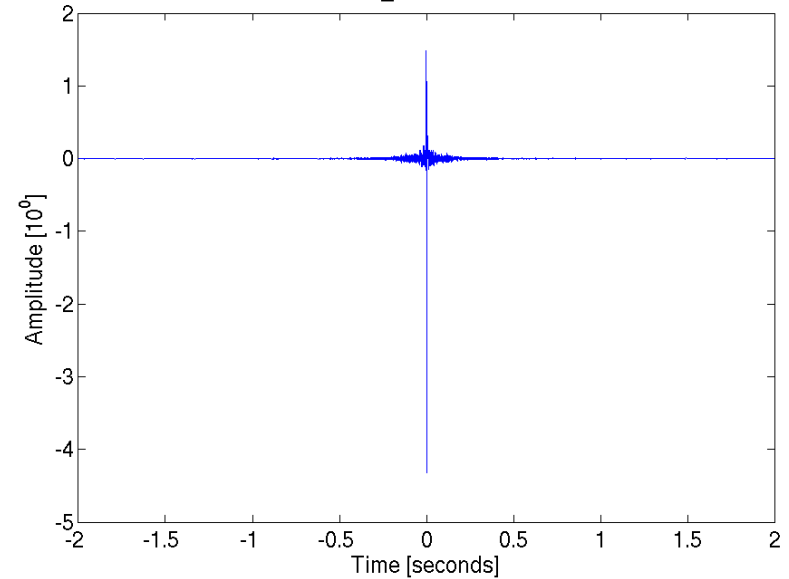


# Transient Noise

L1:LSC-DARM\_ERR at 961069793.770 with Q of 5.7



L1:LSC-DARM\_ERR at 961069793.770



Sunday, 20<sup>th</sup> June 2010, 4:49:39am

Somehow caused by something in the OMC (output mode cleaner).

Good luck with your projects!