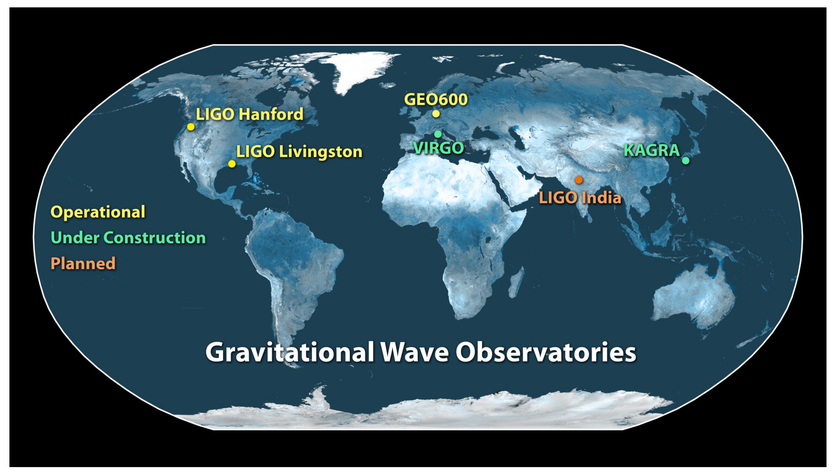
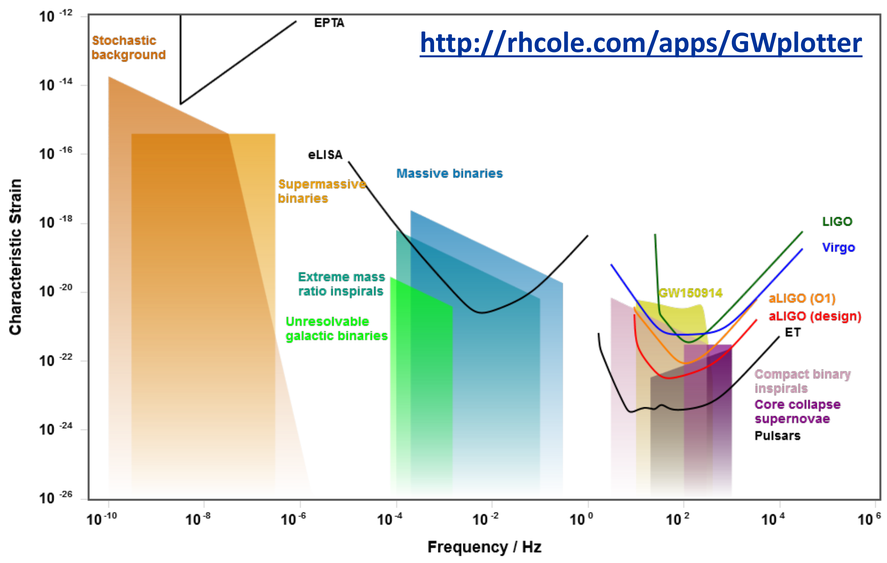
Advanced interferometric gravitational-wave detectors

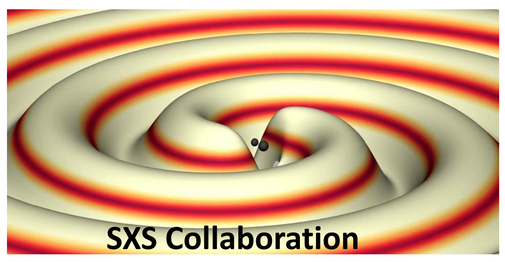


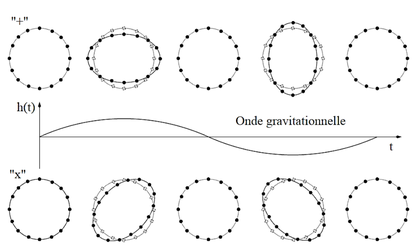
In General Relativity, gravitational waves (GWs) are ripples of the space-time, emitted by accelerated masses and which propagate at the speed of light.

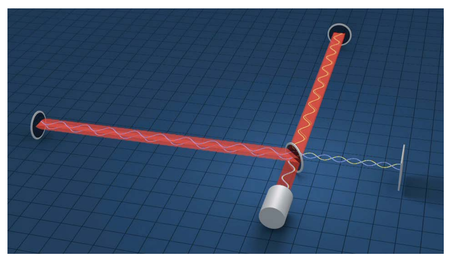


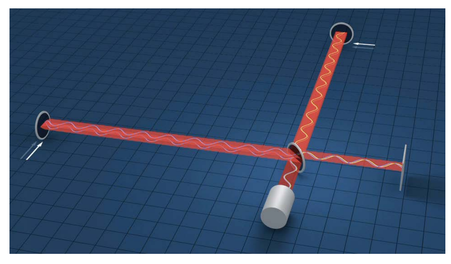
Even though any non-axisymmetric accelerated mass does emit GW, the gravitation is so weak (or the space-time so rigid) that only sources from the cosmos could potentially be detected by instruments like LIGO and Virgo

In the plane transverse to their direction of propagation, GW alternatively stretch and squeeze the space-time in two perpendicular directions. This effect can be revealed by measuring the variation of the time taken by a light beam to travel between two test (free-falling) masses









From Initial to Advanced Detectors

Goal: to improve the sensitivity by one order of magnitude

- Volume of observable Universe multiplied by a factor 1,000
- Rate should scale accordingly

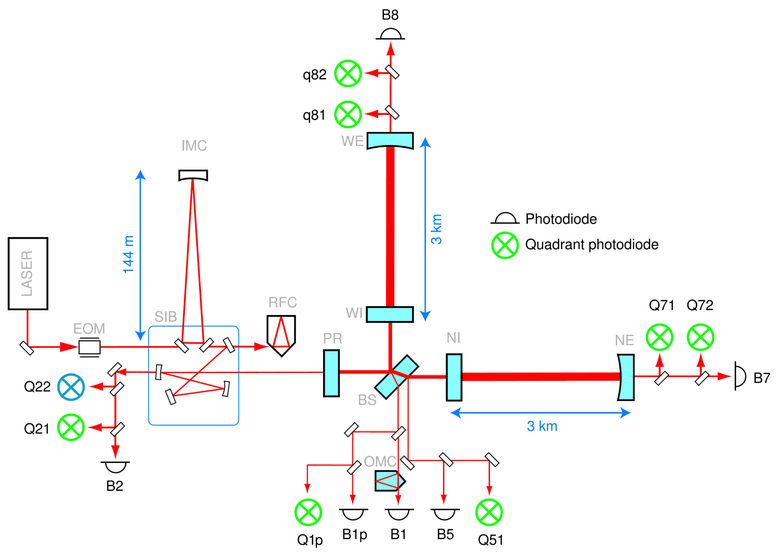
→ Assuming uniform distribution of sources (true at large scale)

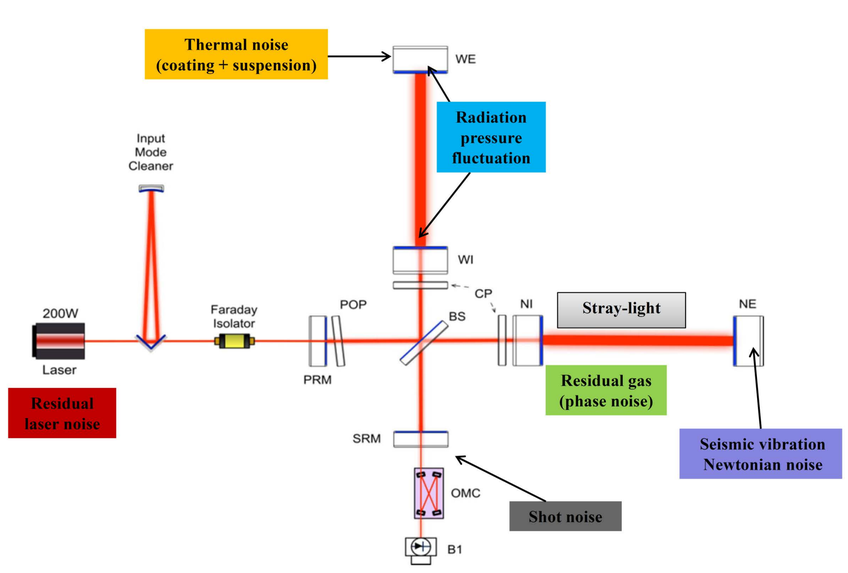
A wide range of improvements

- Input laser power increased
- Mirrors twice heavier
- Beamspot increased on the end mirrors
- Mirors suspended by fused silica bonding
- Vacuum improved in the km-long pipes
- Instrumentation & optical benches suspended and under vacuum

Key challenges

- Control the detector
- Improve the sensitivity
  → Fundamental, instrumental and environmental noises
- Identify and remove the noise transients

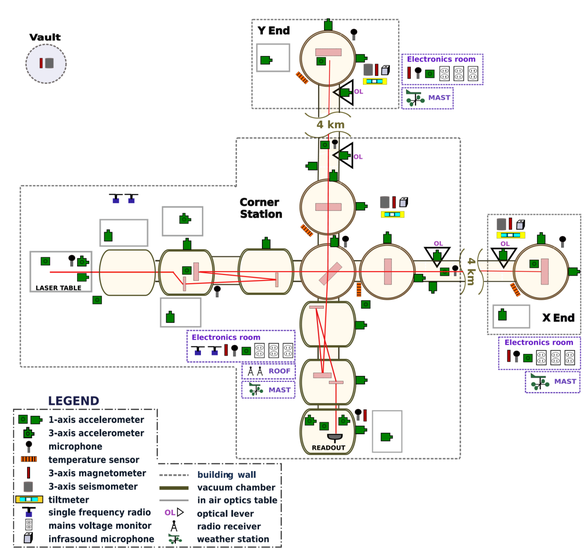




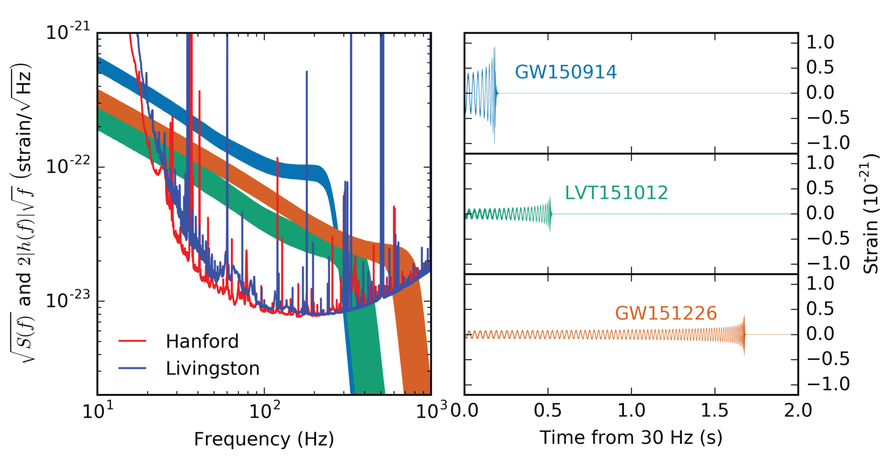
In a Michelson interferometer, variations of the light time travel in the perpendicular arms are converted into changes of the interference pattern at the output port of the instrument

GW interferometric detectors: a timeline

- 1970: first IFO prototype (Forward)
- 1972: IFO design studies (Weiss)
- 1980's: IFO prototypes (10m-long) (Caltech, Garching, Glasgow, Orsay)
- End of 1980's: Virgo and LIGO proposals
- 1990's: LIGO and Virgo funded
- 2005-2011: initial « science » » runs
- 2007: LIGO-Virgo MOU
- Early 2010's: Advanced detectors funded
- 2015: First Advanced LIGO science run
  → GW150914 & GW151226



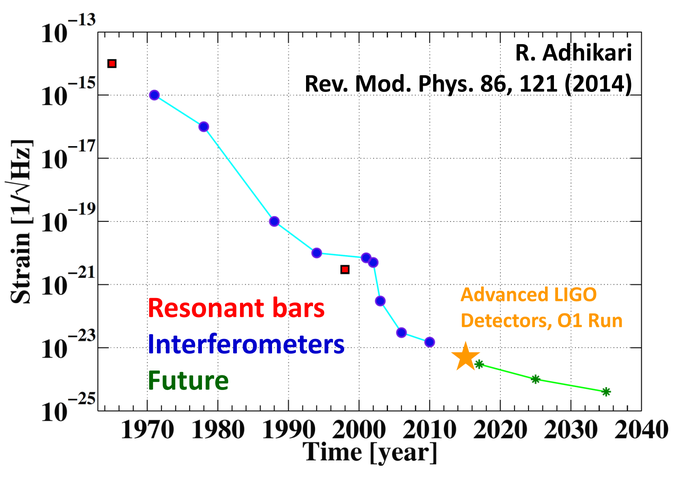
arXiv:1606.04856 [gr-qc]



Observation Run 1 (O1)

- 2015/09 → 2016/01
- Advanced LIGO detectors
- First 2 direct detections of GWs: GW150914 & GW151226

Run O2 to start this fall



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