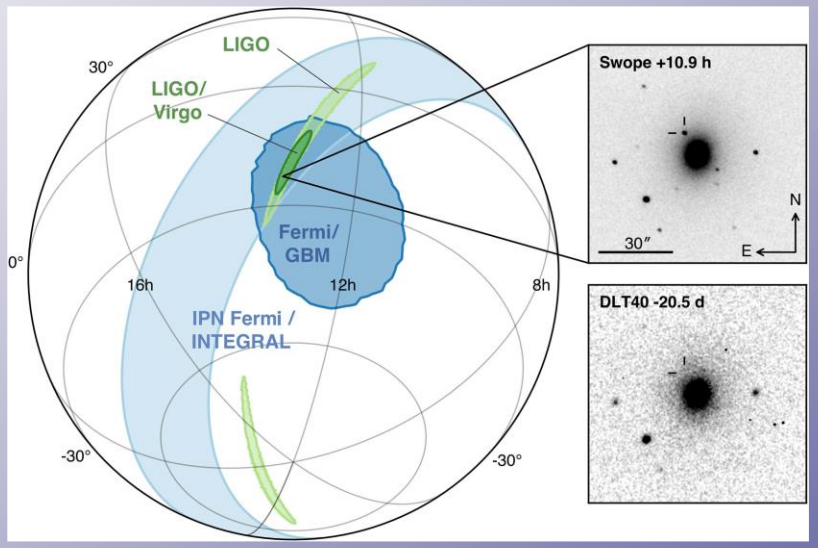
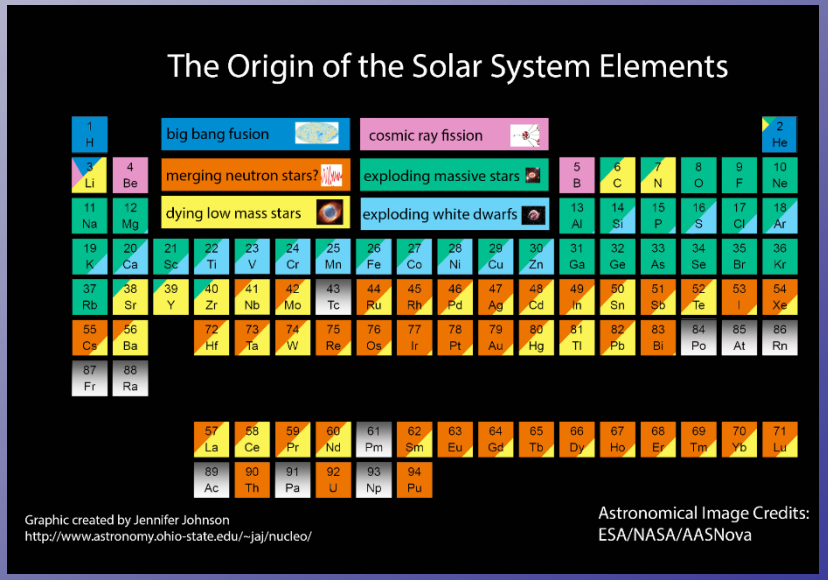
FRONTIERS Online Summer School 2021

Gravitational Wave Astronomy Module

Frontiers has been funded within the framework of the European Union Erasmus+ programme

GW Astronomy



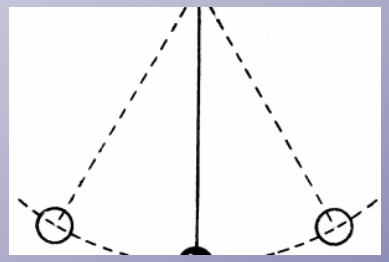


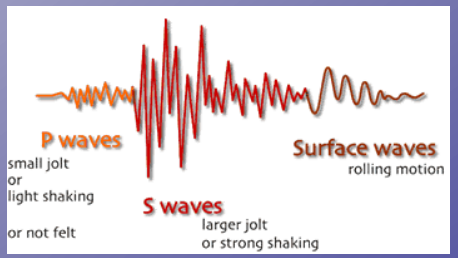
GW Module
The demonstrators

- ***The pendulum***
- Earthquake Interferometer
- ***Discovering and building a Michelson interferometer***
- Finding Black Holes in a Chirp
- ***Gravitational Wave Noise Hunting***
- Control (Class)room
- VIRGO Virtual Visits

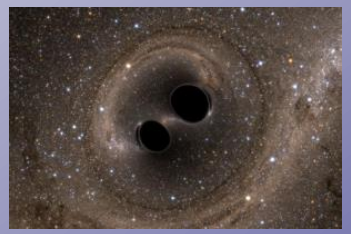
EGO

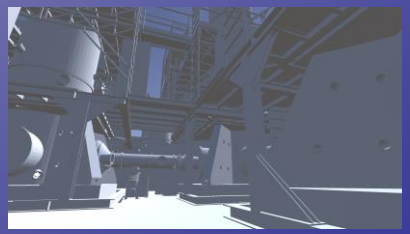
Paris Centre for Cosmological Physics





SPACE-TIME QUEST





Virgo and LIGO sensitivity

Imagine to drop a glass of wine (or water) in the ocean…….

Ocean Surface (S):
70% x 4π x R_terra^2 =
0.7 x 4 x 3.14 x (6.37e6 m)^2
~ 3.6e14 m^2

Volume of the glass (V):
~ 0.25e-3 m^3

Increase of the global sea level:
h ~ V / S ~ 1e-18 m

This is the level of sensitivity we need to reach with GW detectors !!

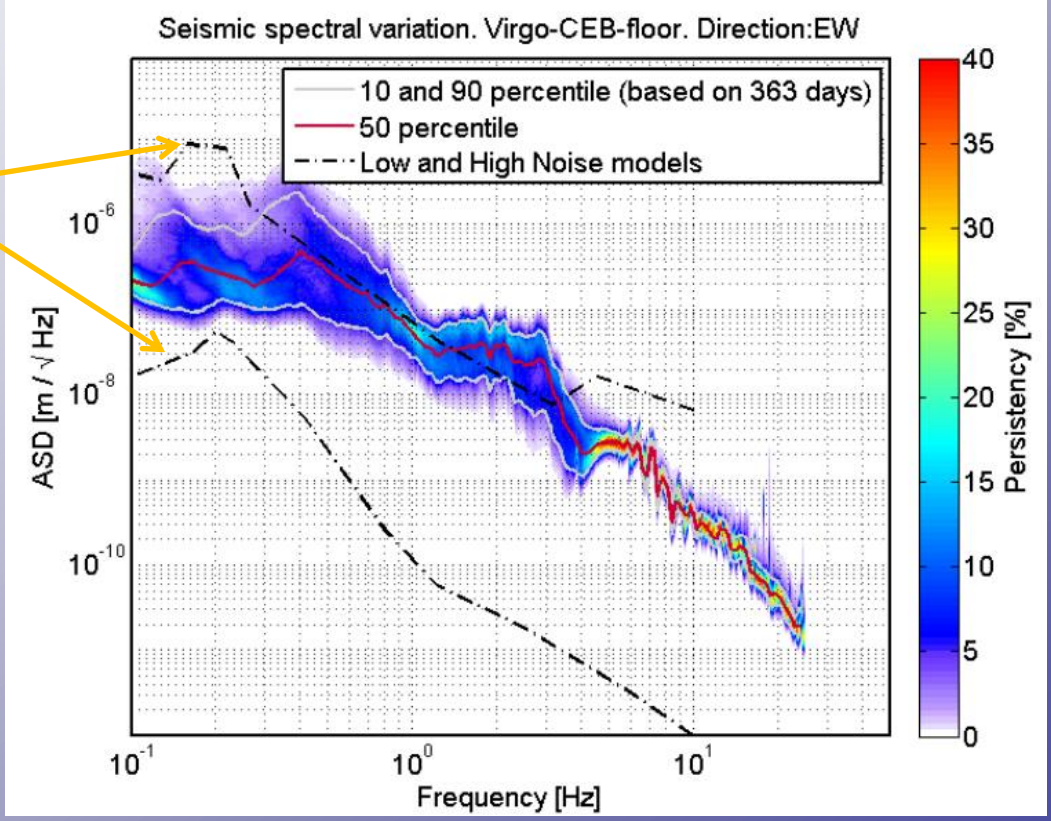
Seismic Noise

- Seismic noise has both natural and human origins and can vary by few orders of magnitude from site to site.

- All ground motion displacement spectra observed worldwide share some common characteristics: they have essentially the same amplitude in all three orthogonal space directions and they exhibit a low pass behavior that follows the empirical law for f > 0.1 Hz

$$x(f) \sim A\ (1\ \mathrm{Hz/f})^2\ \text{m/sqrt(Hz)}$$

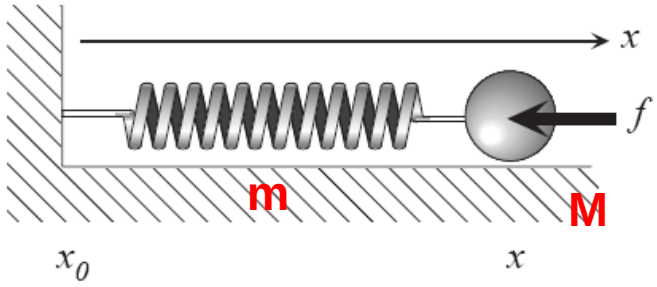
Peterson's High and Low Noise Models



Springs as seismic isolators

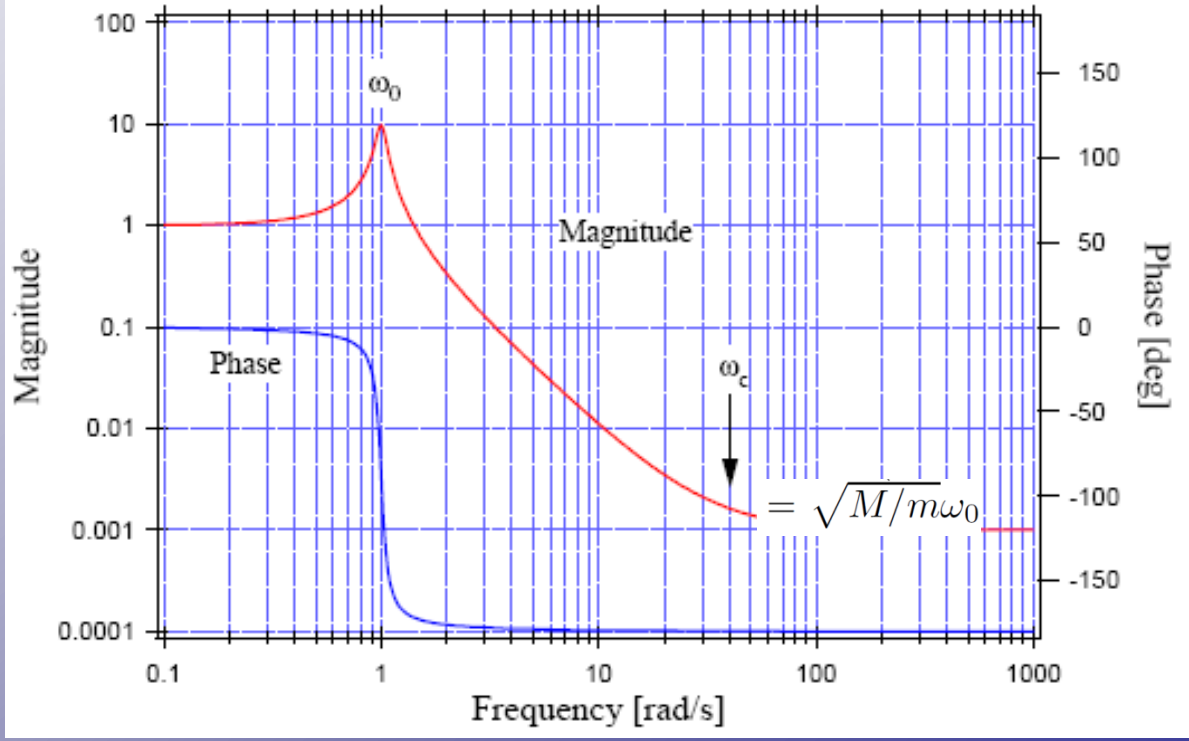
At frequencies higher than the oscillator resonance, the transfer function of an harmonic oscillator is equivalent to a second-order low pass filter.

Massive Spring



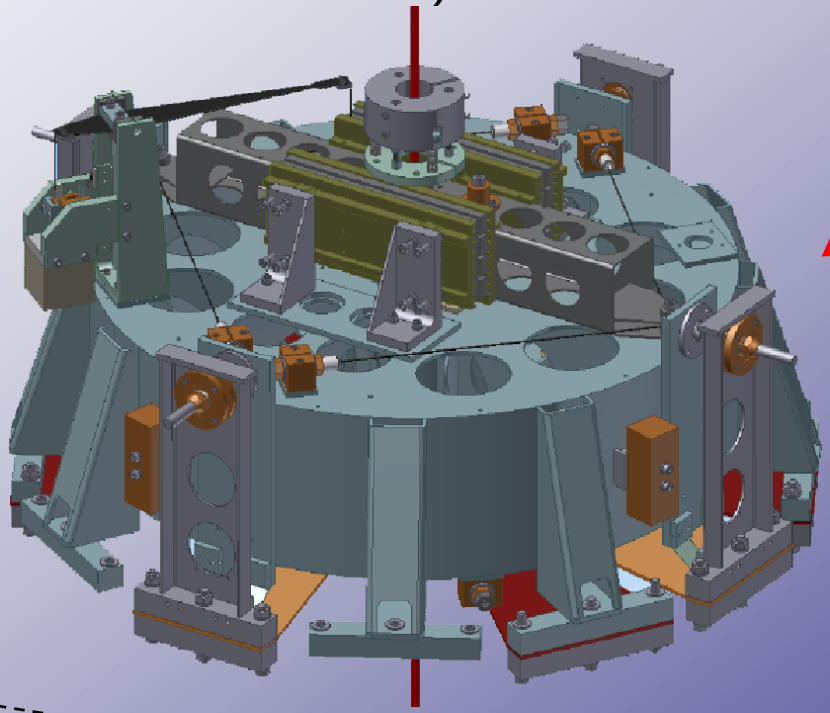
$$H_X = \frac{\omega_0^2(1+i\phi)+\frac{m}{M}\omega^2}{\omega_0^2(1+i\phi)-\omega^2+i\frac{\gamma}{M}\omega}$$

Transfer Function

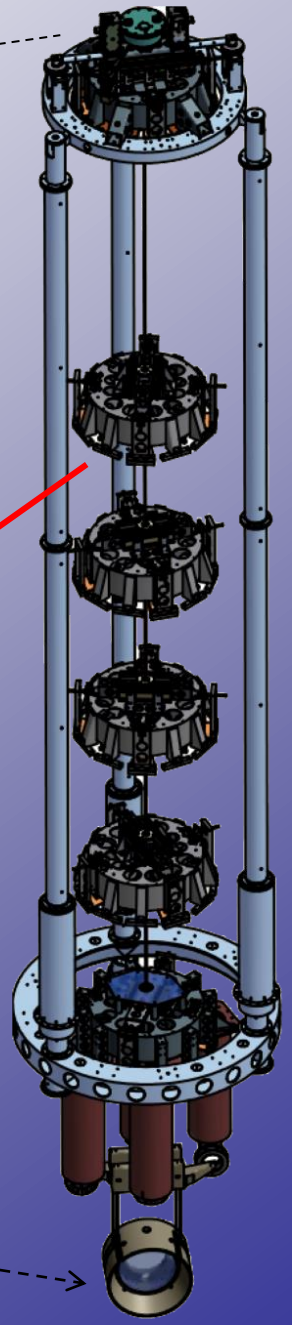


VIRGO superattenuator

It's able to attenuate the seismic motion of the mirrors by more than a factor 10^{12} (a million of a million times)



Standard filter

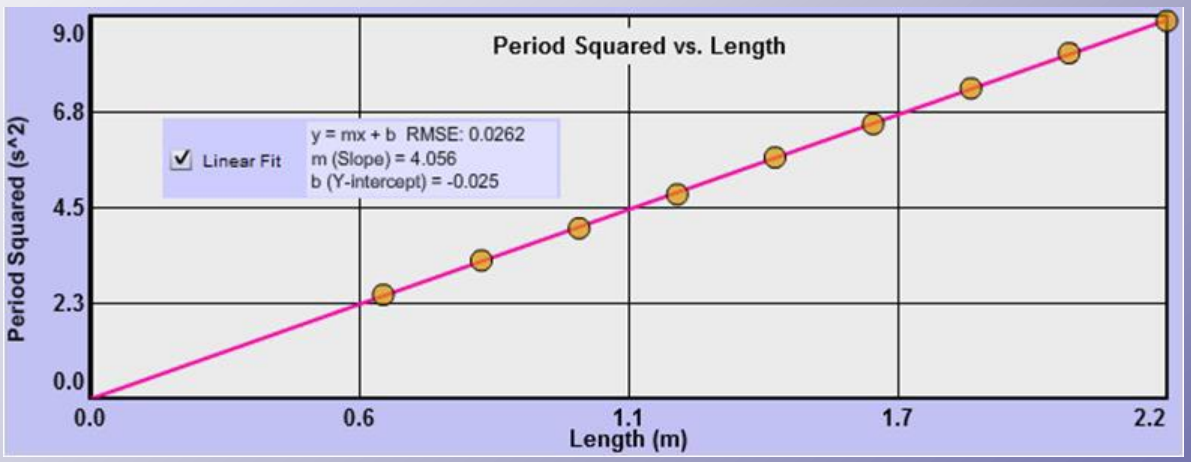


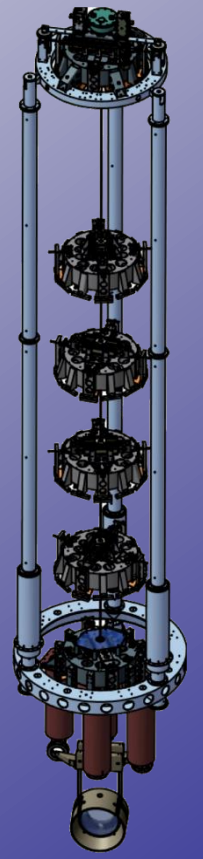
Suspended mirror

GW Demonstrators
The pendulum

- In this lesson we will explore the pendulum, a very simple mechanical system but at the same time an extremely powerful tool for exploring physical phenomena such as oscillations, gravity, the transmission of vibrations and also the concepts of speed, acceleration, energy and resonance.

- ISE Link





GW Demonstrators
Earthquake interferometer

How can you use Virgo data ? Control room data constitute a powerful tool to understand how the environment interact with the detector

- What is the effect of the wind on Virgo ?
- What is the effect of the sea waves ?
- What happen when an earthquake reach the Virgo site ?