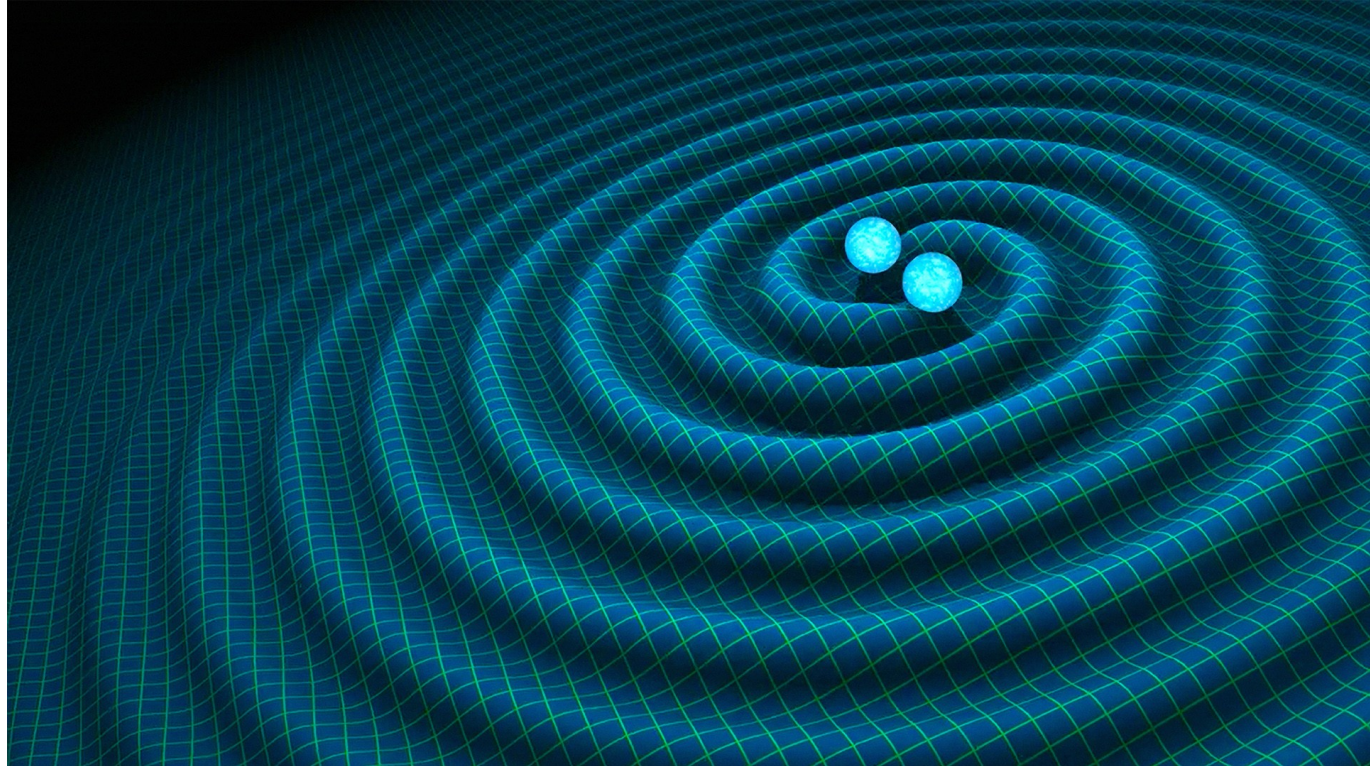


Astroparticle physics – gravitational waves

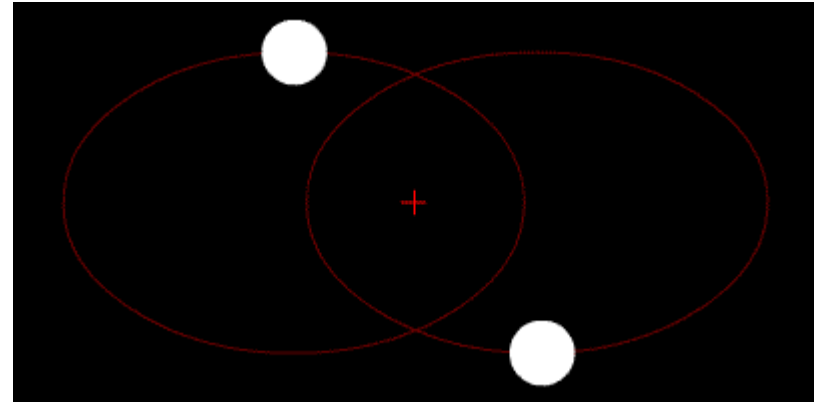
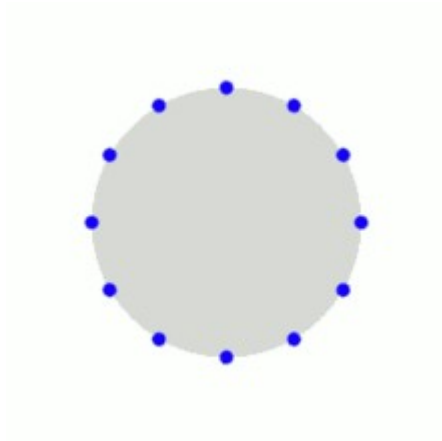


Claudia Wulz and Wolfgang Waltenberger
Institute of High Energy Physics, Vienna
TU Vienna, CERN, Geneva

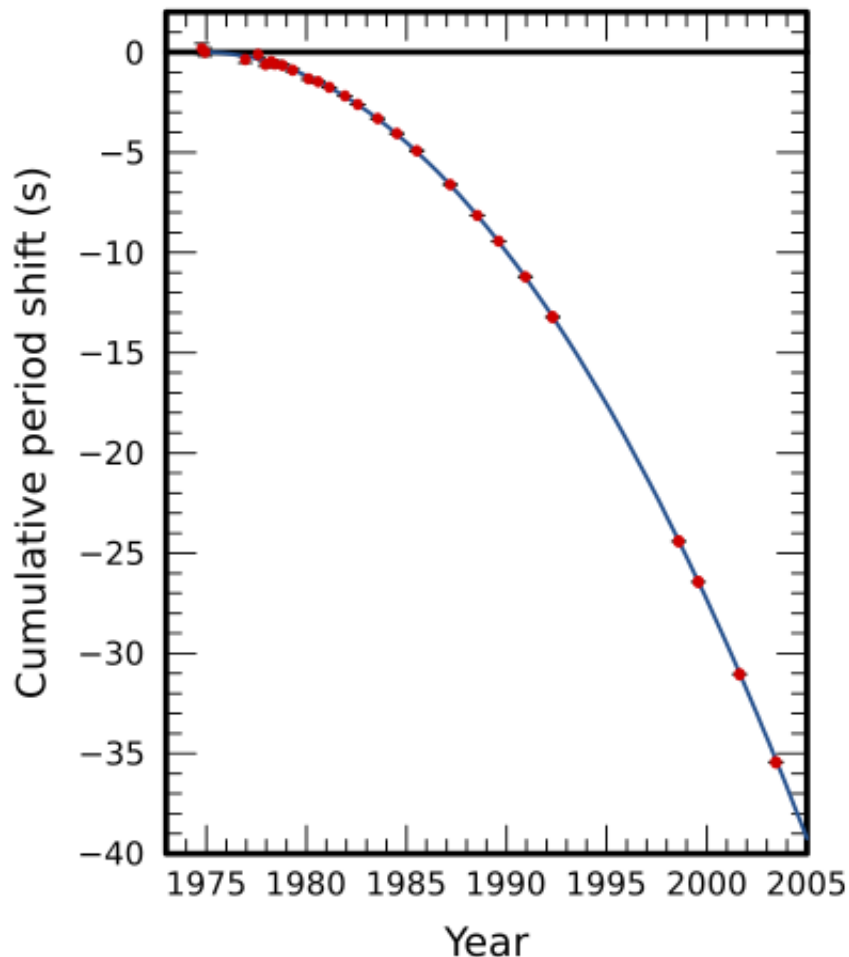
Wintersemester 2017 / 2018

Mass is Always Positive

even anti-matter has positive mass \rightarrow no gravitational monopole or dipole fields,
Only quadrupoles!



Indirect Evidence For Gravitational Waves – Hulse-Taylor Binary



Binary pulsar (one radiating neutron star with another neutron star in orbit)

PSR 1913+16

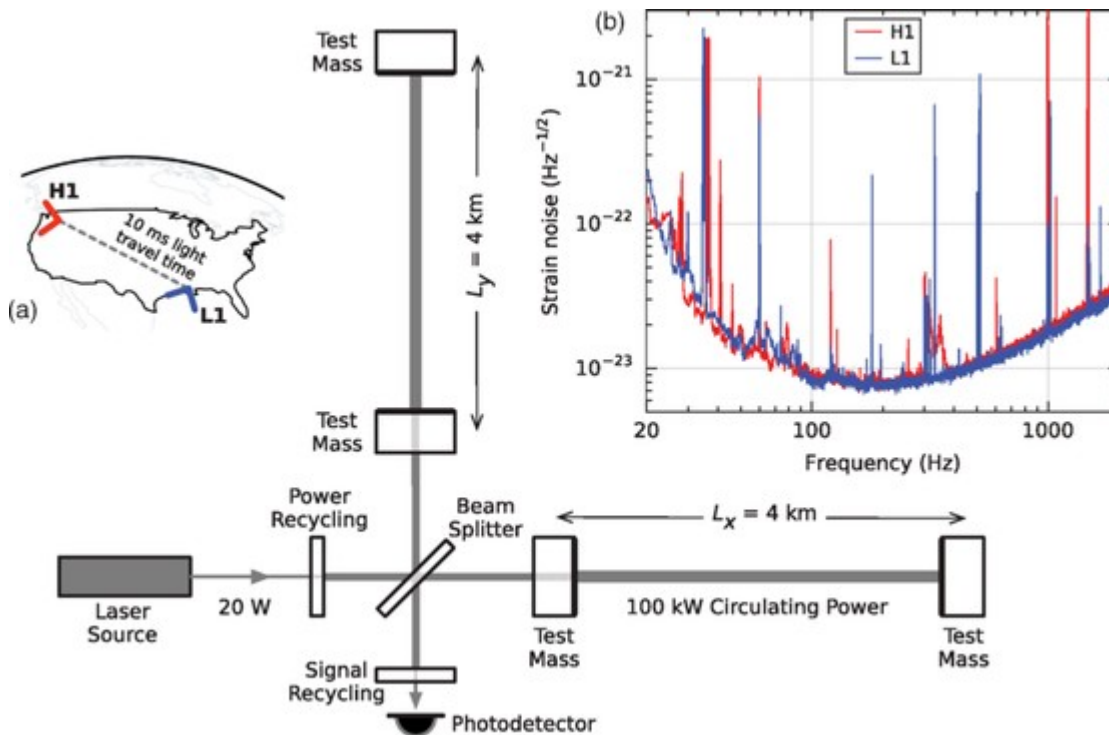
Nobel prize 1993

Red data points: measured epoch of periastron (smallest distance between the stars)

Parabola: theory prediction from general relativity

Direct Evidence For Gravitational Waves – LIGO (USA), Virgo (Italy)

LIGO: Laser Interferometer Gravitational-Wave Observatory



Michelson-Morley Interferometer,

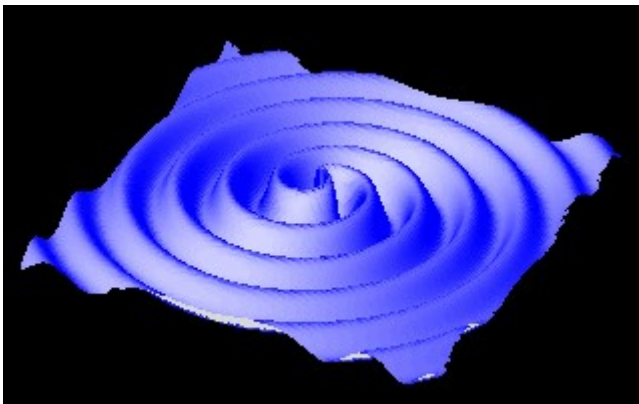
Capable of measuring relative difference of arms of 10^{-22} !
(corresponds to 10^{-4} of size of proton)



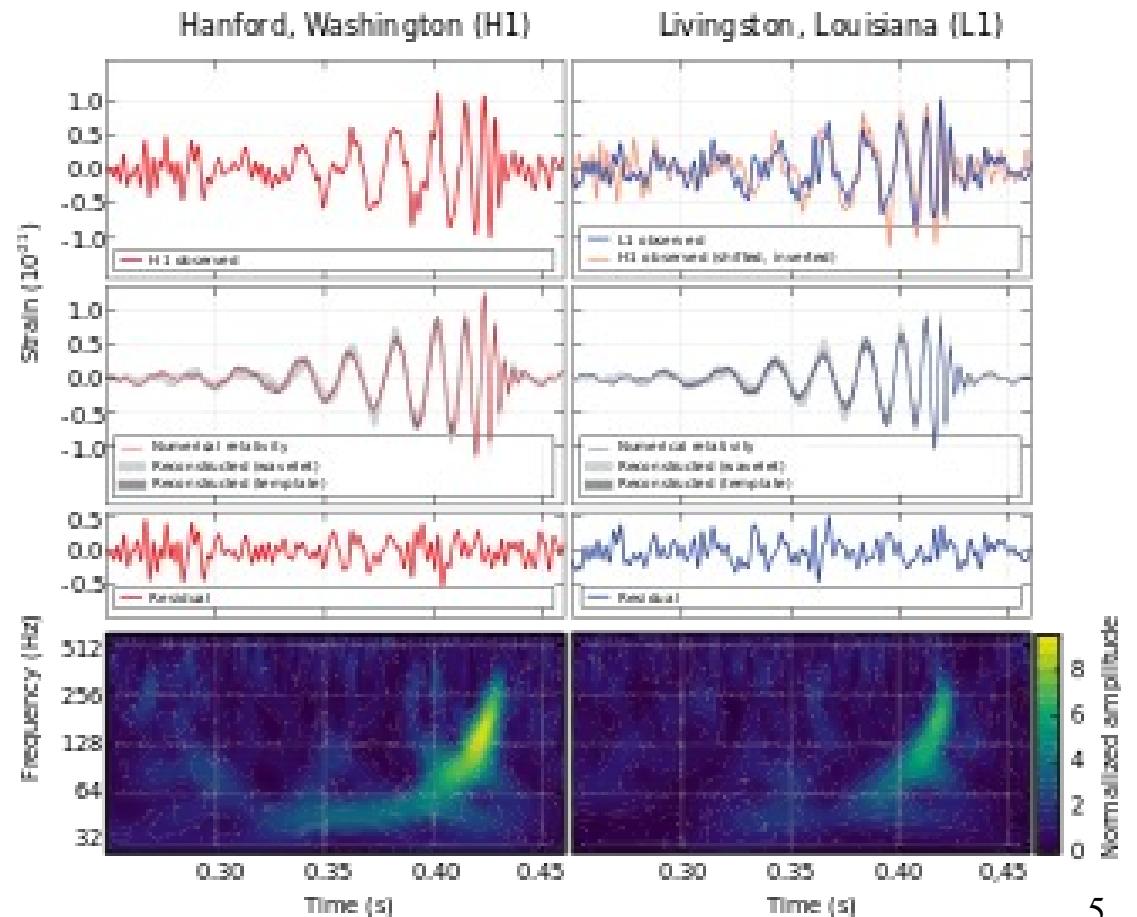
GW150914

GW150914: first direct detection of gravitational waves from a binary black hole merger!

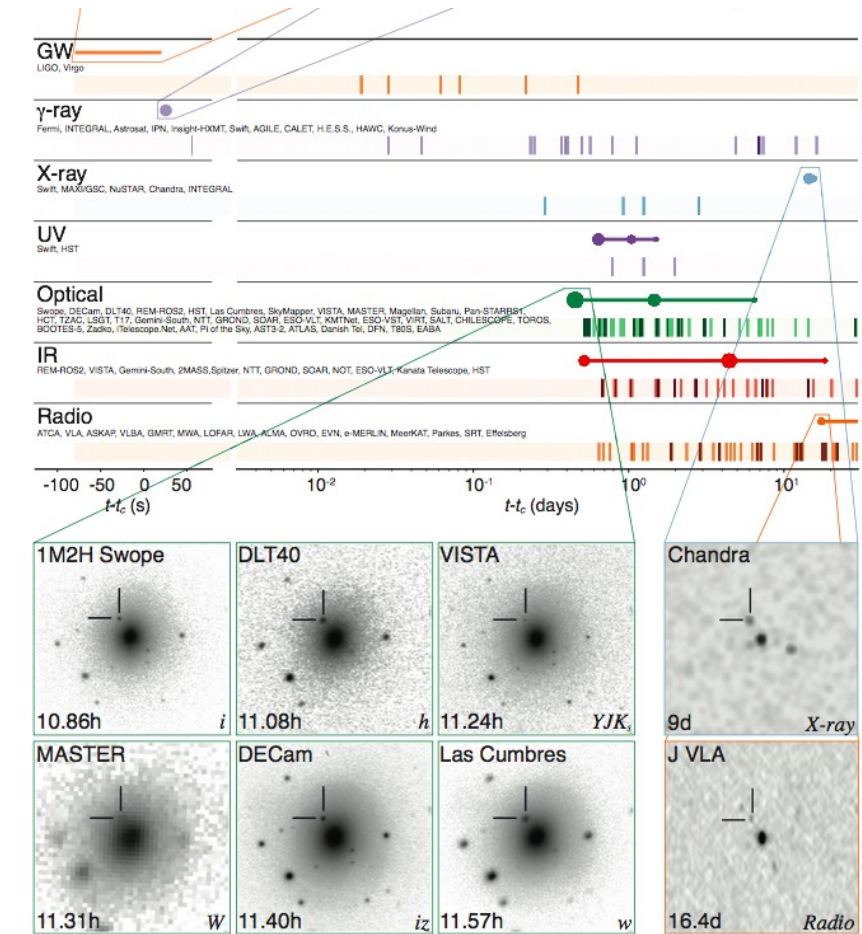
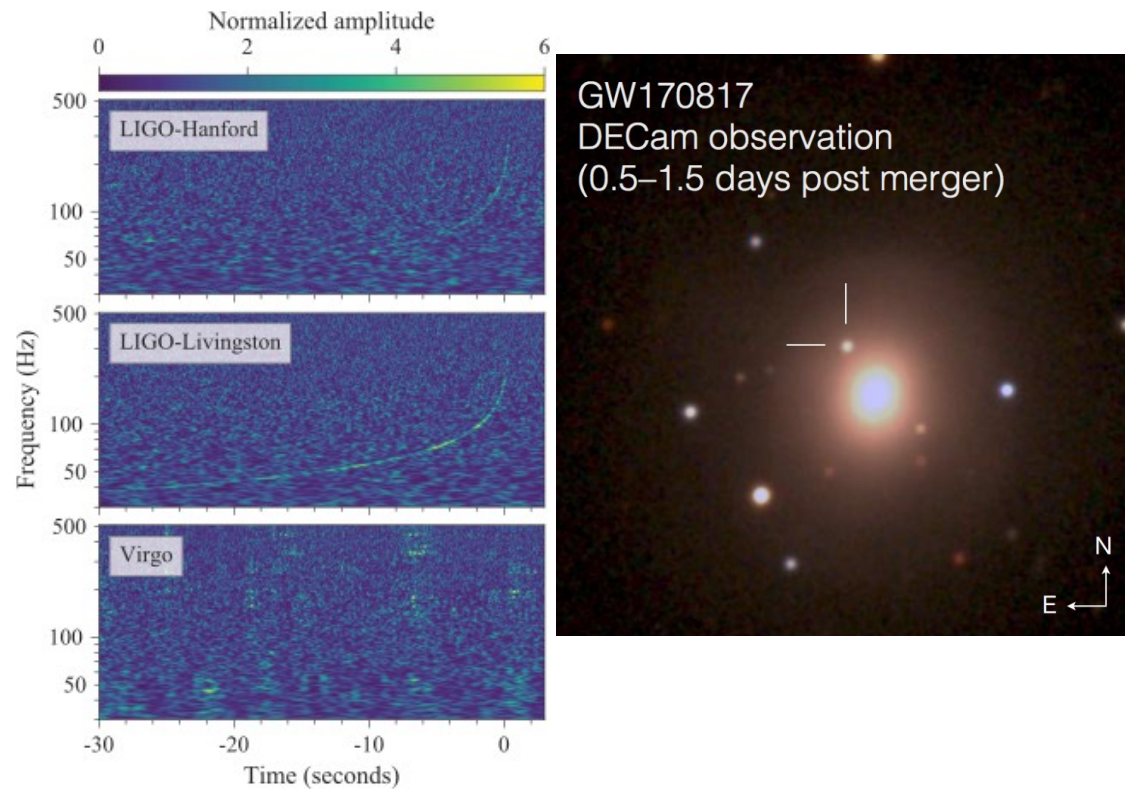
Nobel Prize 2017



Total energy output: ~ 3 solar masses



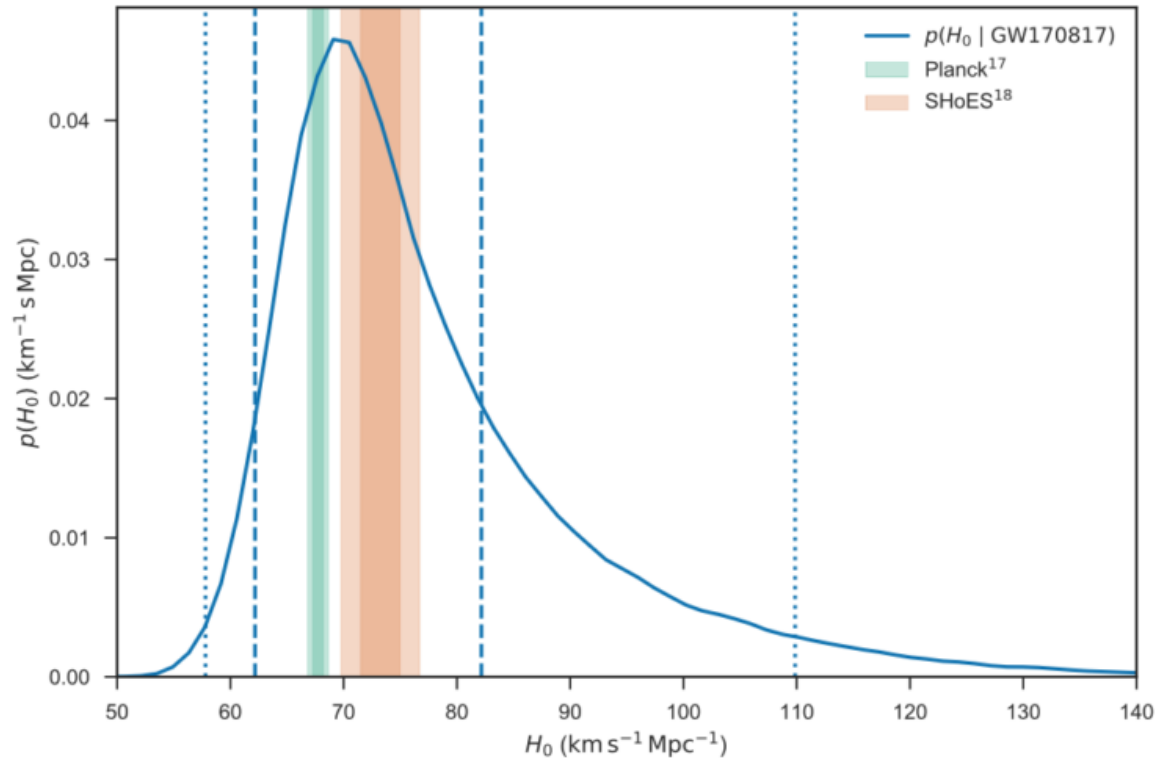
GW170817: Multi-Messenger Signal



Gravity wave detected by
LIGO and Virgo, Aug 17, 2017

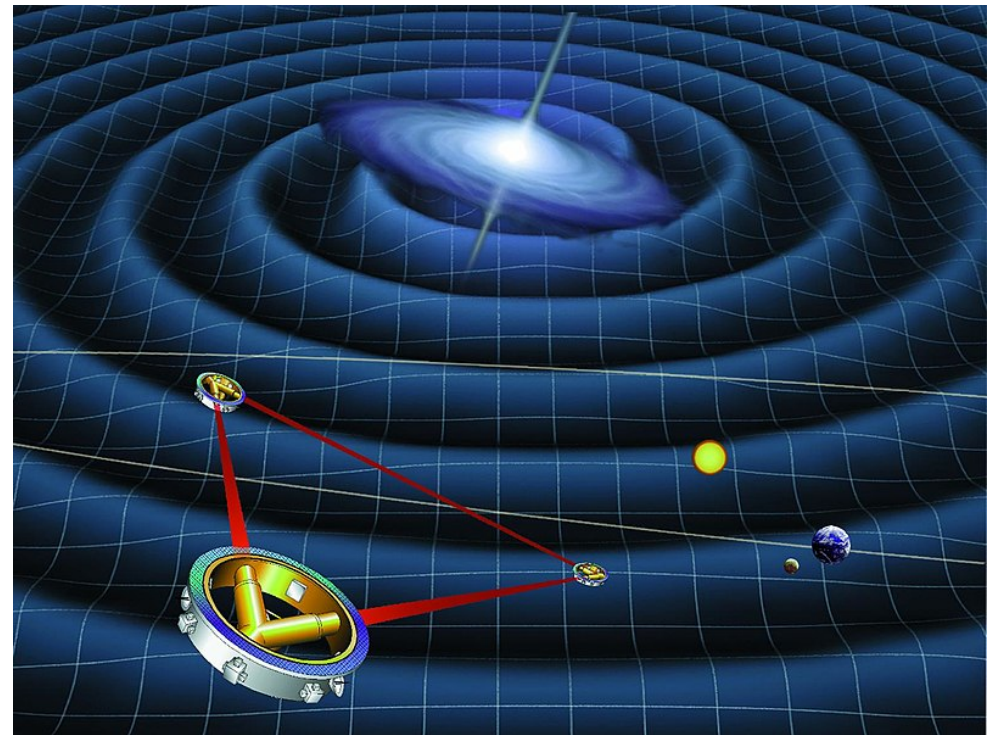
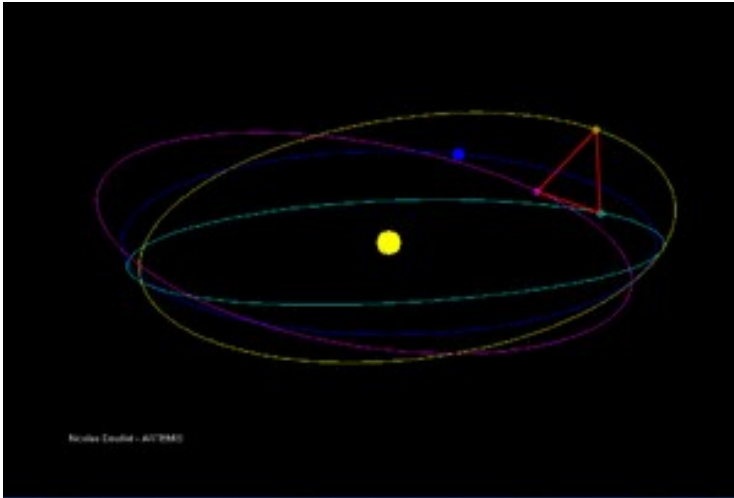
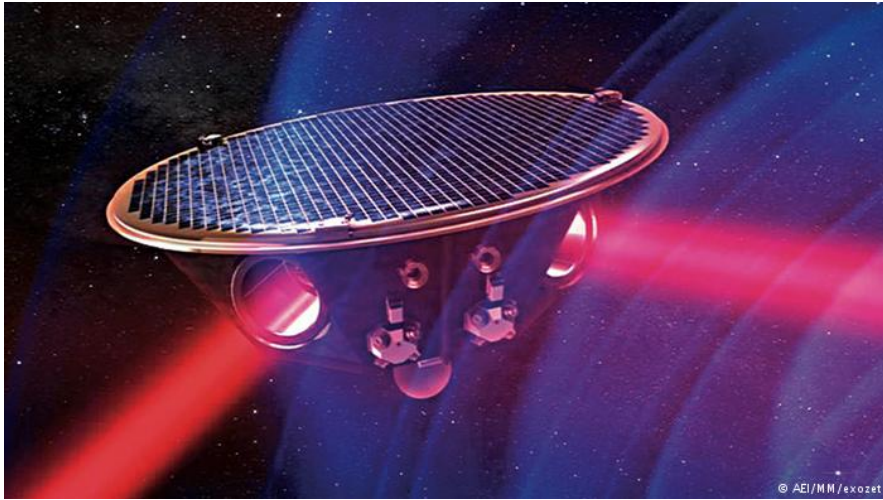
See e.g. [Dark Energy Survey \(DES\)](#)

GW170817: constraining the Hubble constant

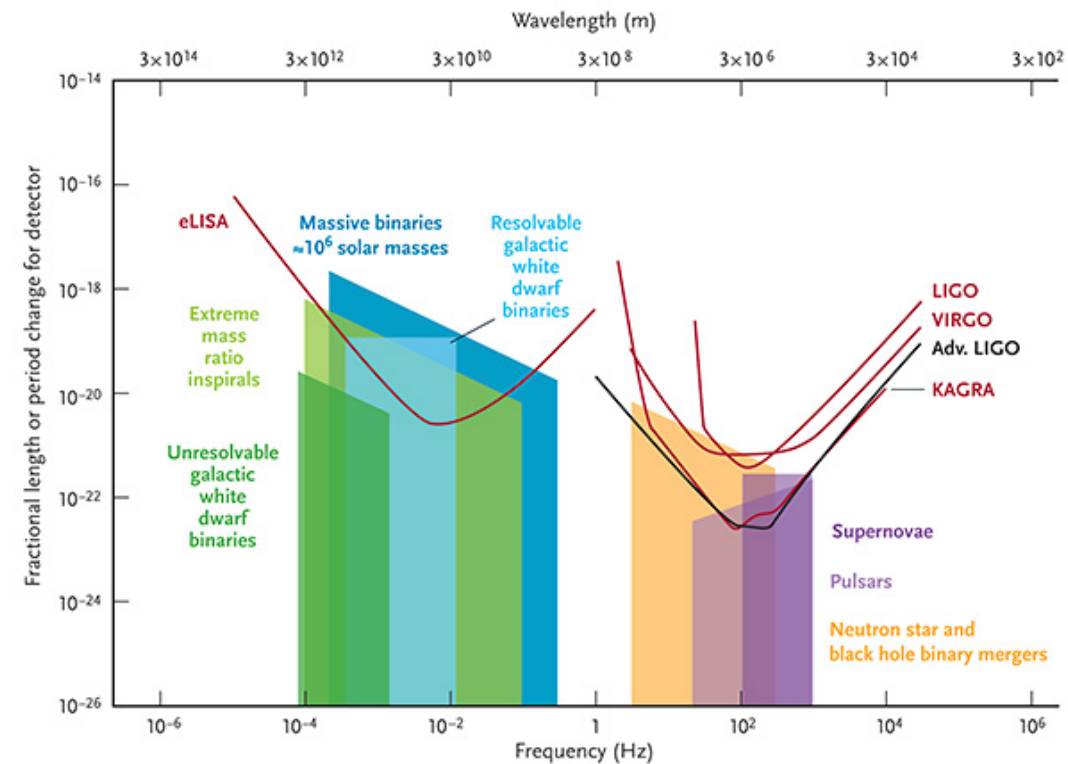
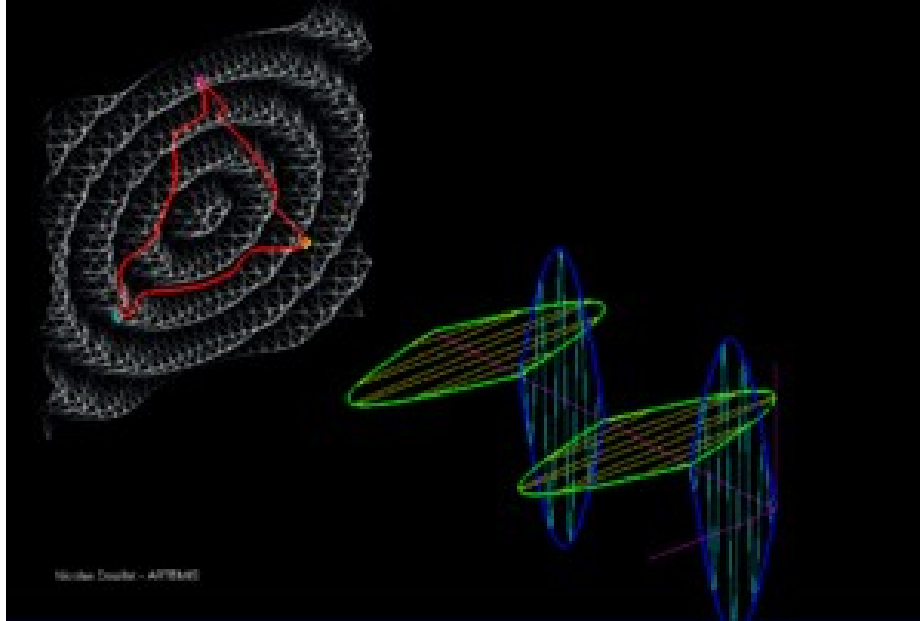


Gravitational waves as
“standard sirens”

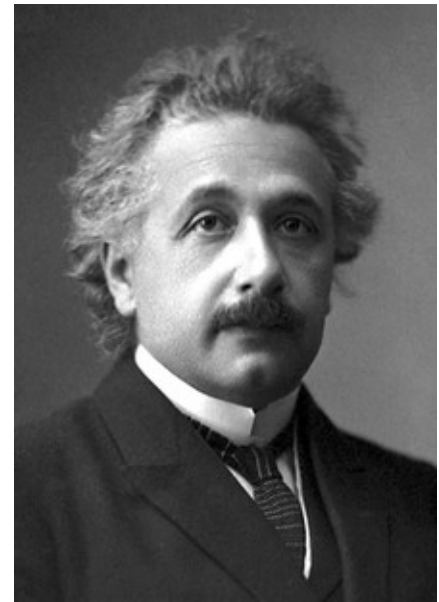
The Future: LISA



LISA: the future



“Das Schönste und Tiefste, was der Mensch erleben kann, ist das Gefühl des Geheimnisvollen. Es liegt der Religion sowie allem tieferen Streben in Kunst und Wissenschaft zugrunde. Wer dies nicht erlebt hat, erscheint mir, wenn nicht wie ein Toter, so doch wie ein Blinder. Zu empfinden, dass hinter dem Erlebbaren ein für unseren Geist Unerreichbares verborgen sei, dessen Schönheit und Erhabenheit uns nur mittelbar und in schwachem Widerschein erreicht, das ist Religiosität. In diesem Sinne bin ich religiös. Es ist mir genug, diese Geheimnisse staunend zu ahnen und zu versuchen, von der erhabenen Struktur des Seienden in Demut ein mattes Abbild geistig zu erfassen.”



Albert Einstein