Gravitational waves

CosPT workshop, 10 May 2022, IJCLab

Tito Dal Canton
for the A2C/GW group

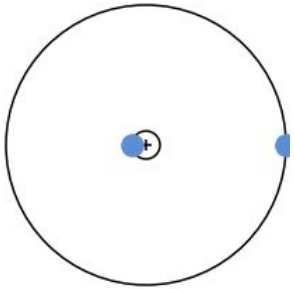
Gravitational-wave theory

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Flat spacetime

Small perturbation

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$



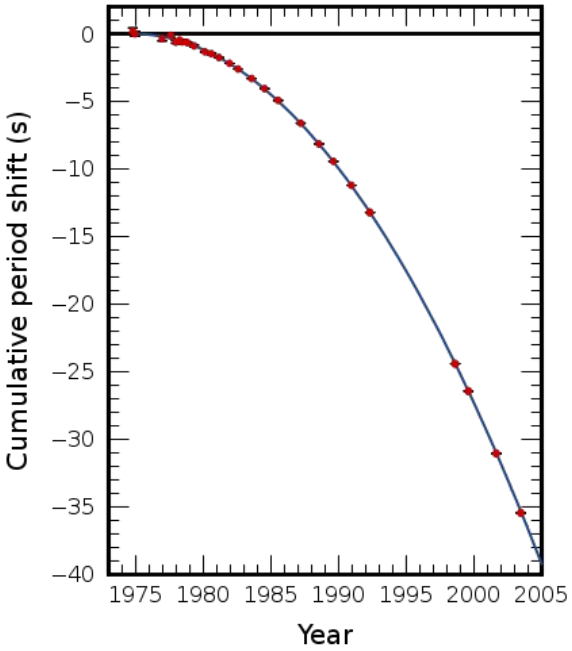
r ~ 100 Mpc

Mass ~ 10 M_{Sun}
Velocity ~ c
Mass quadrupole Q

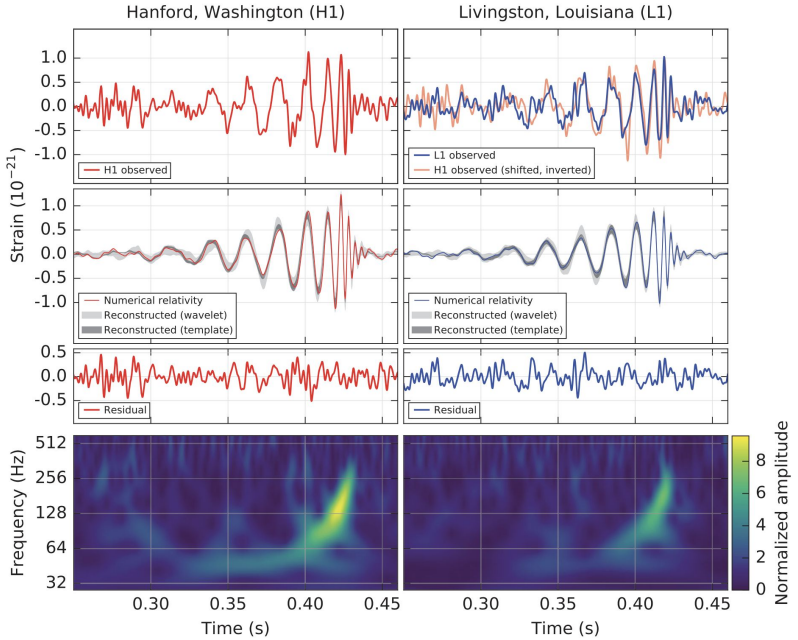
$$h_{ij} \sim \frac{G}{c^4} \frac{\ddot{Q}}{r} \sim 10^{-21}$$

Observational evidence of gravitational waves

Orbital decay of binary pulsars



Direct local measurement of $h(t)$



Gravitational-wave detectors

Test mass

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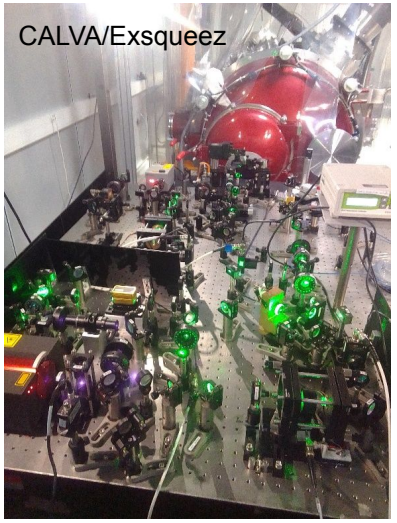
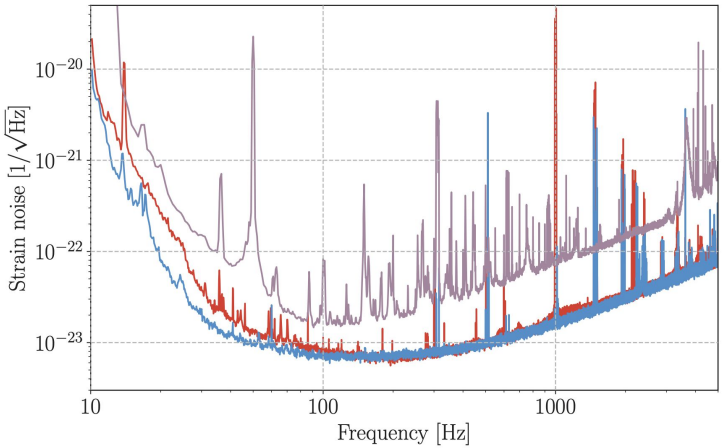
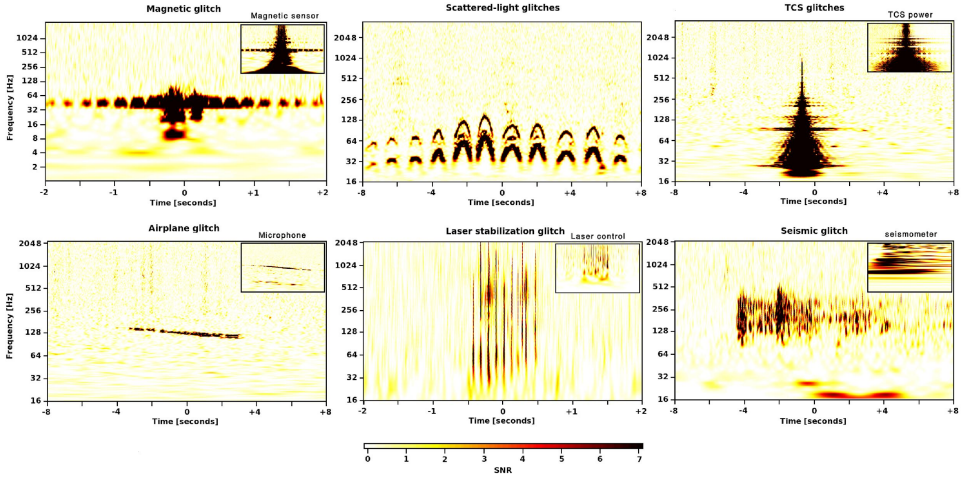


Gravitational-wave data analysis





Noise and data-quality characterization
Searching for GW signals in the data
Astrophysical interpretation, parameter inference
Population inference
Followup or cross-match with other sectors (GRBs, optical, neutrinos…)

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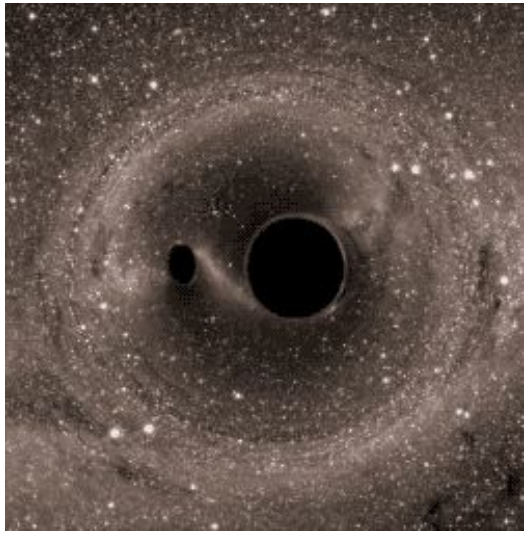
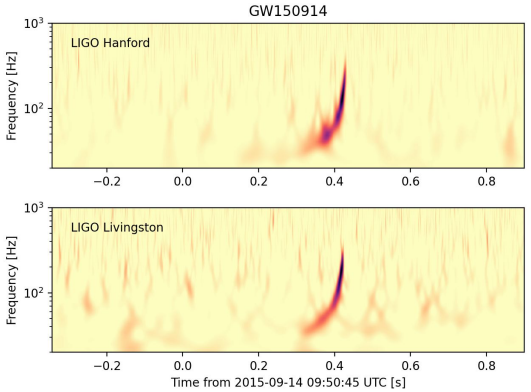
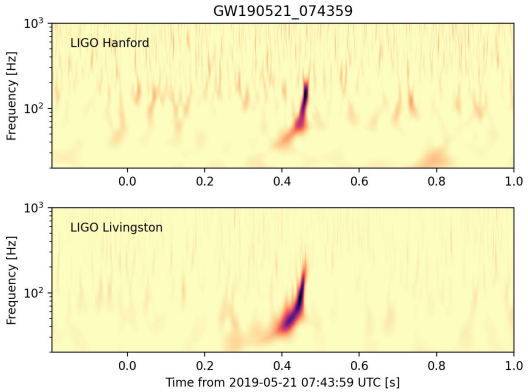
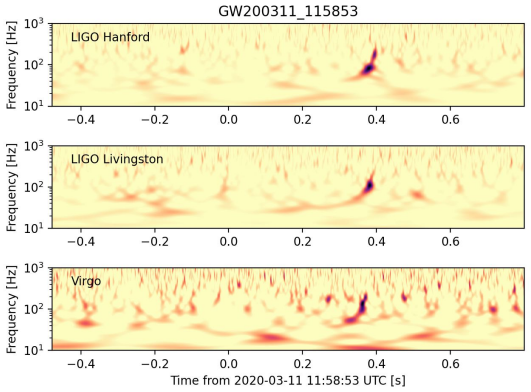
GWs from binary black hole mergers





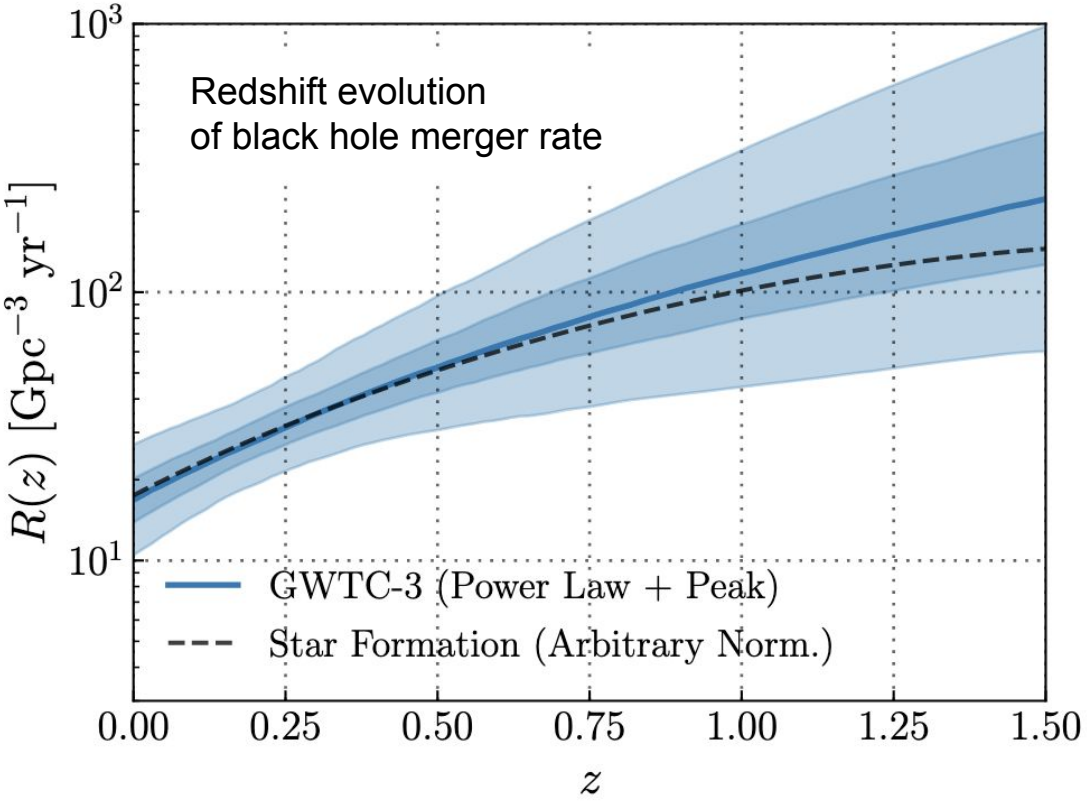




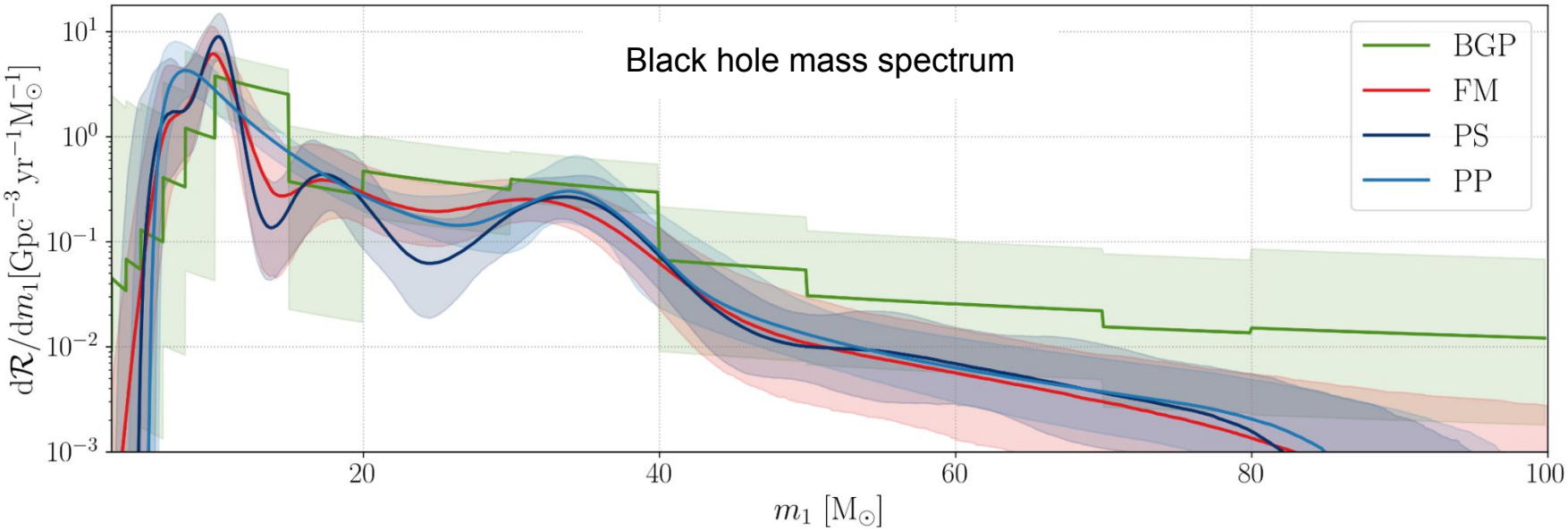
Binary black holes exist and merge!

~80 observations in GWTC-3

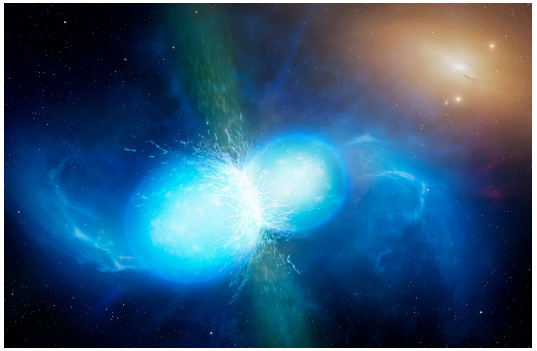
GWs from binary black hole mergers

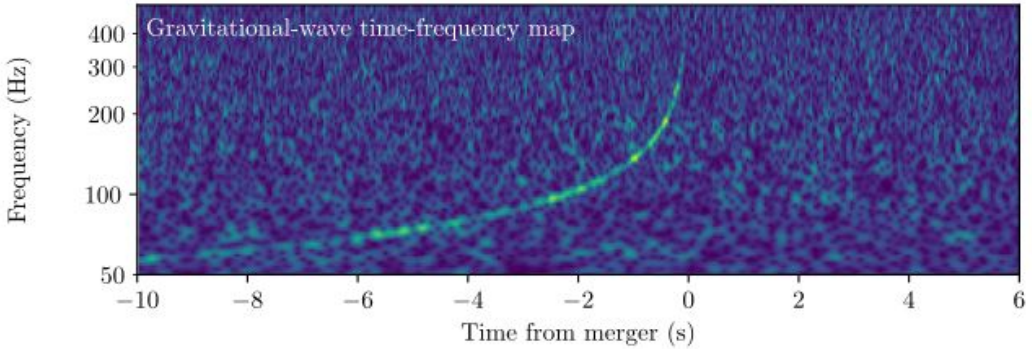


GWs from binary black hole mergers

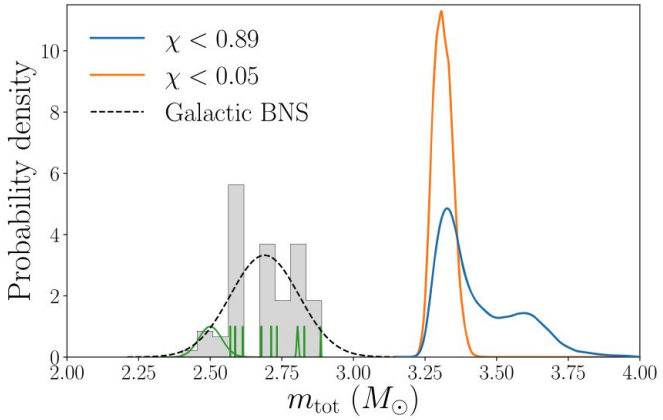


GWs from binary neutron star mergers



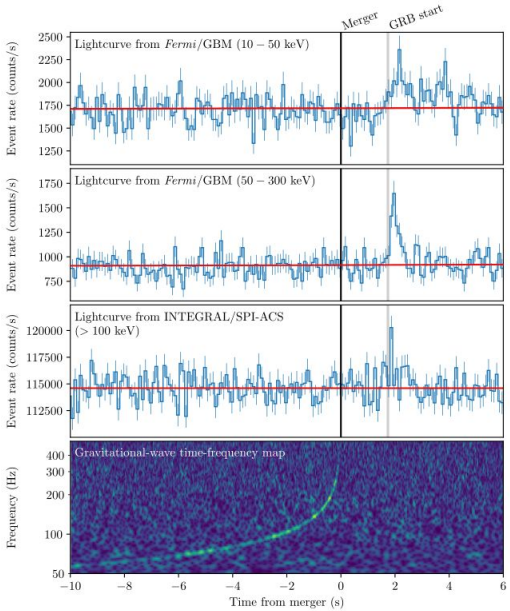


2 observations in GWTC:
GW170817 and GW190425

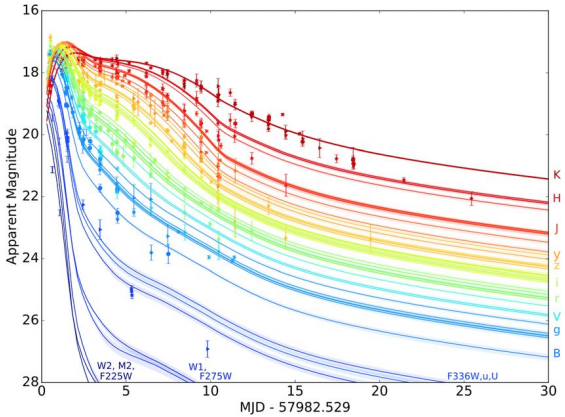


GWs from binary neutron star mergers

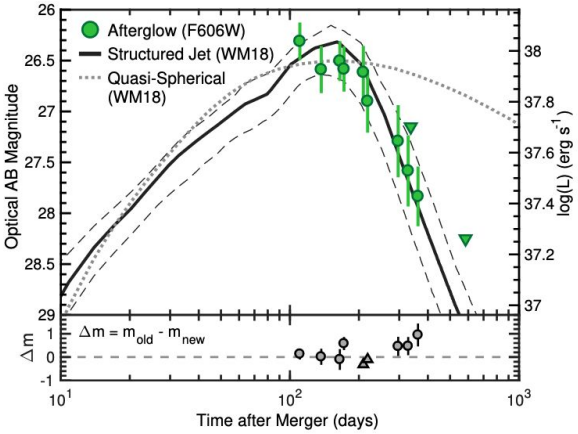
Short GRB



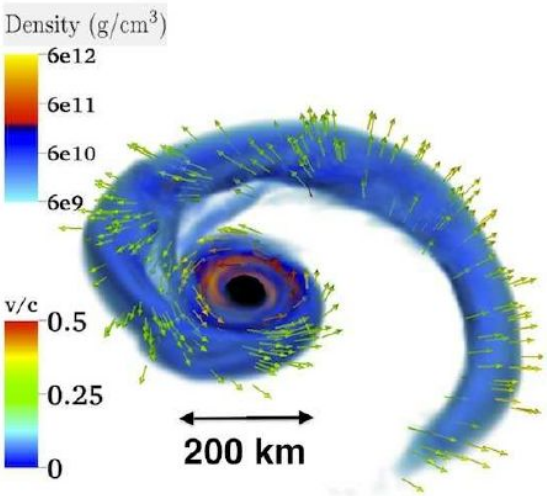
Kilonova

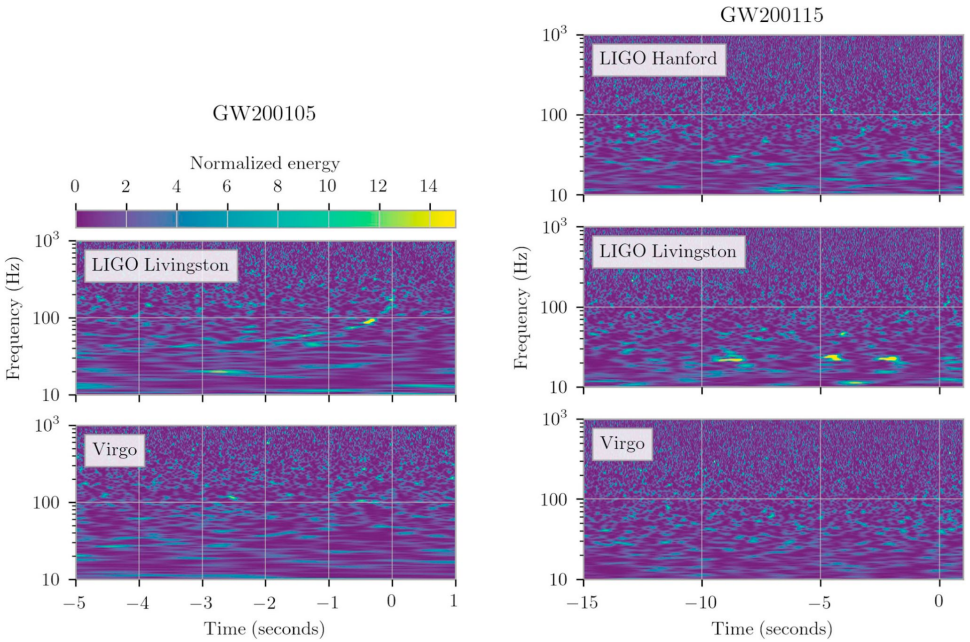


Long-term optical afterglow



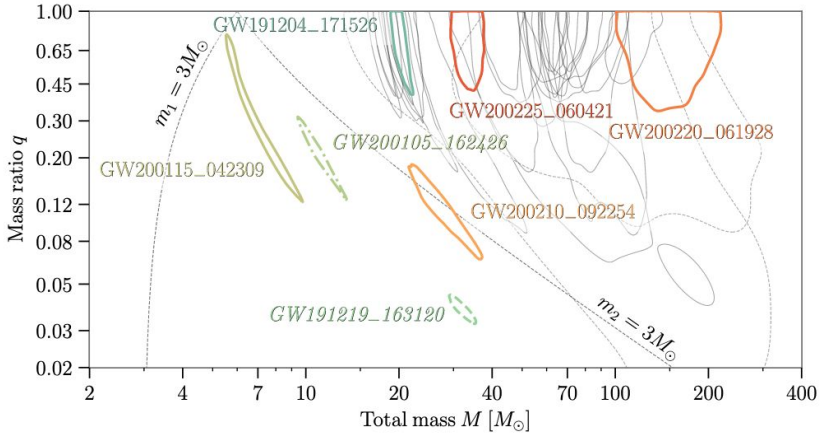
GWs from neutron-star–black-hole mergers

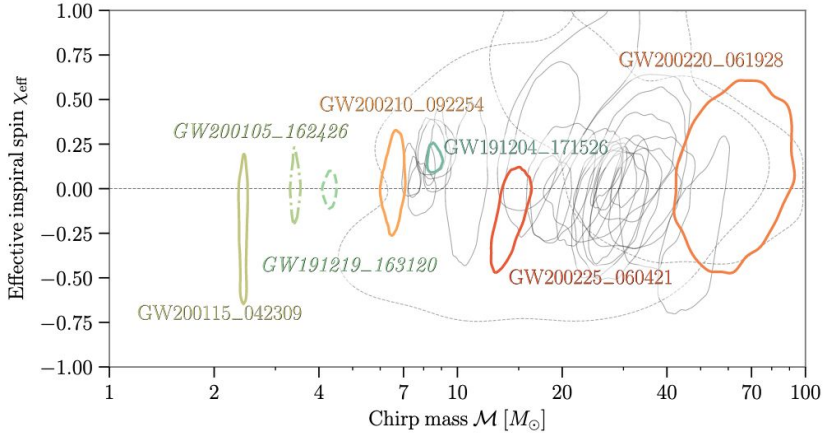




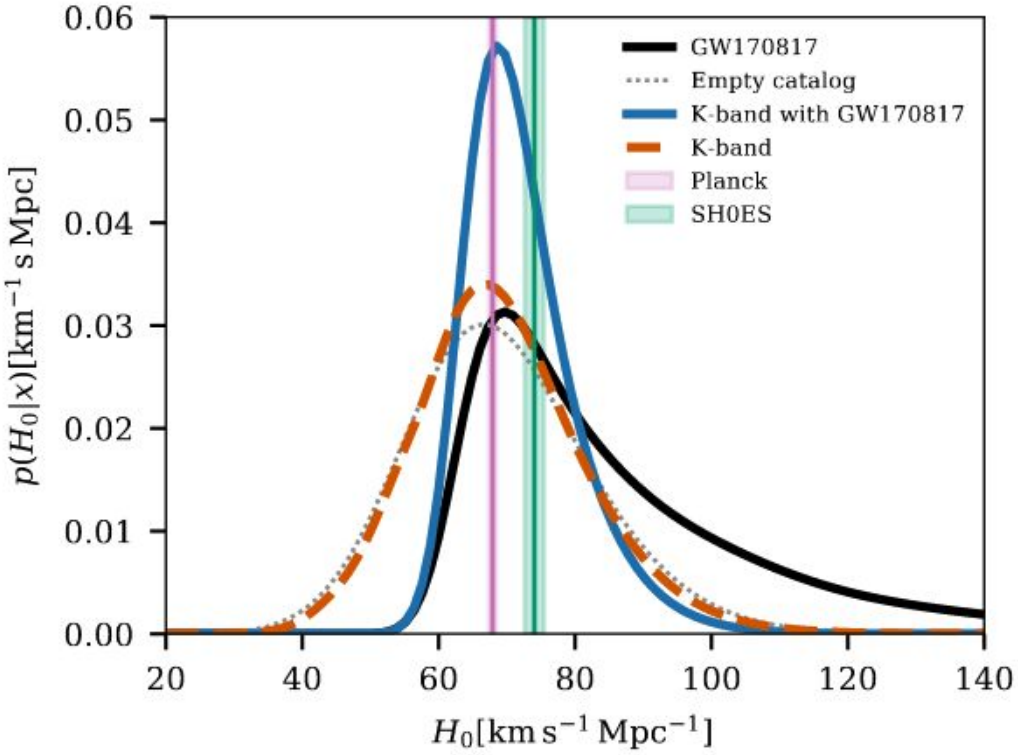
~2 observations in GWTC-3

Group picture of recent compact binary mergers

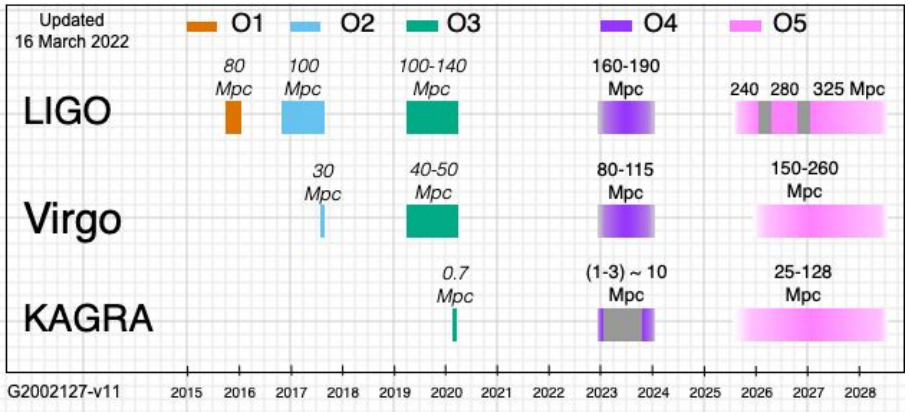




H_0 measurement with NS and BH mergers



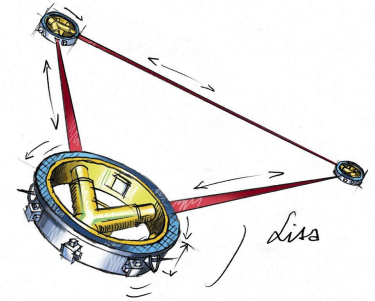
Evolution of GW detectors



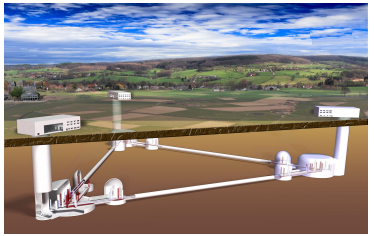
Present: second-generation ground-based detectors

Near future: "post-O5 era" (mid-2020s to early 2030s)

Far future (mid-2030s): space detectors

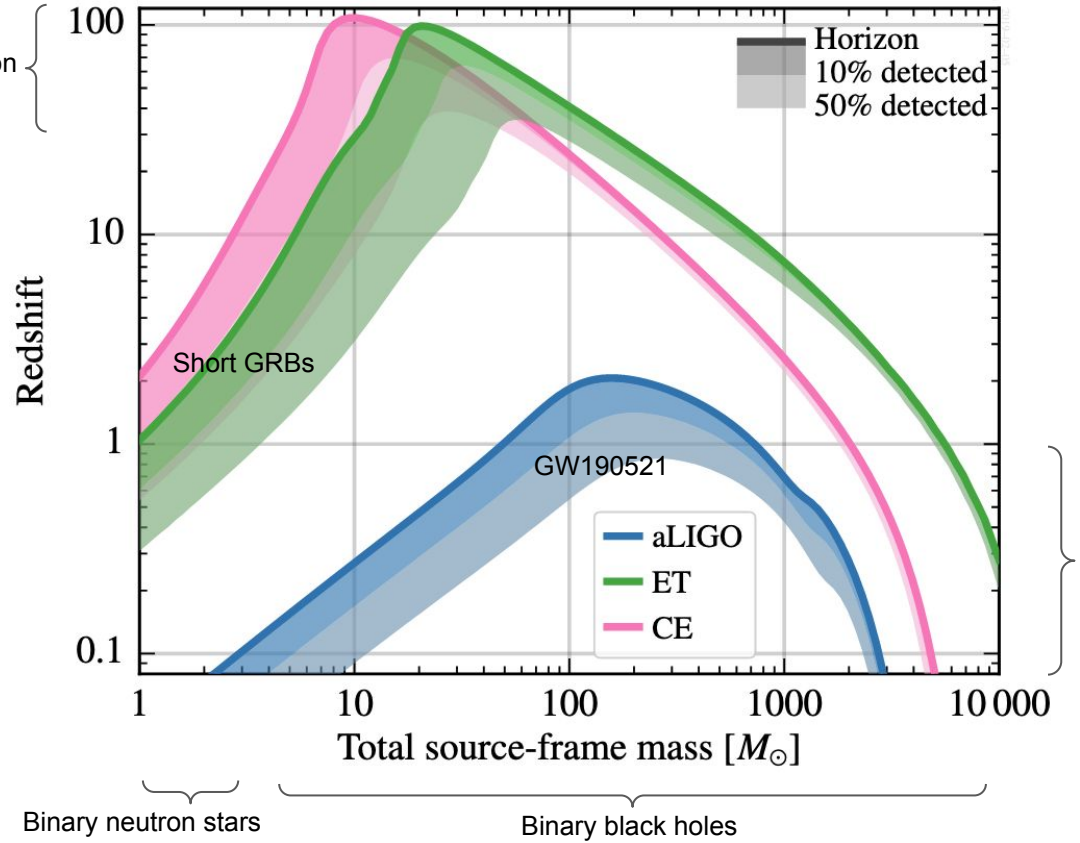


Far future (mid 2030s): Third-generation ground-based detectors

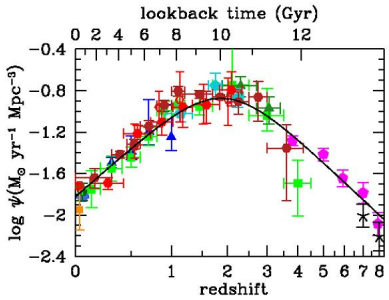


Einstein Telescope and Cosmic Explorer

Before star formation



Signals with
S/N ~ 200
(~10x present)

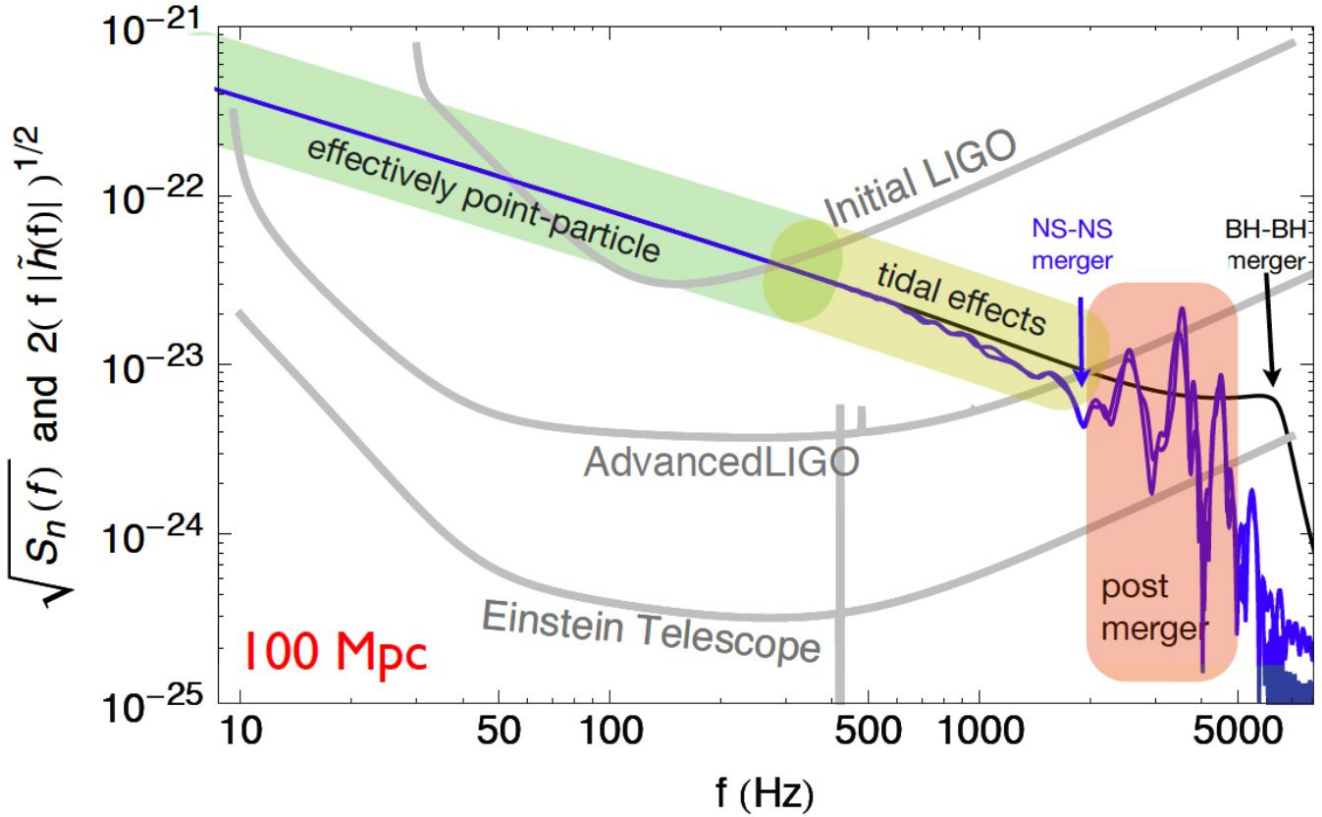


Star formation history

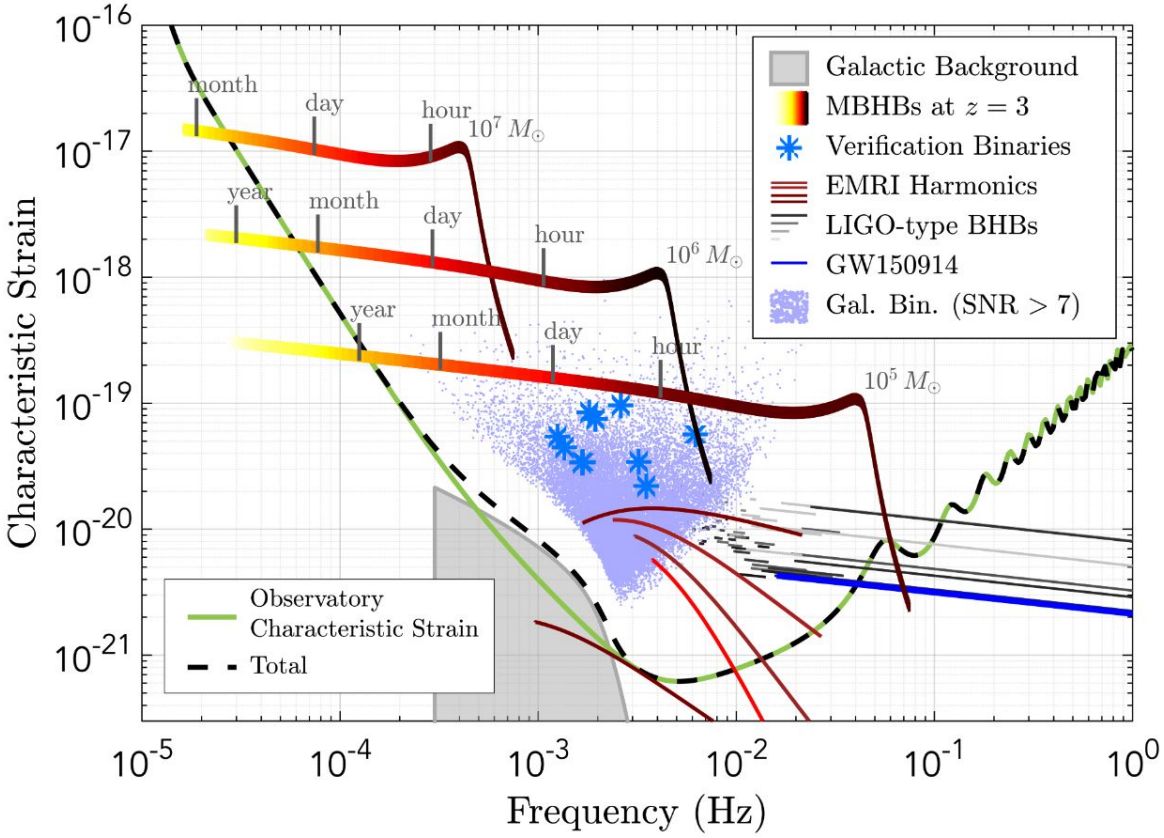
Binary neutron stars

Binary black holes

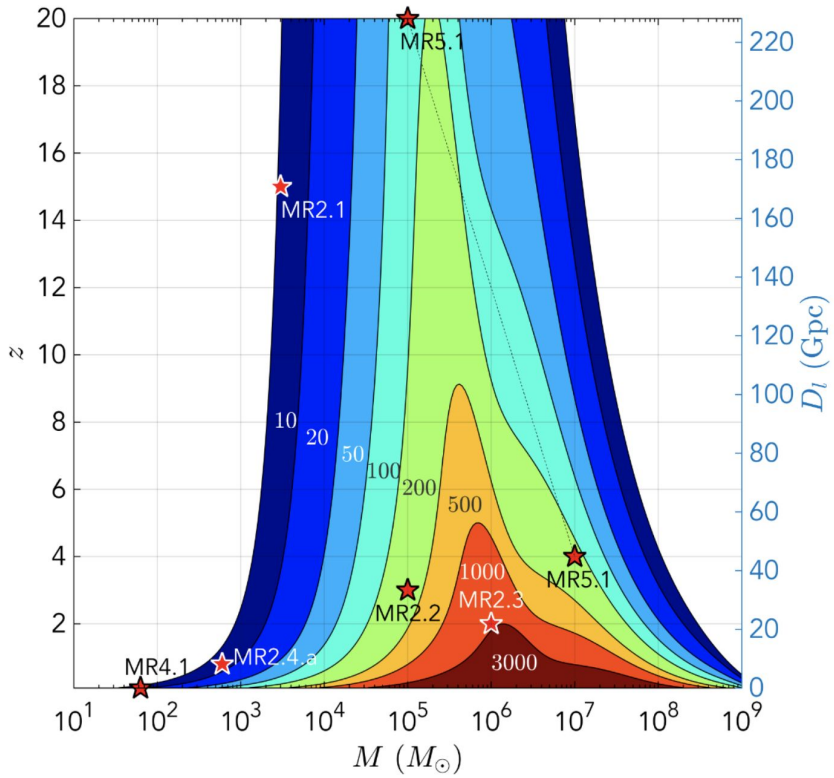
Einstein Telescope and Cosmic Explorer

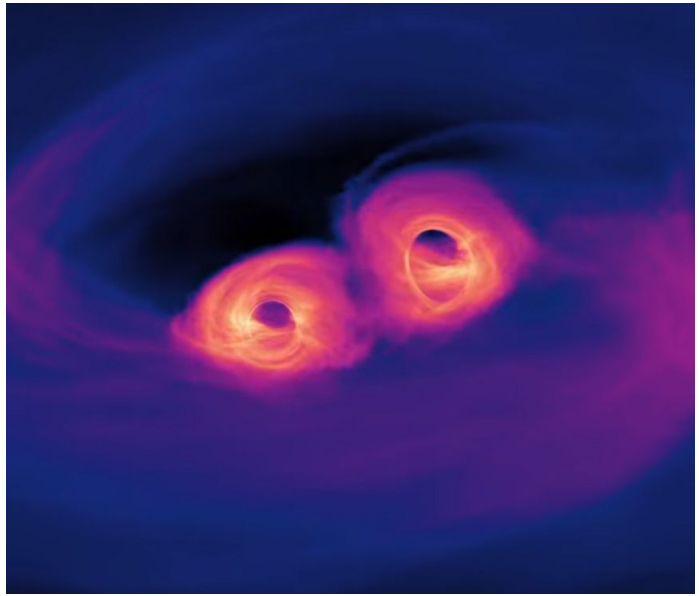


Laser Interferometer Space Antenna



Laser Interferometer Space Antenna





Thank you!