L’entrata in presa dati di Virgo

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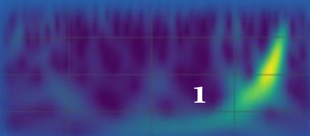


A closer look to the detector

GW amplitude and their effect: what we want to measure

The amplitude of gravitational waves is proportional to the quadrupole moment of the source masses through the constant

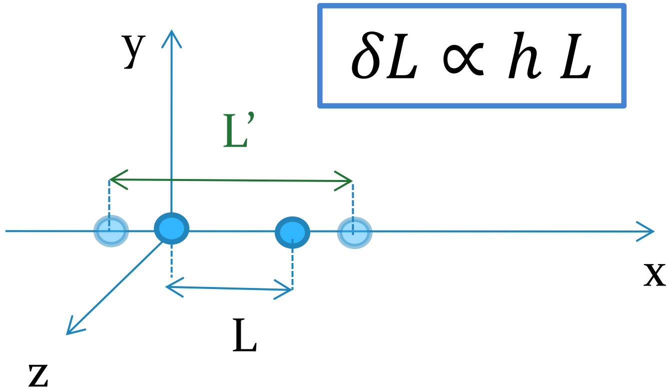
$$h_{jk}^{TT} = \frac{2G}{rc^4}\left(\frac{d^2 I_{jk}^{TT}}{dt^2}\right)_{t-r/c}$$

$G/c^4 \approx 10^{-45}\ N^{-1}$

→ **Only astrophysical sources can produce detectable effects**

Binary compact objects (BBH, BNS, BH-NS), pulsars, bursts, stochastic bkg

$$\boxed{\delta L \propto h\,L}$$



Typical amplitude: $\boldsymbol{h \approx 10^{-21}}$

The distance between two free-falling masses separated by ~Km will change by

$\boldsymbol{\delta L \approx 10^{-18}}$**m**

How small is "small"? Let's get the feeling…

Let's suppose you pour a **glass of wine** into the **ocean**.

➢ *What is the rise of sea-level you get?*

That's the order of magnitude of effect we want to detect!

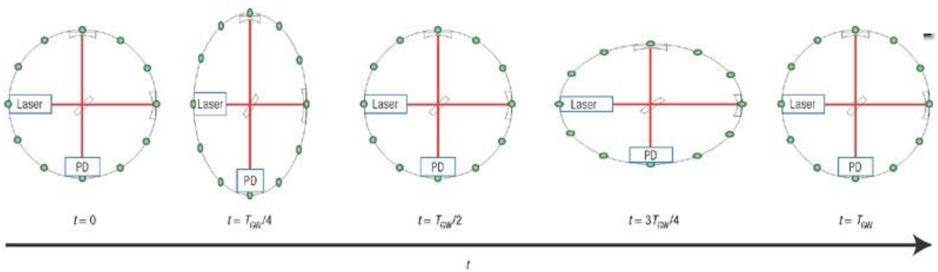
Michelson Interferometry to detect GWs

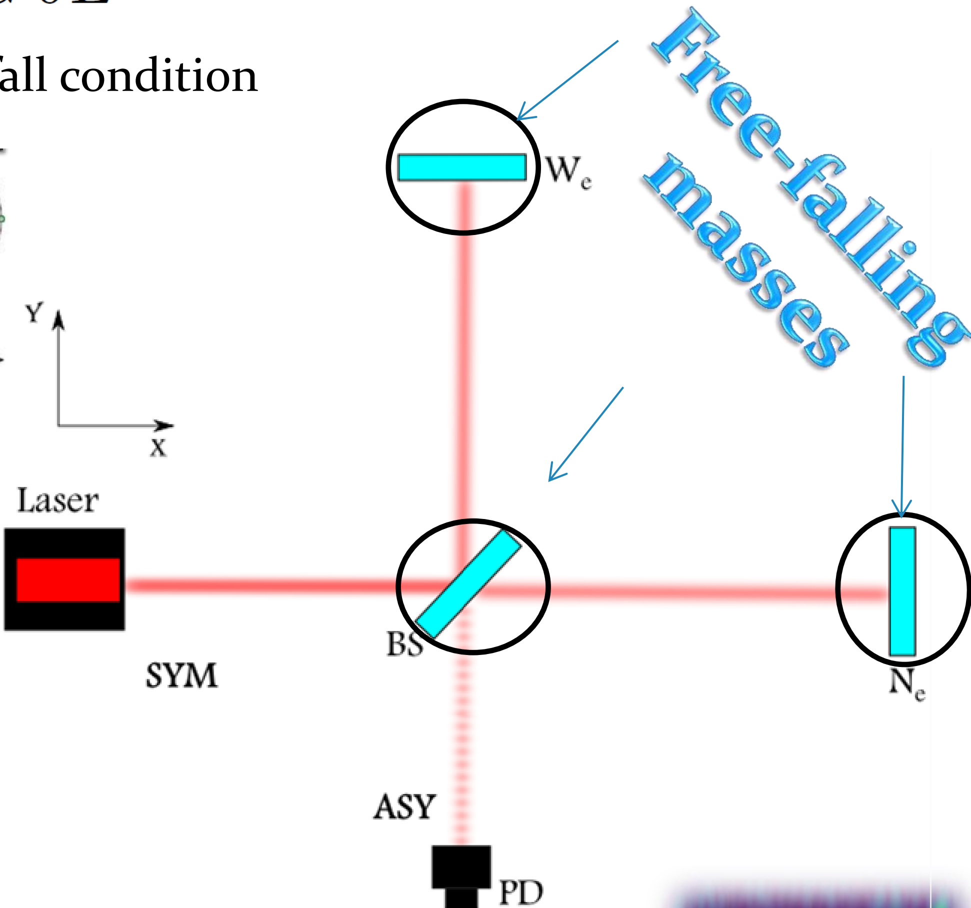
$$\boxed{\delta L \propto h\, L}$$

Use an interferometer as a transducer: convert displacements into optical signals

$$\delta\phi = G\,\delta L$$

Suspended mirrors to reproduce the free-fall condition





GWs produce a differential variation of the arm lengths which is revealed at the ***antisymmetric port*** (ASY) of the interferometer

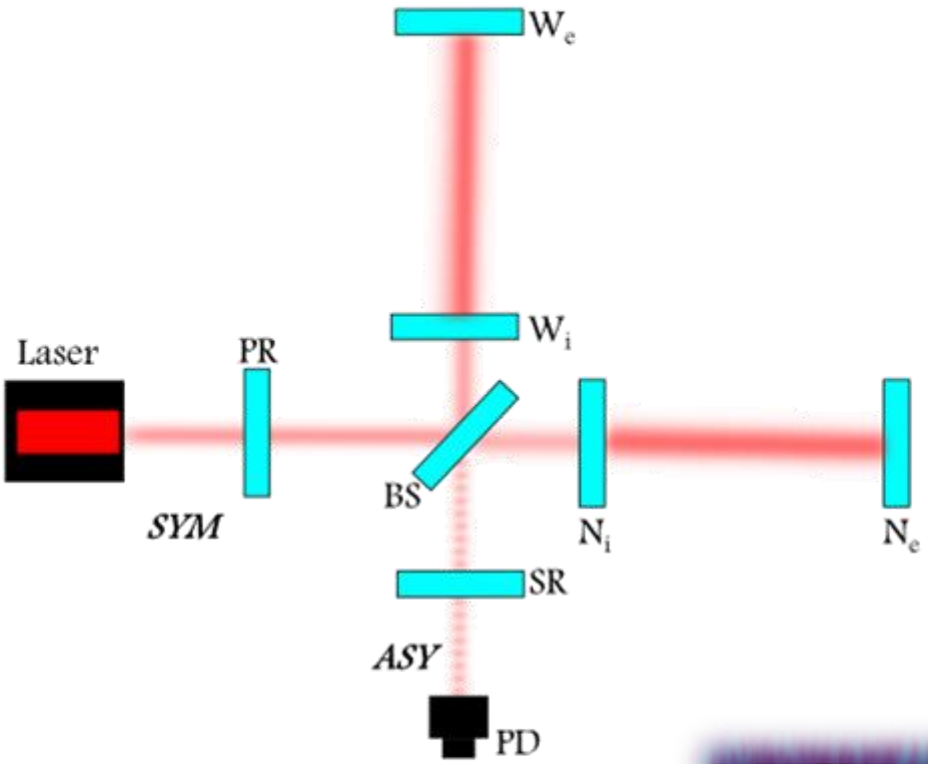
Michelson Interferometry to detect GWs

$\delta L \propto h\, L$

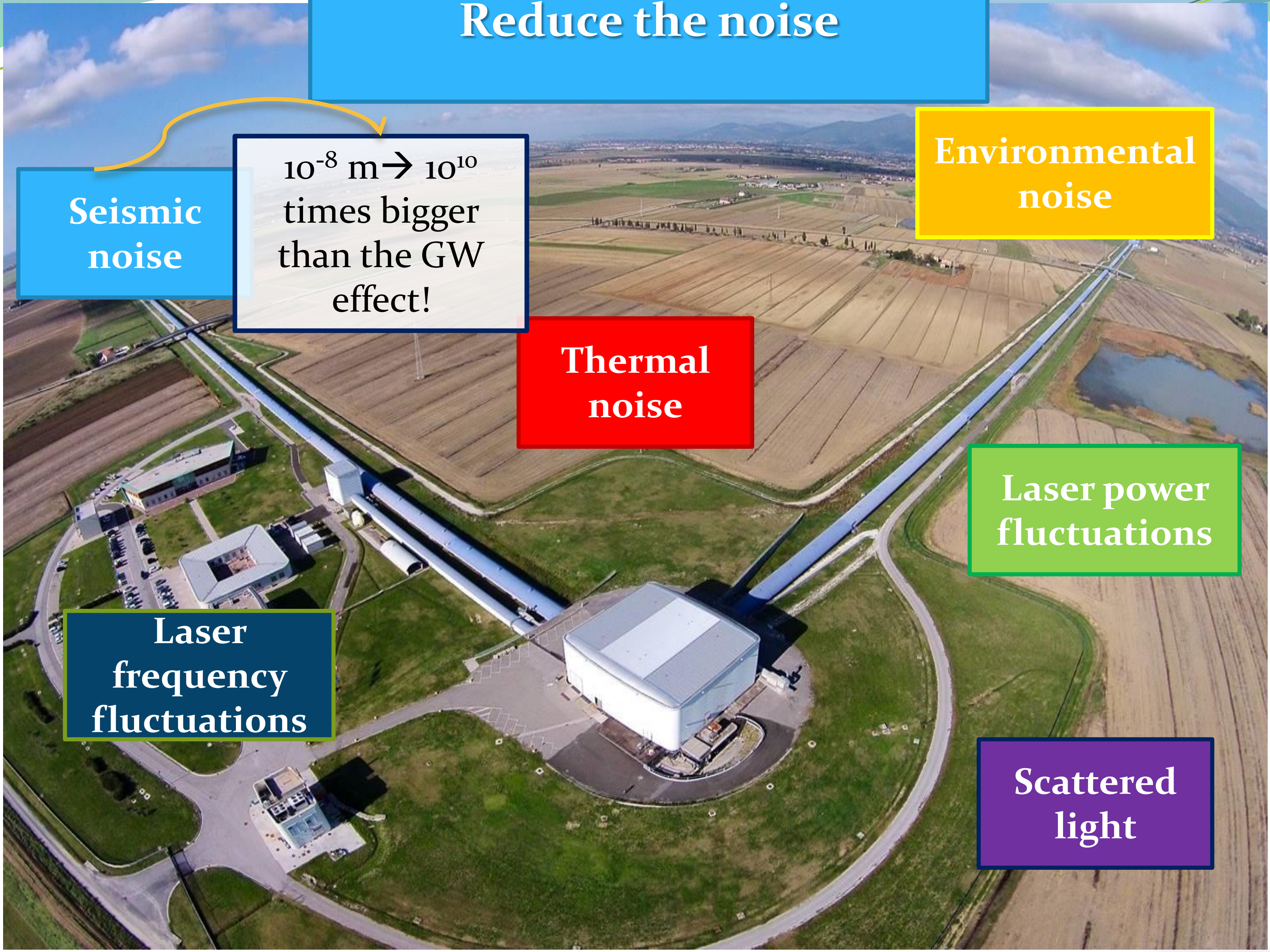
To make a GW detector out of a Michelson interferometer, it's necessary to improve the SNR: **enhance the signal** and **reduce the noise**

Enhance the signal

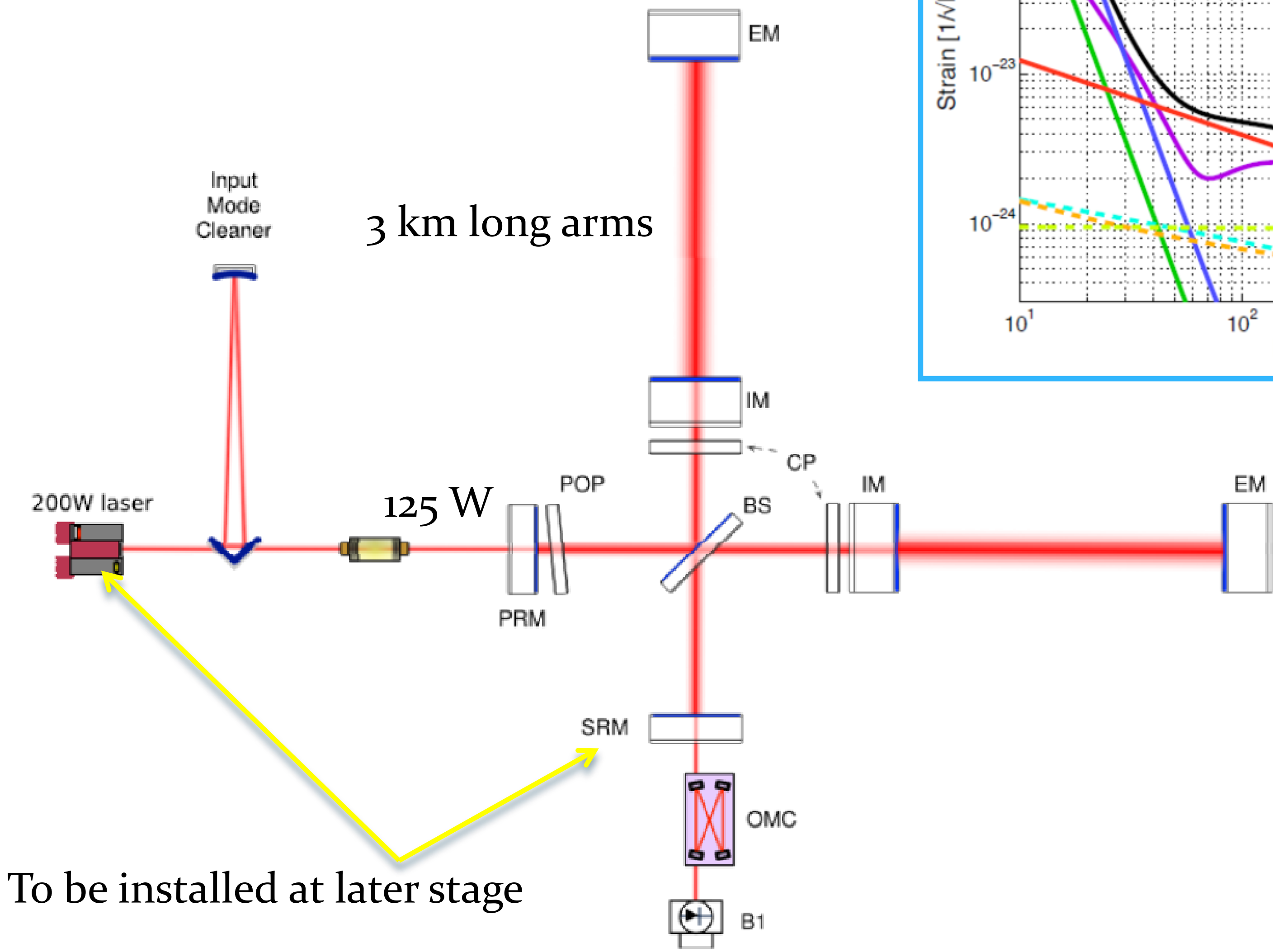
- Fabry-Perot cavity for "longer arms"
- Working point at ***dark fringe*** ($P_{out} \sim 0$) to allow a null measurement and avoid the coupling of all the common technical noises
- Increase the power: more powerful laser and recycling mirror to recover the power reflected from the arms (***PR***)
- Recycling mirror to enhance GW audio sidebands (***SR***)

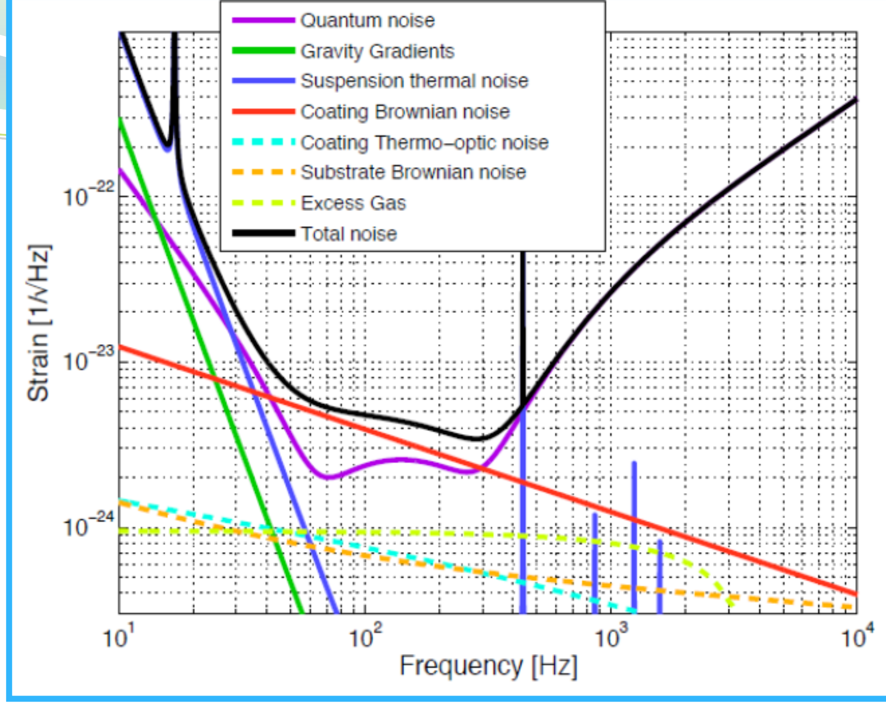


Reduce the noise



Advanced Virgo optical scheme

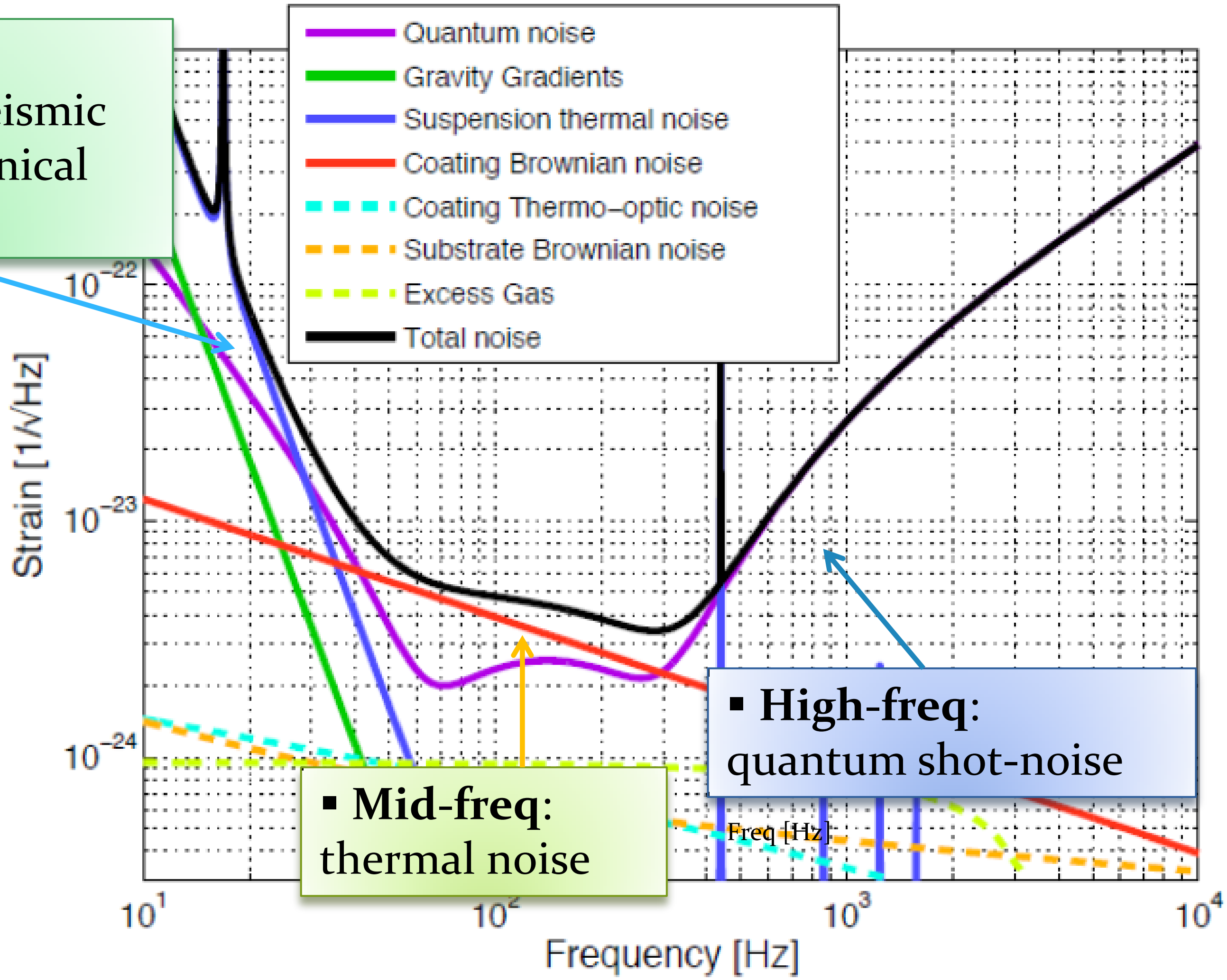




The goal: reduce the noise to approach the design sensitivity

Limiting noises at different frequency ranges:

- **Low-freq**: newtonian noise, seismic noise, residual technical noises



- **Mid-freq**: thermal noise

- **High-freq**: quantum shot-noise

Advanced Virgo: how did we make it work

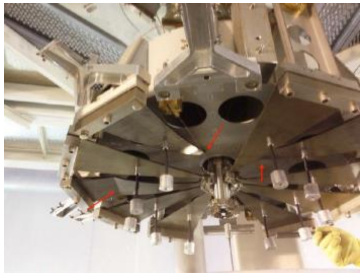
- Integration
- Commissioning
- **O2 Scientific Run**

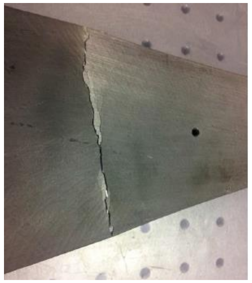
Integration

Started in 2012 and completed on Oct 2016

Many issues slowed down the integration process:

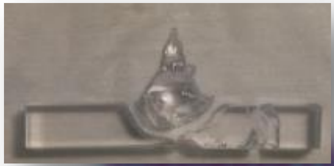
- Maraging blades breaking (used for vertical seismic attenuation in the Superattenuator) → after a deep analysis, all the damaged and suspect blades have been replaced





- Scratches on one of the optics in the central area → *optics replaced*

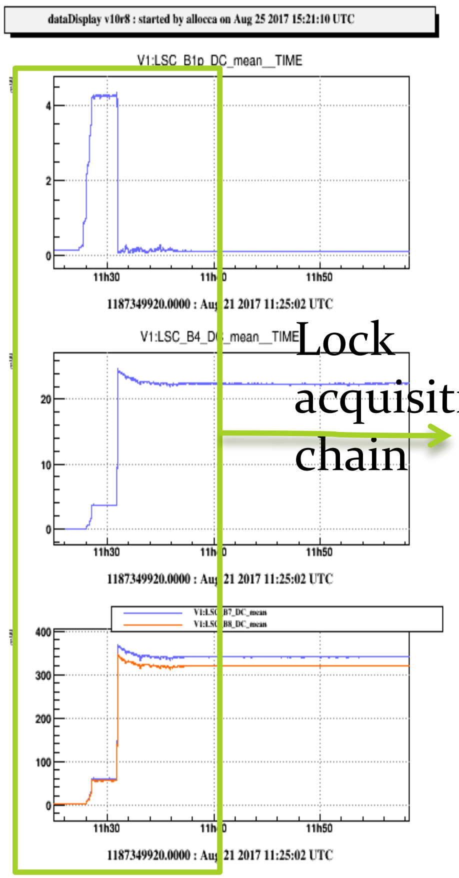
- Monolithic suspension breaking issue due to fast dust particles hitting the fiber and producing fractures → *Temporary solution for O2 scope:* ***back to steel wires for payloads*** *(choice driven by schedule considerations)*



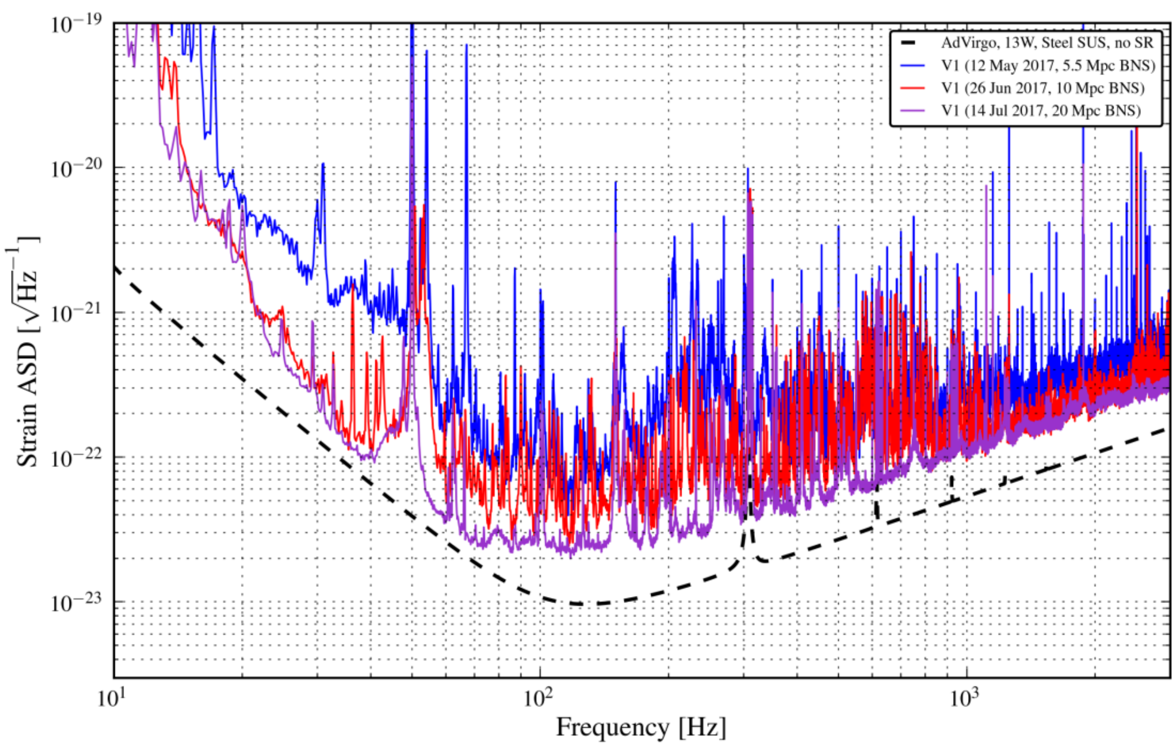
Commissioning

As fast as possible to join LIGO in O2

Bring the interferometer to the good working point, improve the duty cycle, identify and remove noise sources



Lock acquisition chain



VIRGO

Commissioning

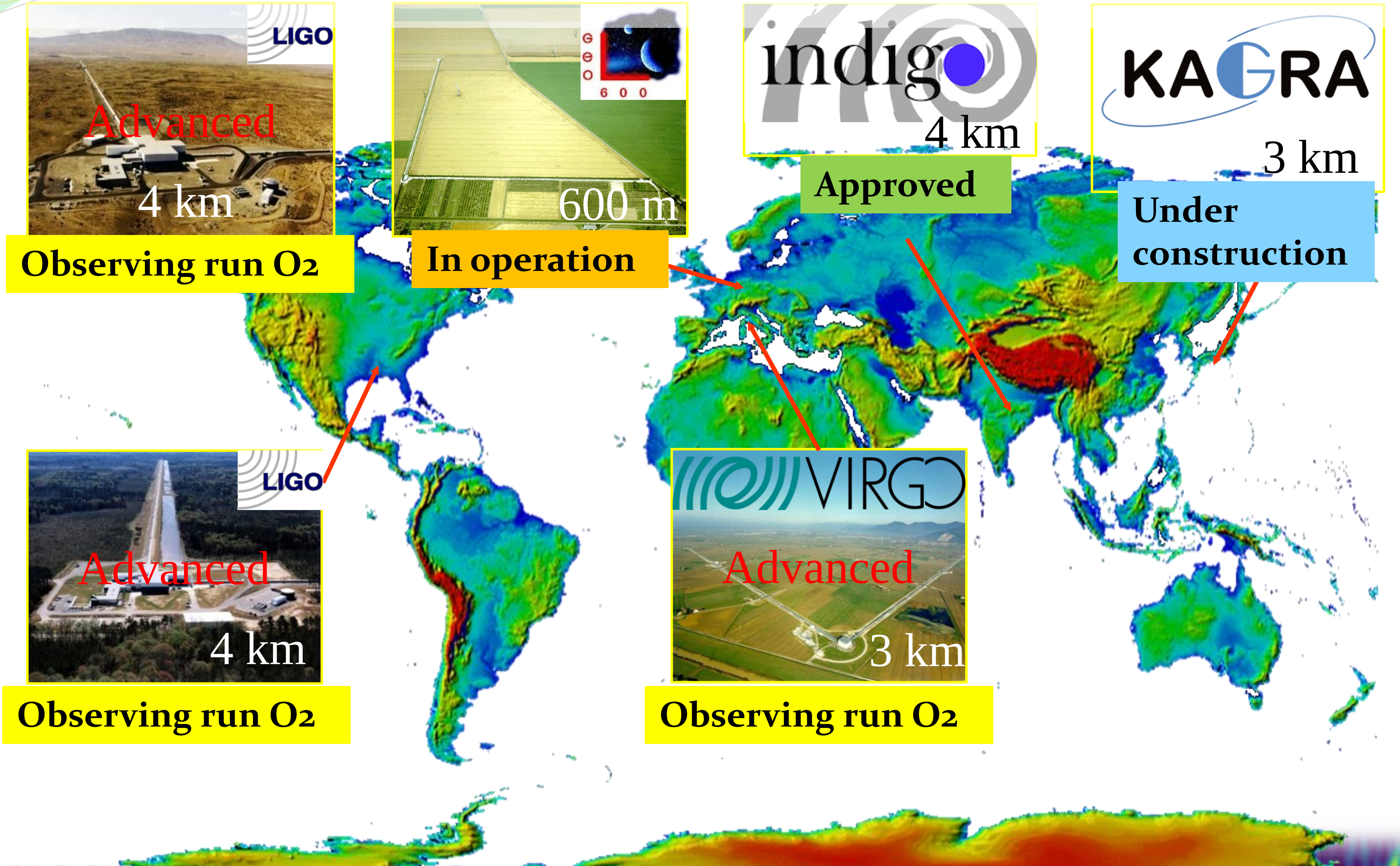
As fast as possible to join LIGO in O2

Commissioning timeline: LIGO vs Virgo

	LIGO (H&L)	Virgo
First one arm lock	Mid 2012	June 2016
First full ITF* lock	Spring 2014	January 2017
First ITF* lock in final configuration	February 2015	March 2017
	~ 4 years	~ 1 year
	Final sensitivity: ~60Mpc	Final sensitivity: ~28Mpc

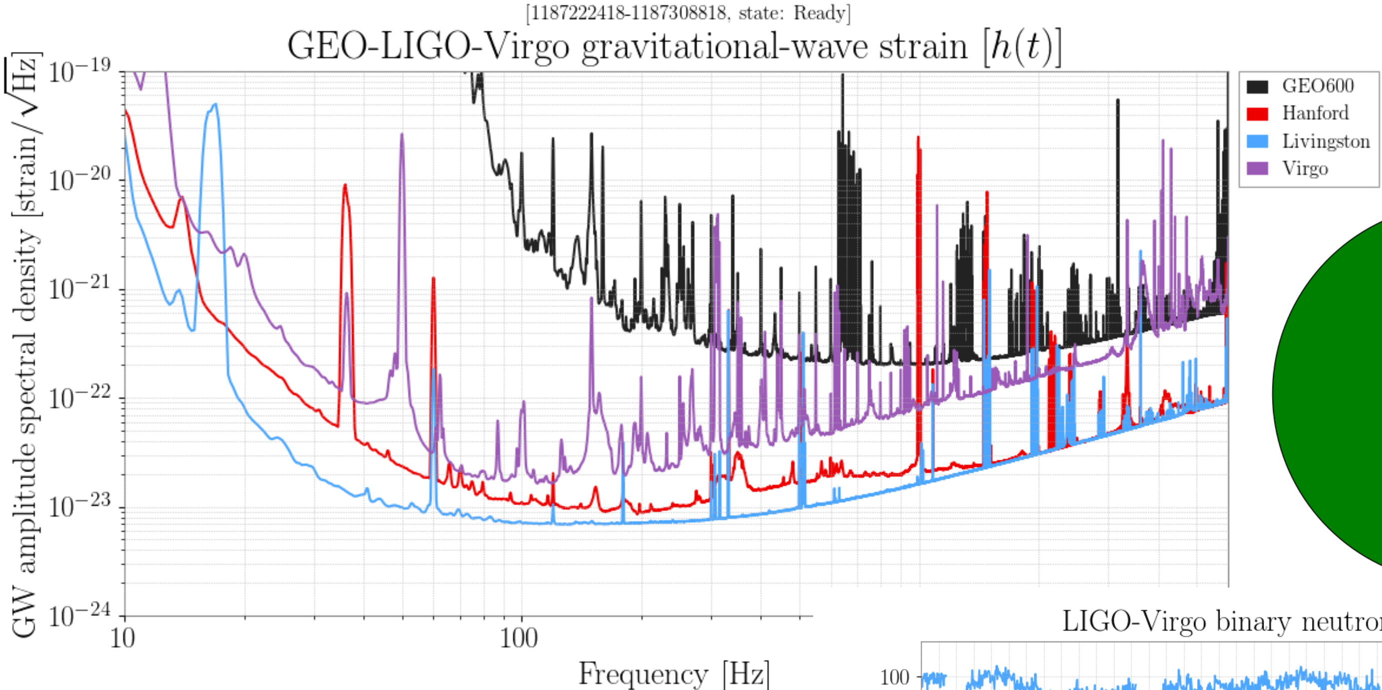
*ITF = interferometer

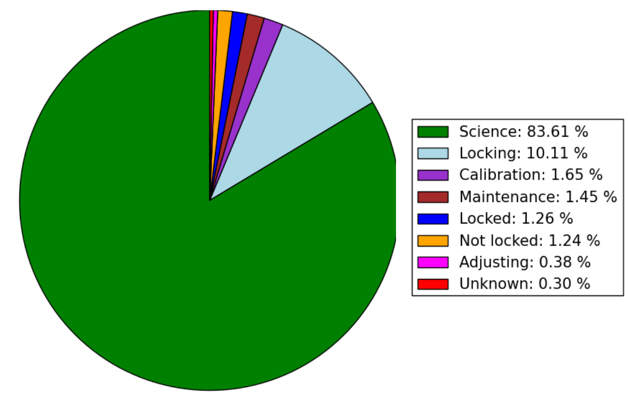
O2: joint science run with LIGO

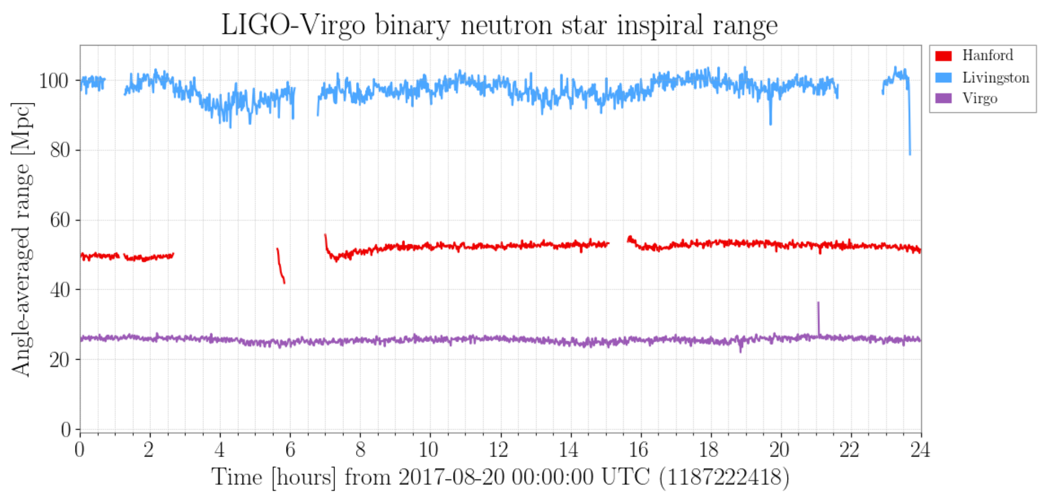


AdV O2 performance

Sensitivity (as of 20/08/2018)







The longest lock segment lasted about **69 hours**!

Summary and perspectives

- After huge efforts, Virgo was able to join LIGO in the O2 observation run, succeeding in the detection of GW from BBH and BNS
- After the run, the installation of many upgrades has started (better vacuum system, monolithic suspension re-installation, high power laser installation, …) and the following commissioning phase will double the detector sensitivity before the beginning of O3.

Thank you