Gravitational waves

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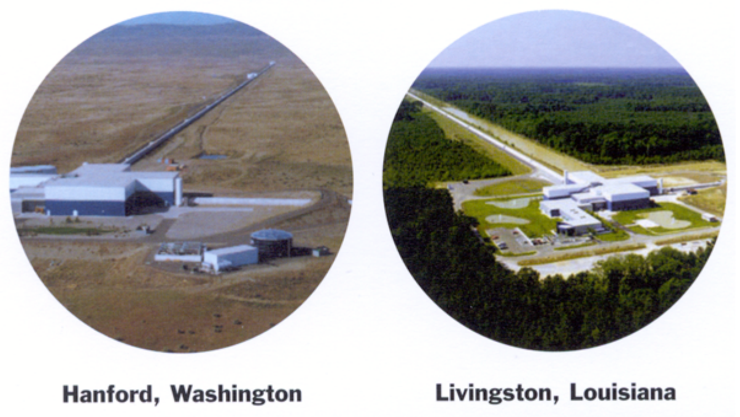
LIGO and the first detections of GW

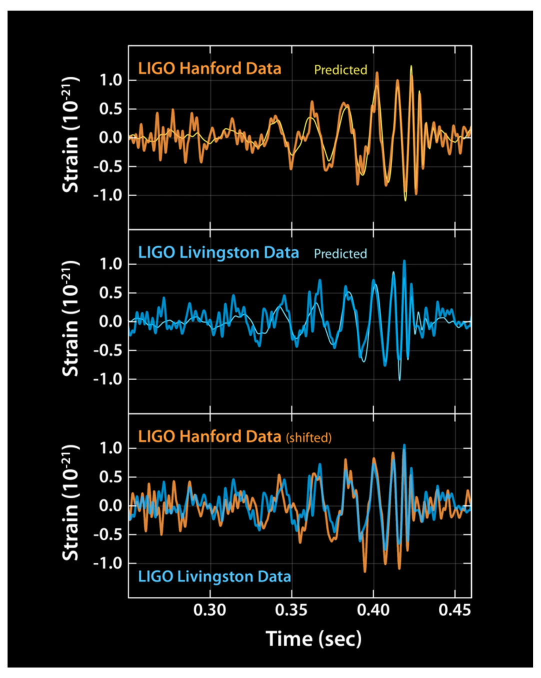
- 2 detectors (Handford/Washington, Livingston/Louisiana)
- 2-arm-detectors on Earth, each arm is 4 km long
- Effective in a high-frequency band $f \in [10, 10^4]$ Hz



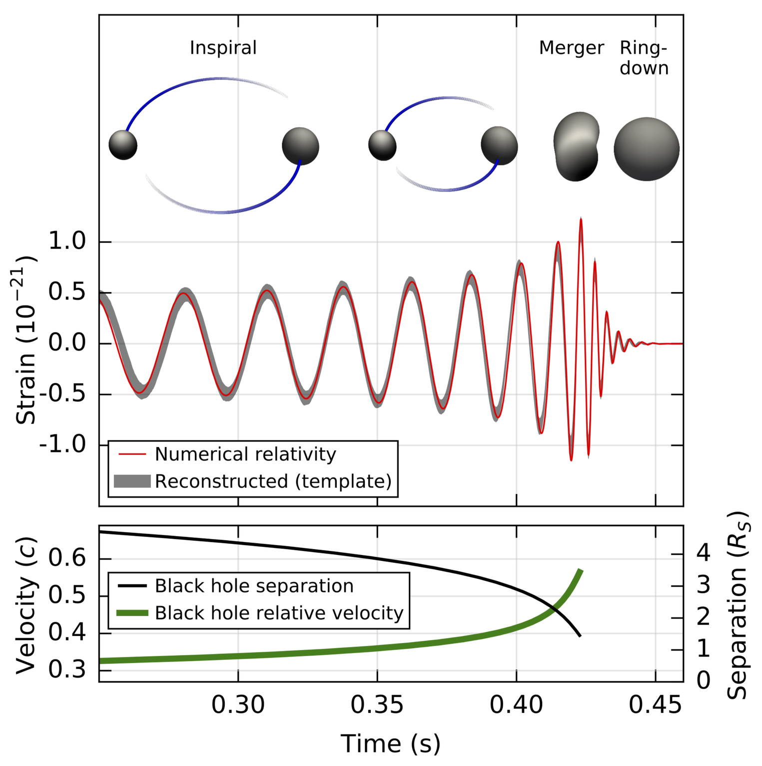
GW150914: First direct detection of GW

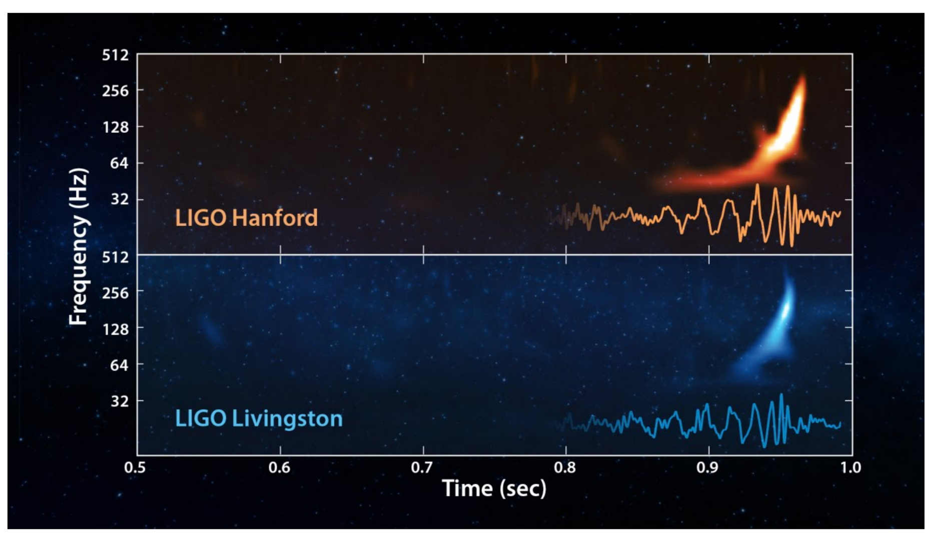
P. Abbott *et al.*, PRL 116, 061102 (2016)

- BH merger: 36 $M_\odot$ and 29 $M_\odot$ BH merged into a 62 $M_\odot$ BH
- 3 $M_\odot$ radiated as GW in about 200 ms



Top and middle panels: The simulated wave-forms (fine lines) are in perfect agreement with the measurement (bold lines).
Lower panel: Superposition of the signals from the 2 LIGO detectors.



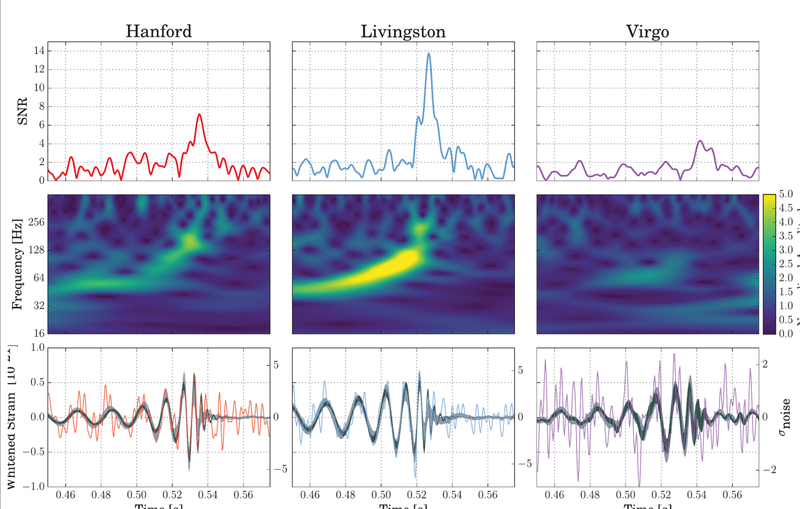


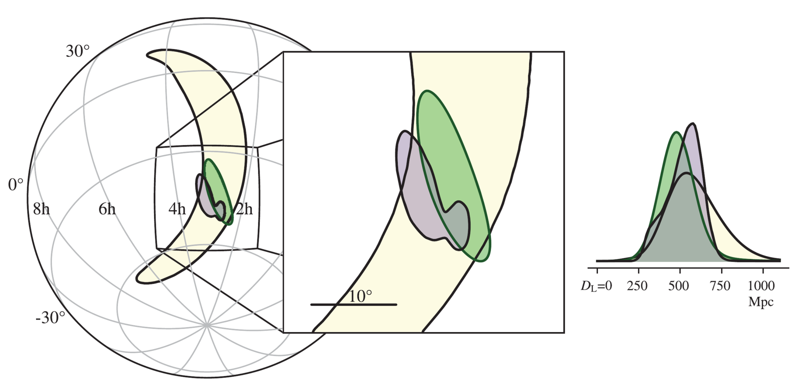
Characteristic chirp from the merger. The signal was detected with a 10ms time intervall between the two sites, due to the propagation time of the GW.

GW170814: First detection with 3 detectors

P. Abbott *et al.*, PRL 119, 141101 (2017)

- Network of 3 detectors (LIGO in the USA and VIRGO in Italy)
- Allows to improve the localization of the source on the sky

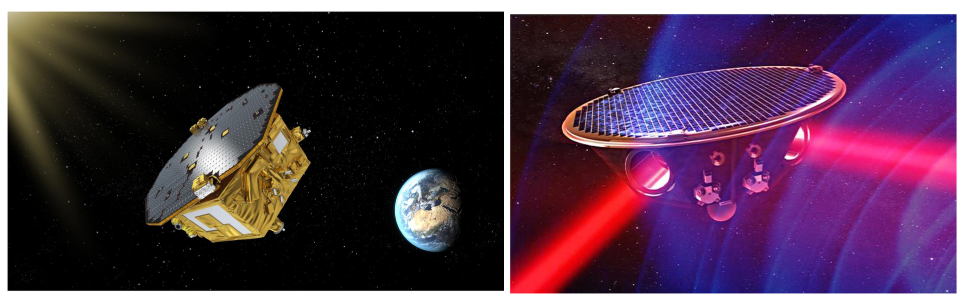




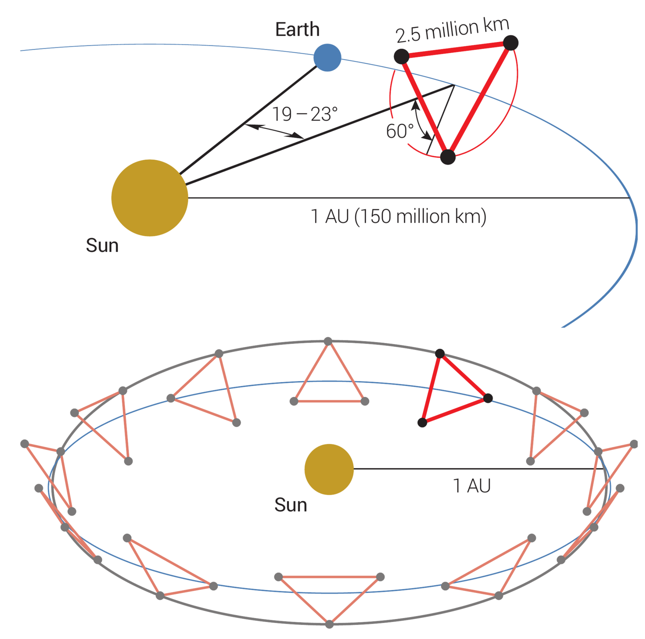
LISA and LISA Pathfinder

P. Amaro-Seoane *et al.*, arXiv:1702.00786

- Next ESA L3 mission (~2034 or earlier)
- Interferometer in space with 3 satellites (3 times 2 laser links)
- Arms of ~2.5 millions km
- Effective in the low-frequency band $f \in [10^{-4}, 10^{-1}]$ Hz



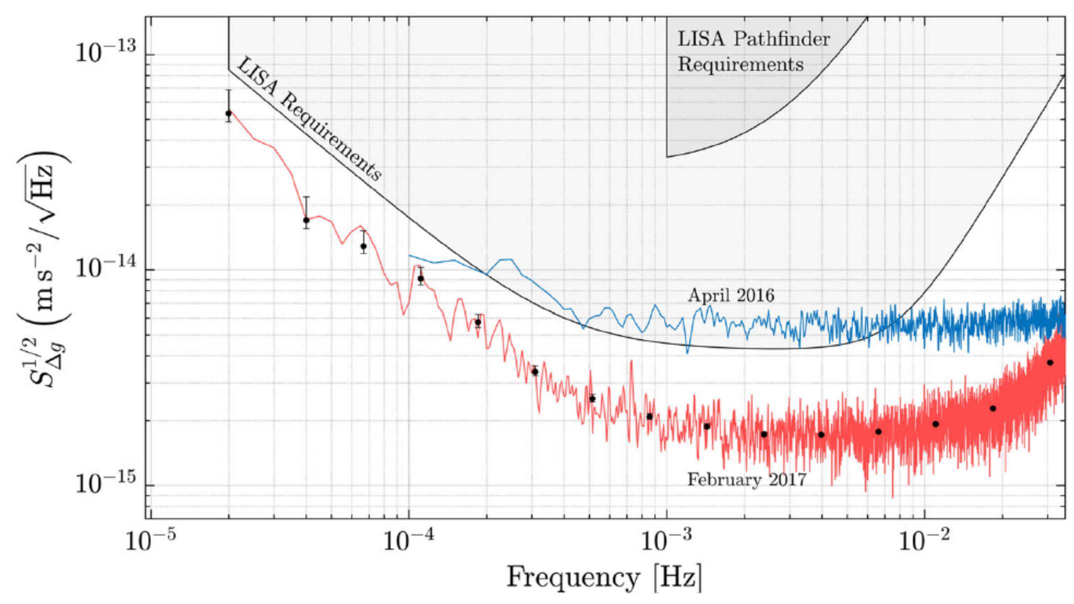
One of the satellites as tested with the LISA Pathfinder mission (left), without the laser links. On the right, satellite concept also depicting the arms of the interferometer.



LISA Pathfinder

M. Armano *et al.*, PRL 120, 061101 (2018)

- Test of the LISA technology (16 months, until 17.07.17)
- 2 metal cubes in free-fall (shielding provided by the satellite)
- Relative position of the cubes up to 1 pm



Residual relative acceleration of the test masses as a function of the frequency. The expectations for the original LISA Pathfinder as well as for a future spaceborne detector such as LISA are cleary exceeded.

Multimessenger astronomy

P. Abbott *et al.*, PRL 119, 161101 (2017)
P. Abbott *et al.*, ApJL 848, L13 (2017)

- GW170817: Binary neutron star
- Detection of GW and the so-called EM counterpart (various types of EM radiation, e.g. gamma ray burst)
- Future: combination of GW and EM observations, possibility to predict the merger in advance thanks to GW