Detecting binaries across the gravitational-wave spectrum

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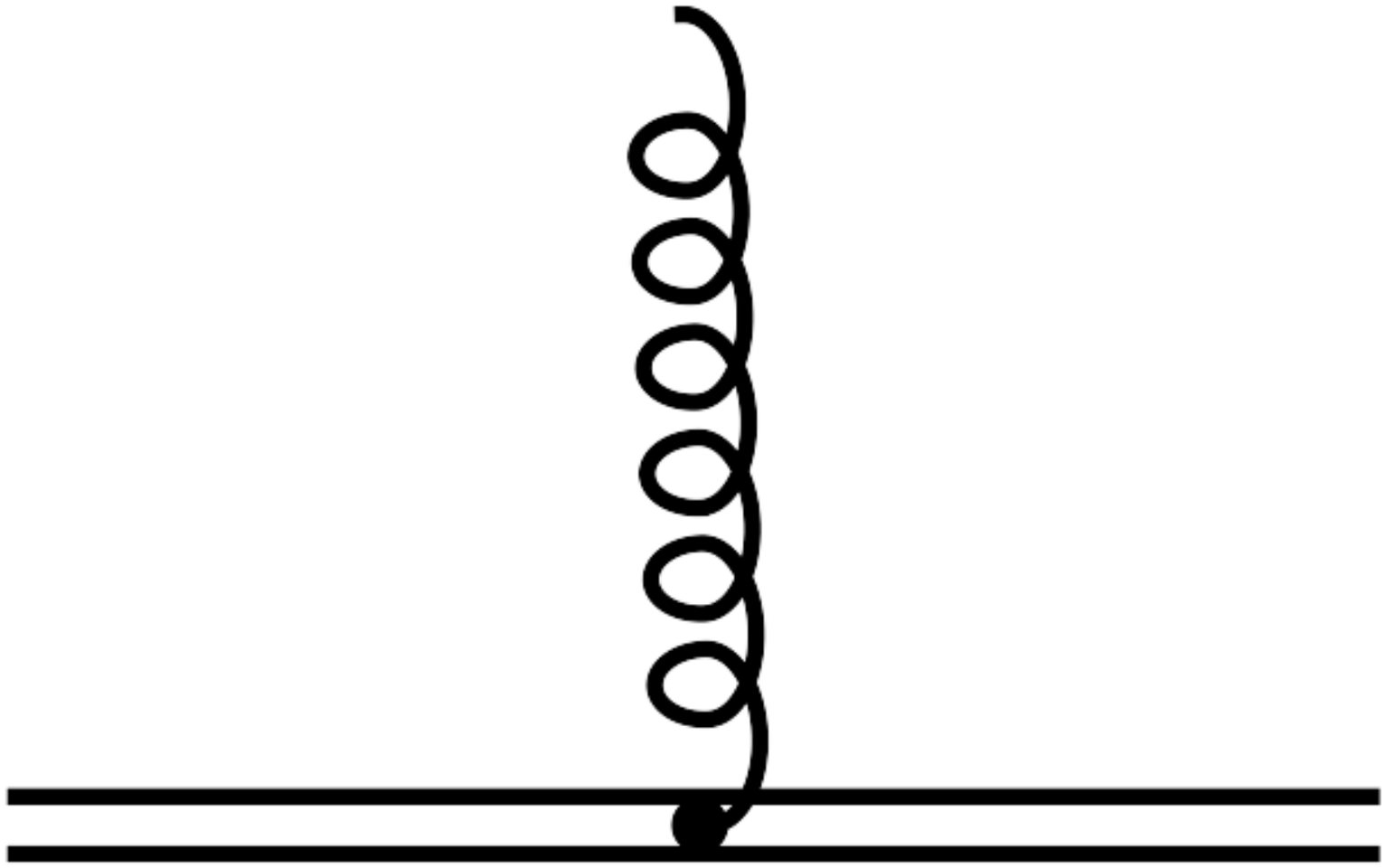
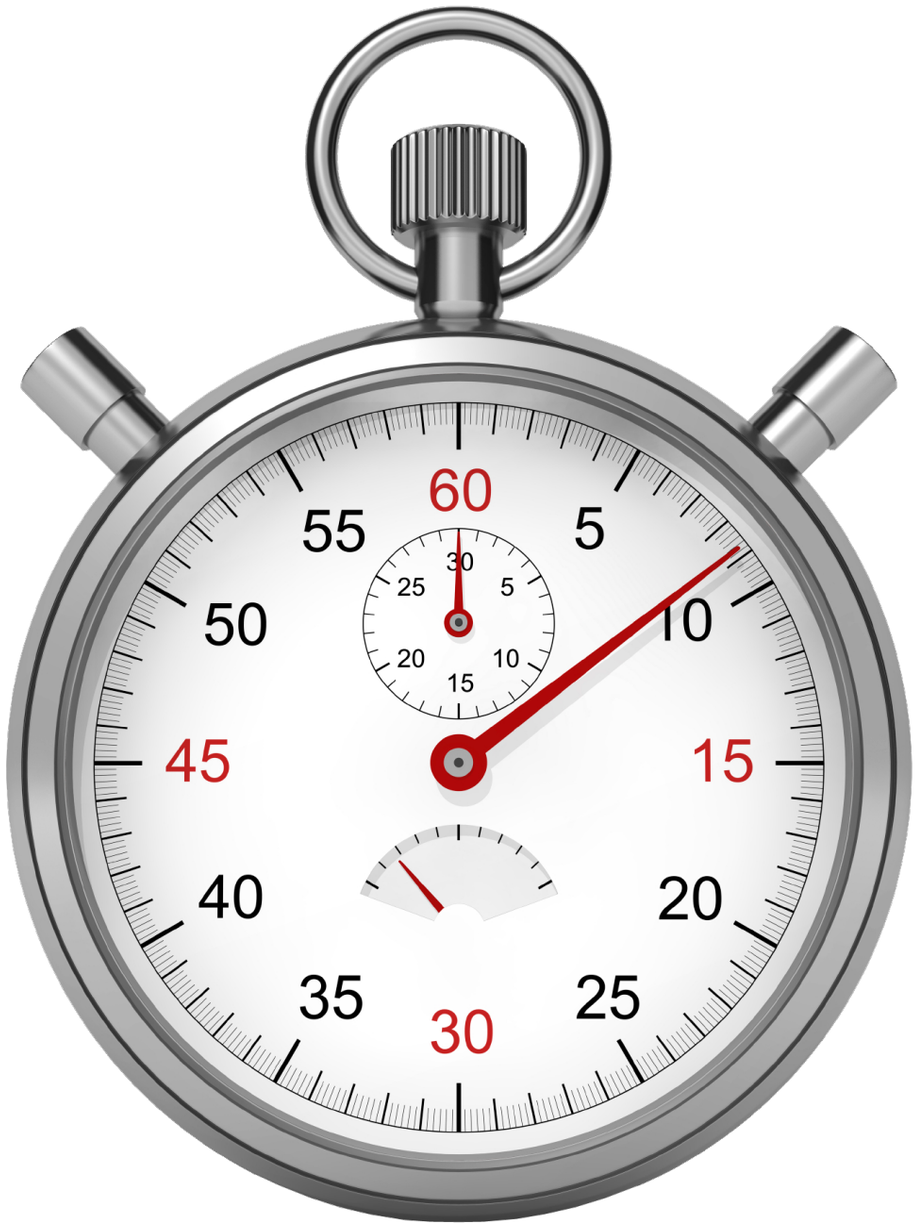
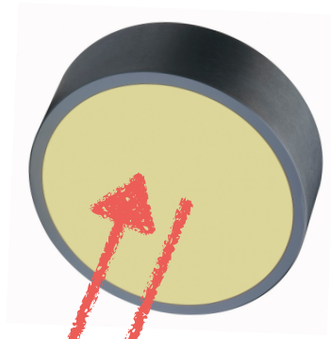
Gravitational wave



Gravitational-wave detector



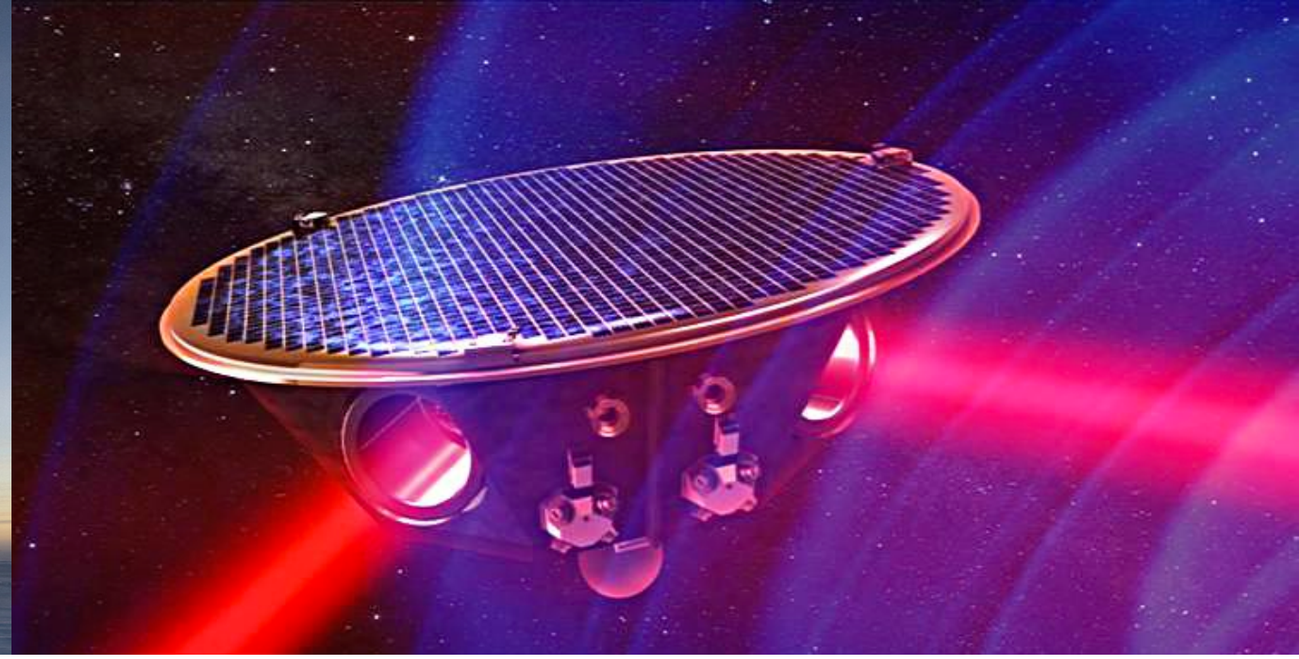
Gravitational-wave detector



$$L_{12} = L_{12}^{\text{no gw}} + \frac{1}{2}\int_1^2 h(\lambda)\,\mathrm{d}\lambda$$

pulsar timing

Doppler tracking,
eLISA, LIGO



Gravitational-wave detectors

Galactic binaries

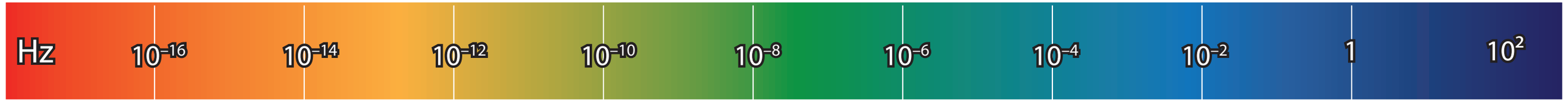
captures into MBHs

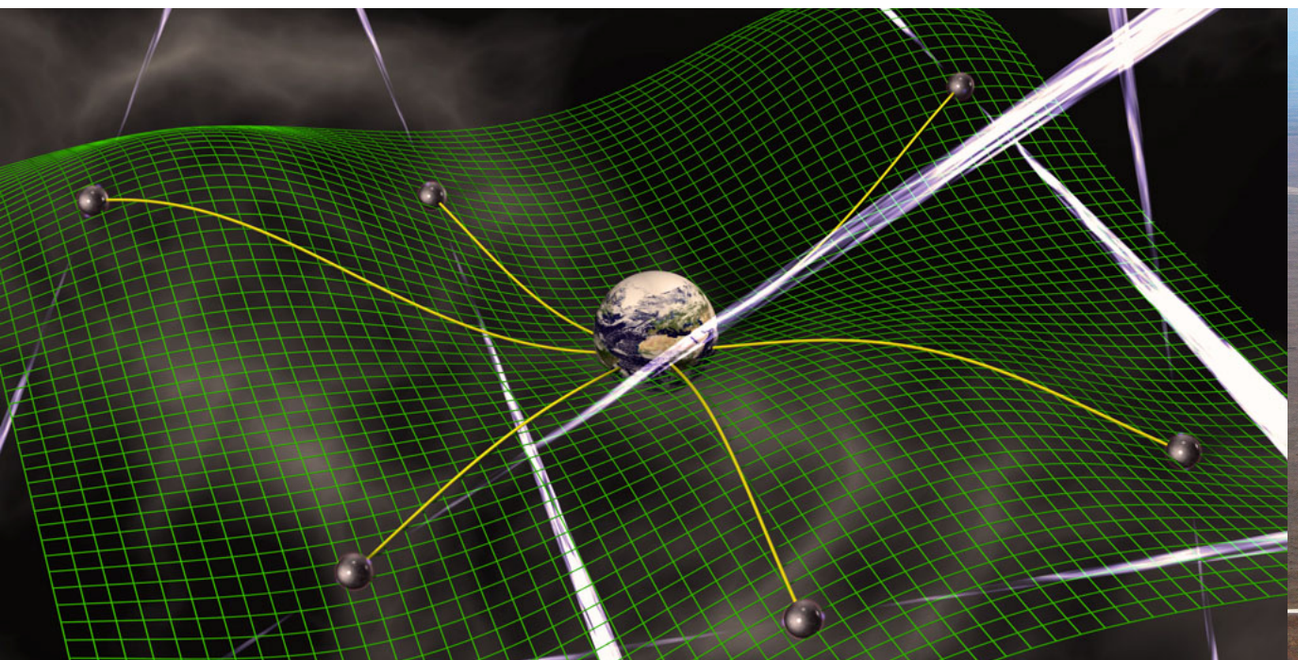
rotating NS

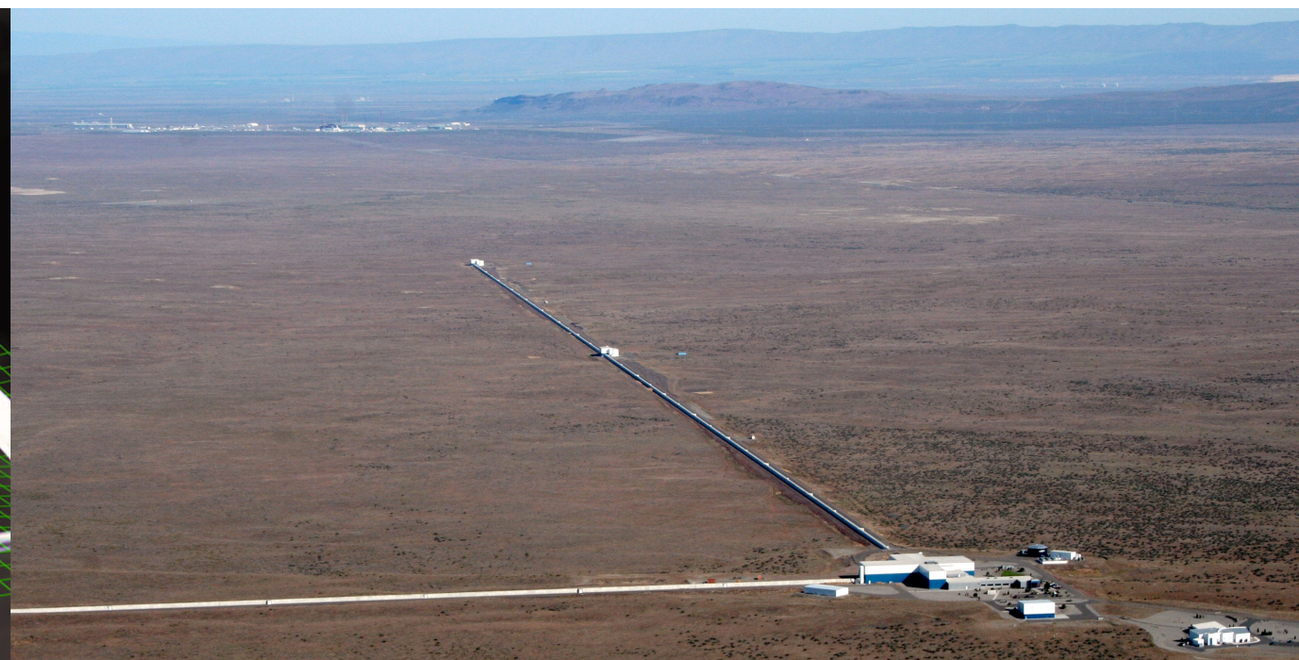
merging NS, BH

massive black-hole binaries

early-Universe quantum fluctuations

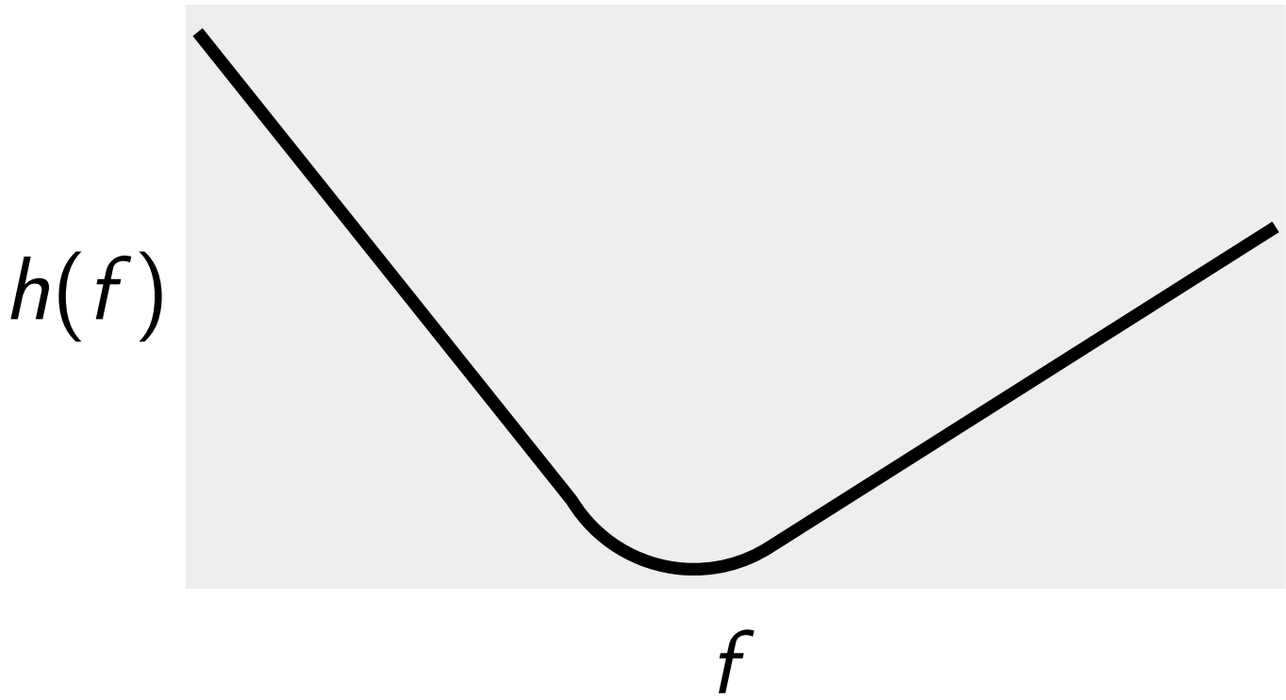




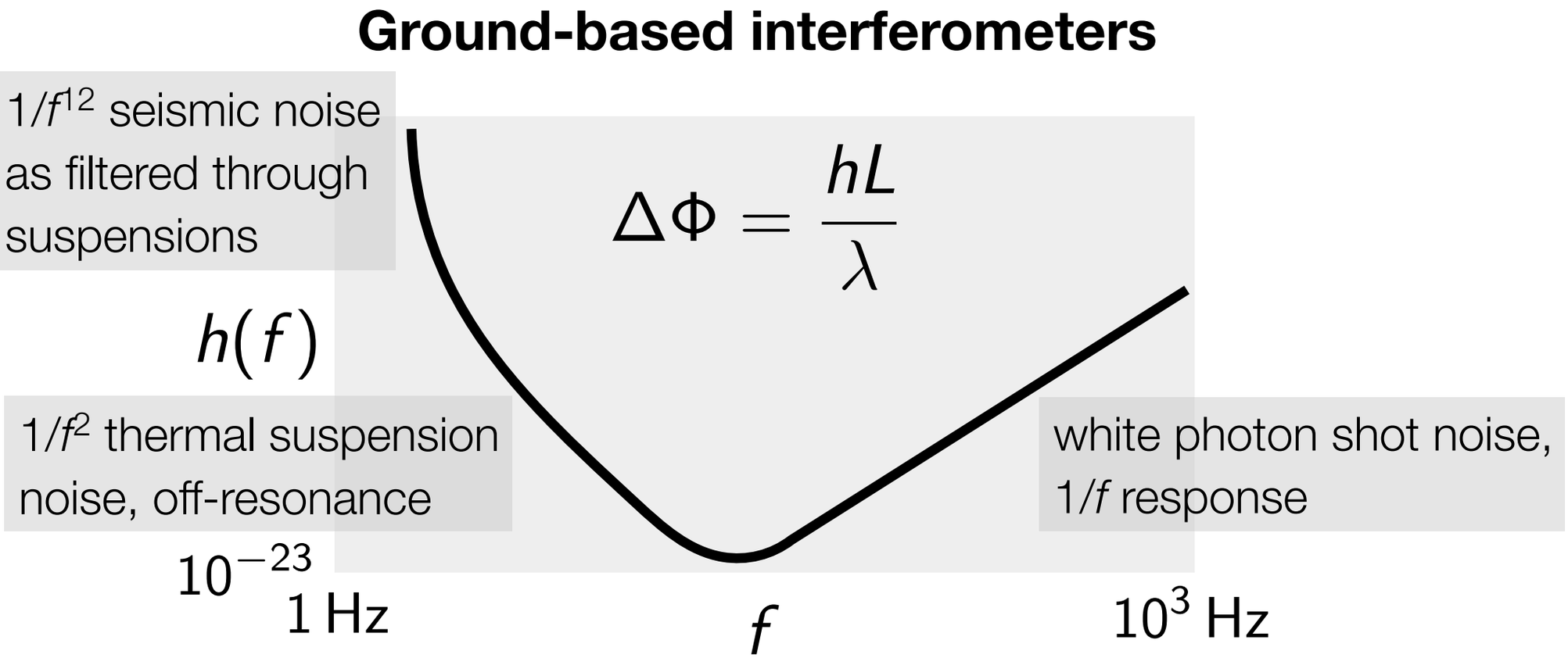


Gravitational-wave detector sensitivity

Universal: “it must get better before it gets worse”

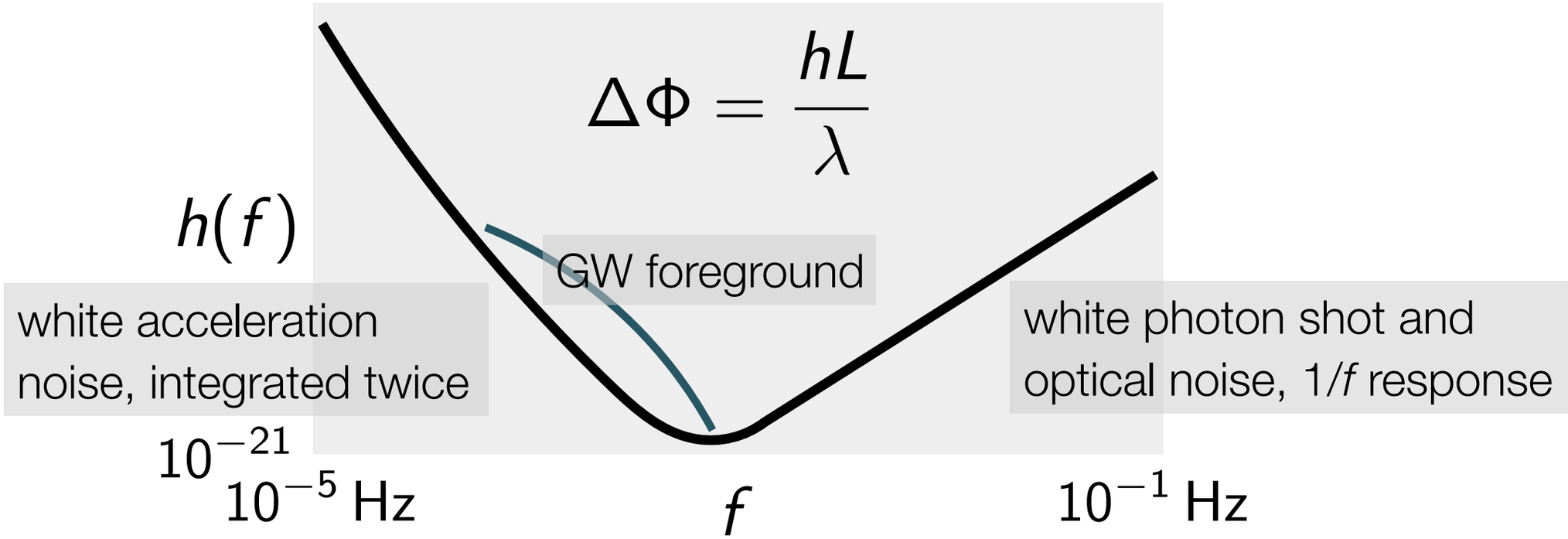


Gravitational-wave detector sensitivity

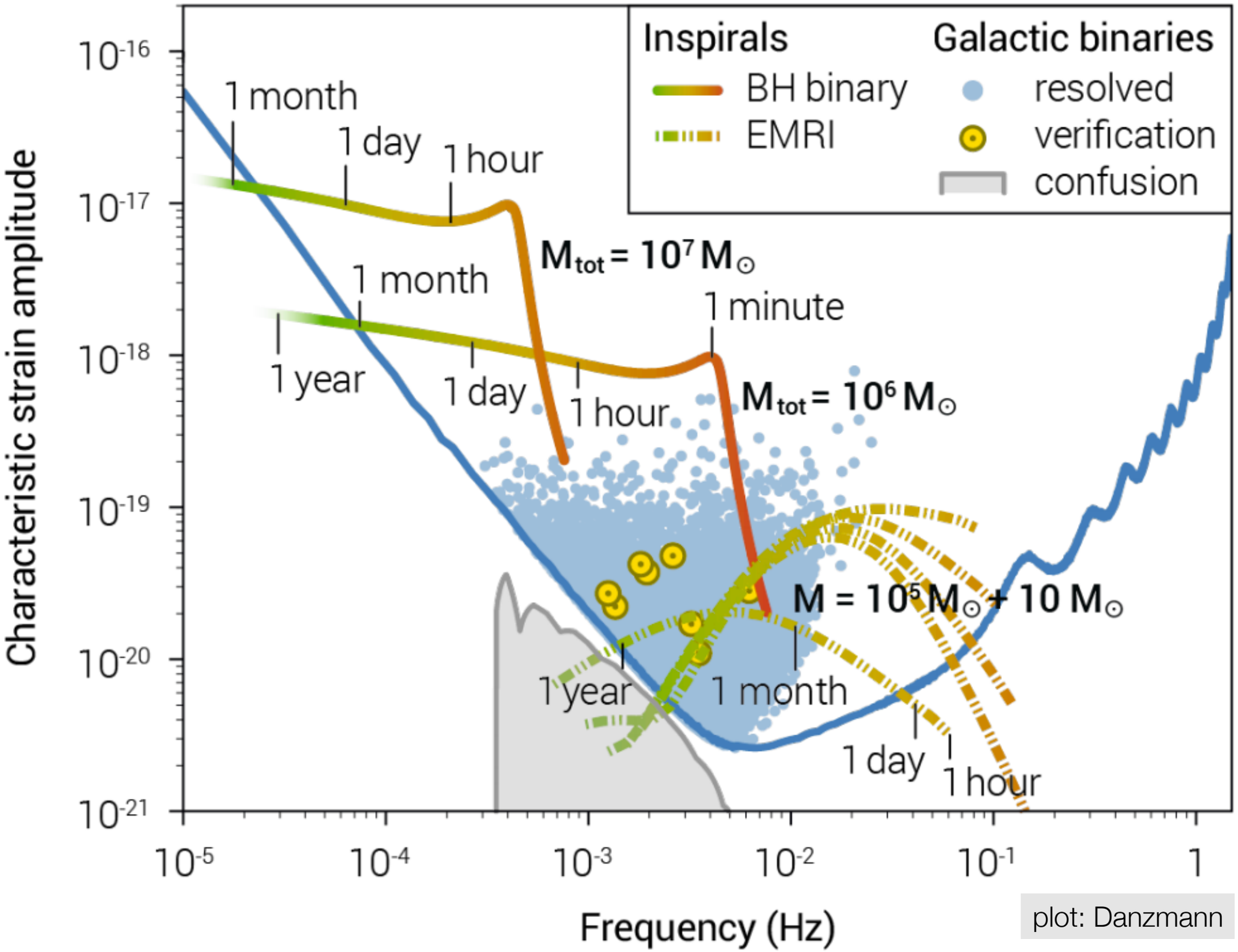


Gravitational-wave detector sensitivity

Space-based interferometers

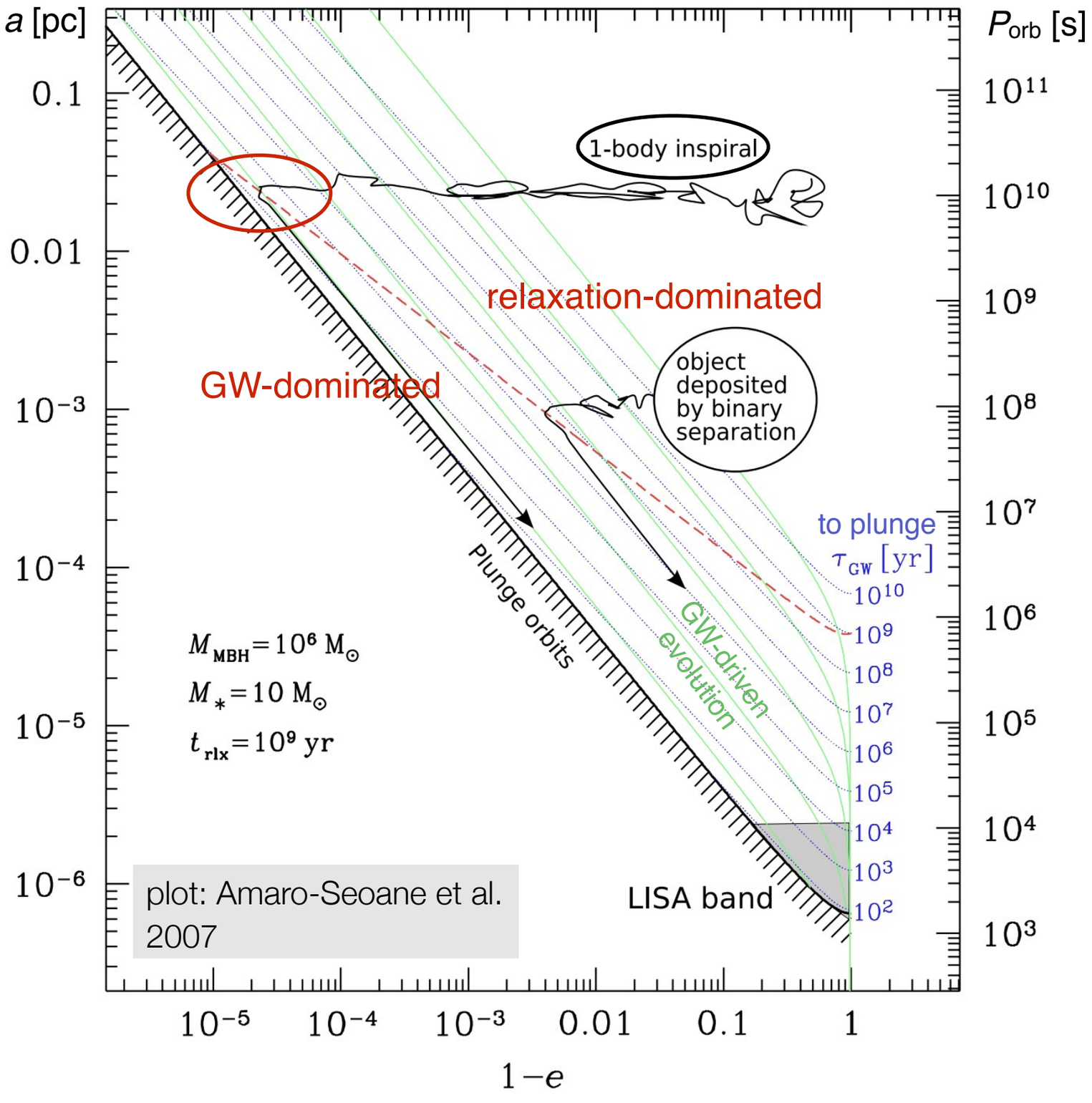


eLISA: ESA's Cosmic Vision L3 mission (start/launch 2019/2034)



plot: Danzmann

extreme mass-ratio inspirals with 10^4–10^7 $M_\odot$ MBH produce GWs detectable by eLISA



EMRIs originate in dense nuclear clusters when **compact objects** are captured by the MBH after **two-body relaxation**, tidal stripping of binaries or giants, or star formation in a disc.

There are **many complications**: mass segregation, triaxial potentials, resonant relaxation…

Rates are very uncertain, and depend on MBH density, nuclear cluster populations, compact-object fractions.

EMRIs have very complex GWs with 100,000s cycles in the LISA band, so they offer **excellent parameter estimation** and **tests of BH nature**.

Pulsar…

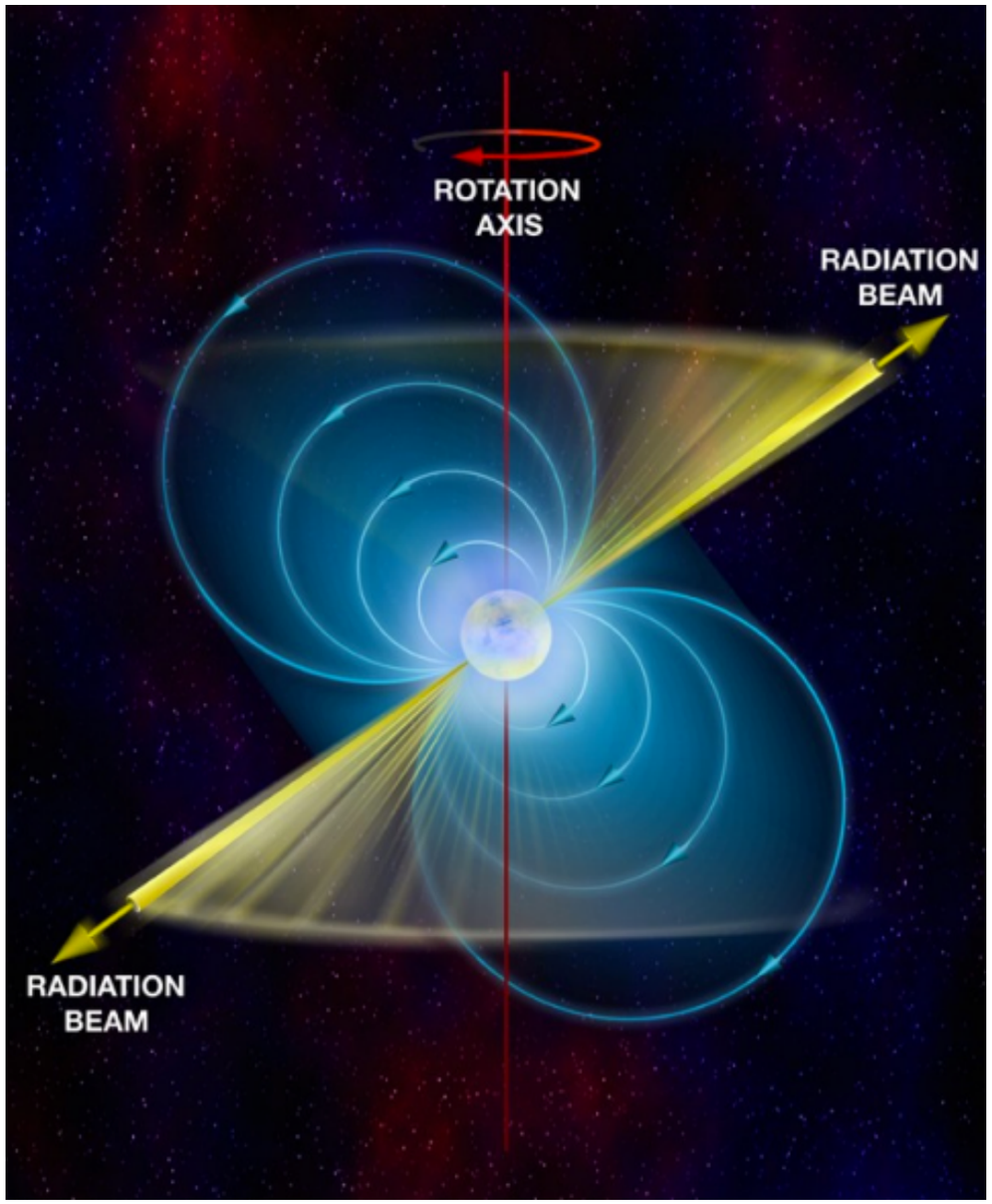
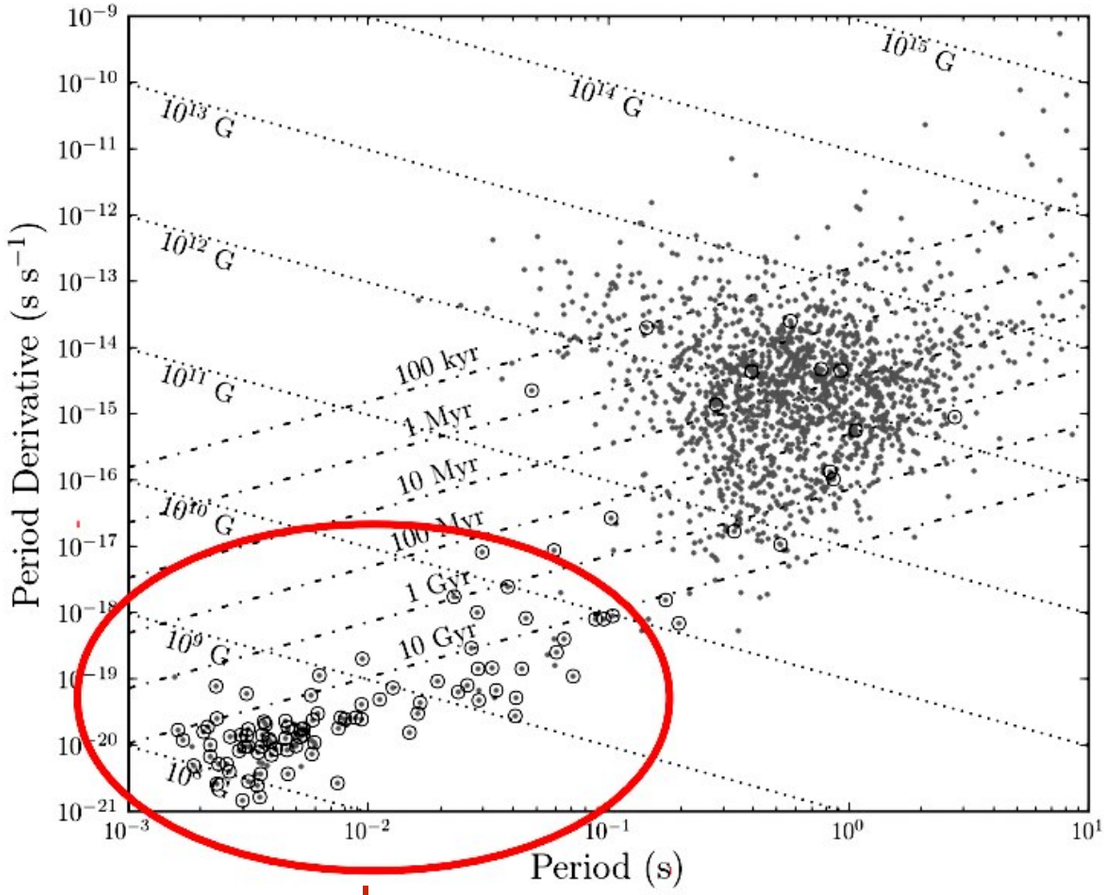


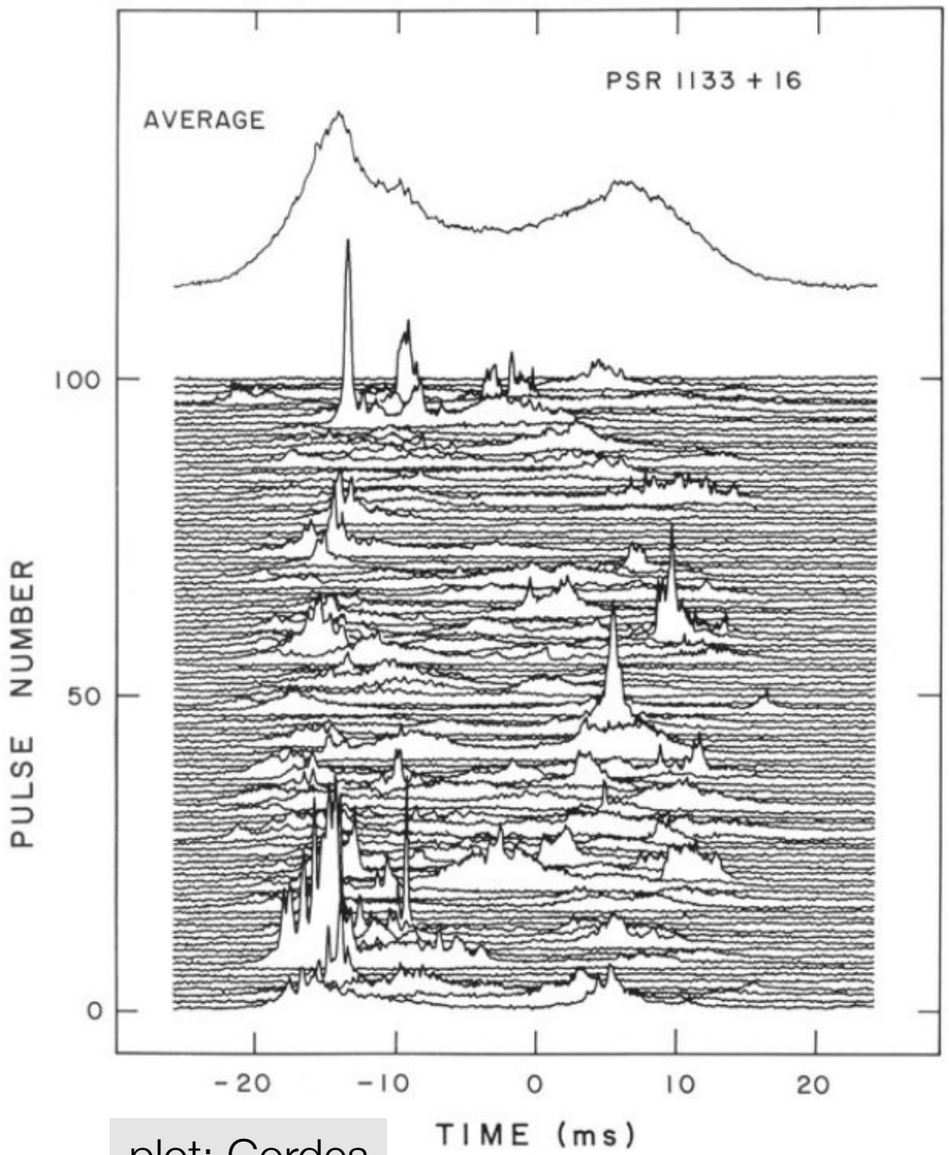
image: Saxton



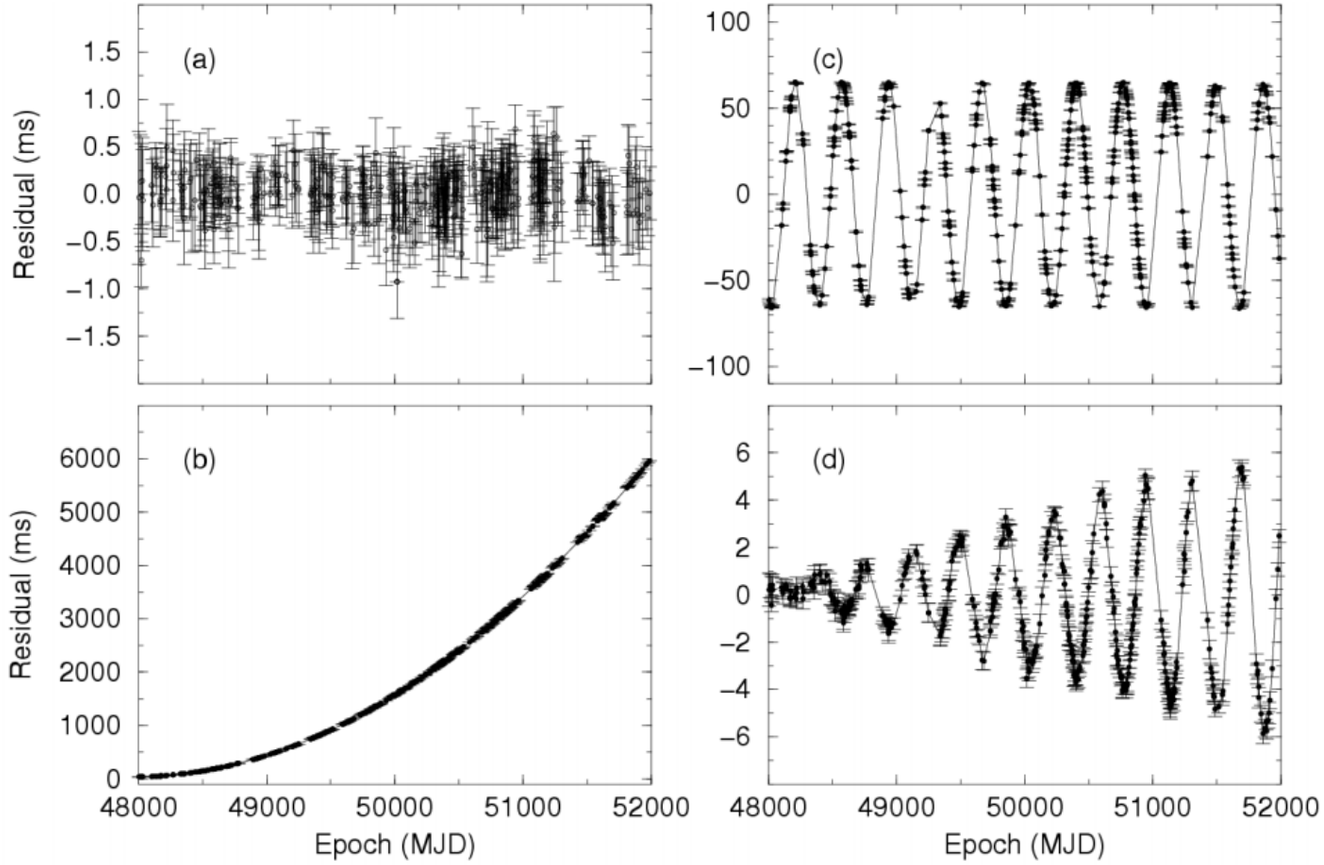
msec pulsars

plot: Lorimer and Kramer

Pulsar timing…



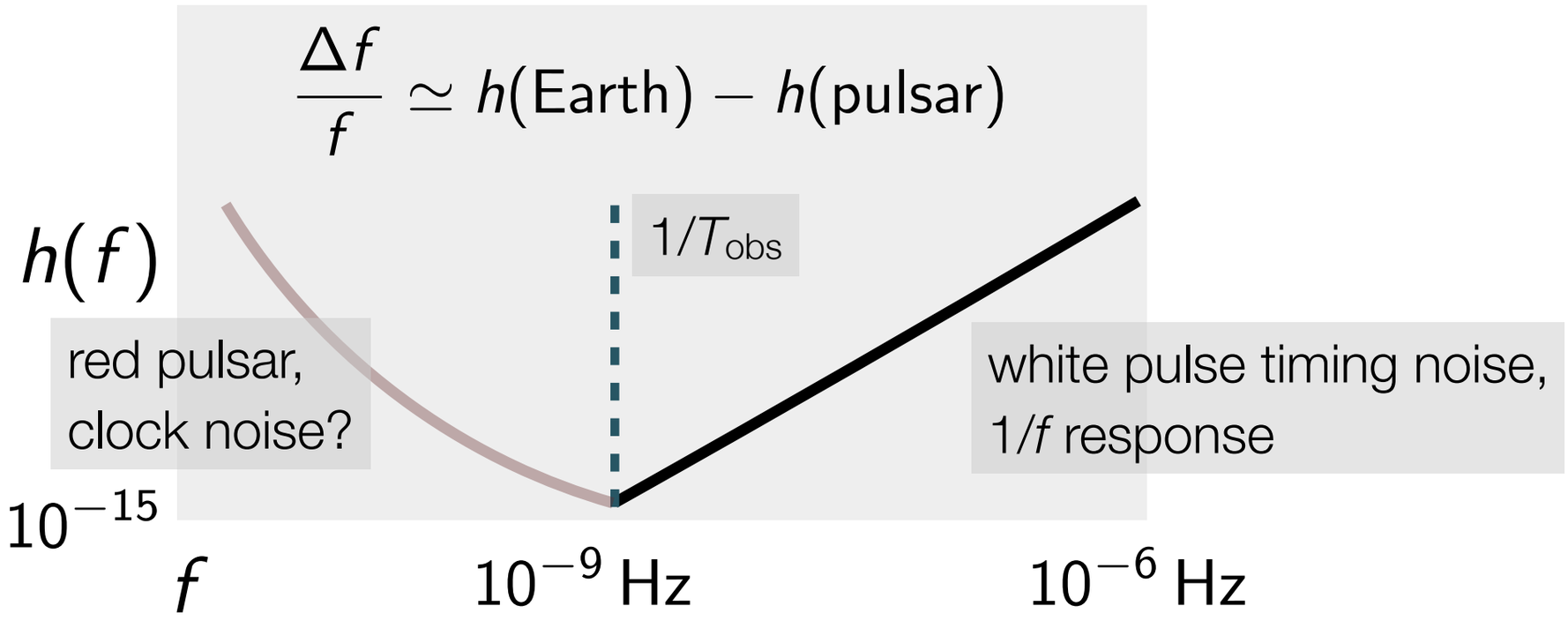
plot: Cordes



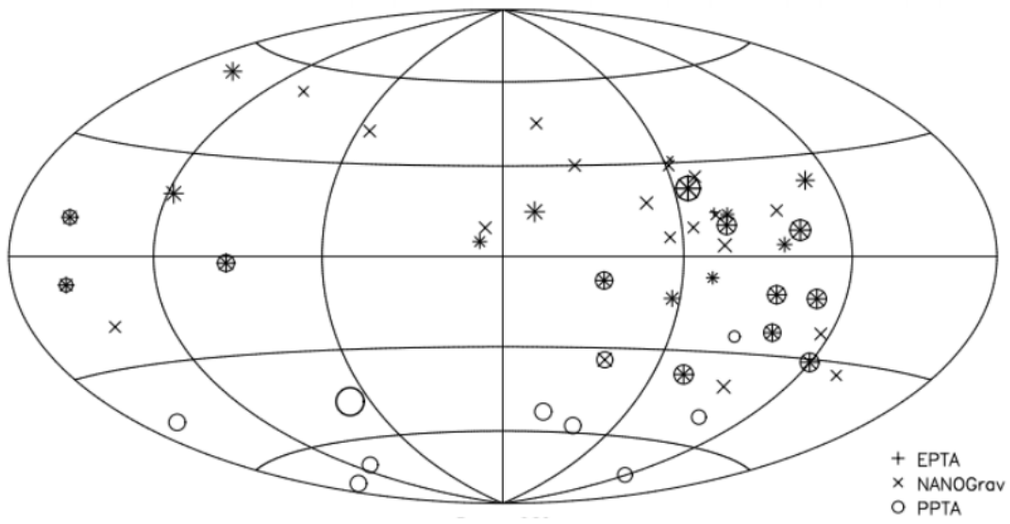
plot: Lorimer and Kramer

Gravitational-wave detector sensitivity

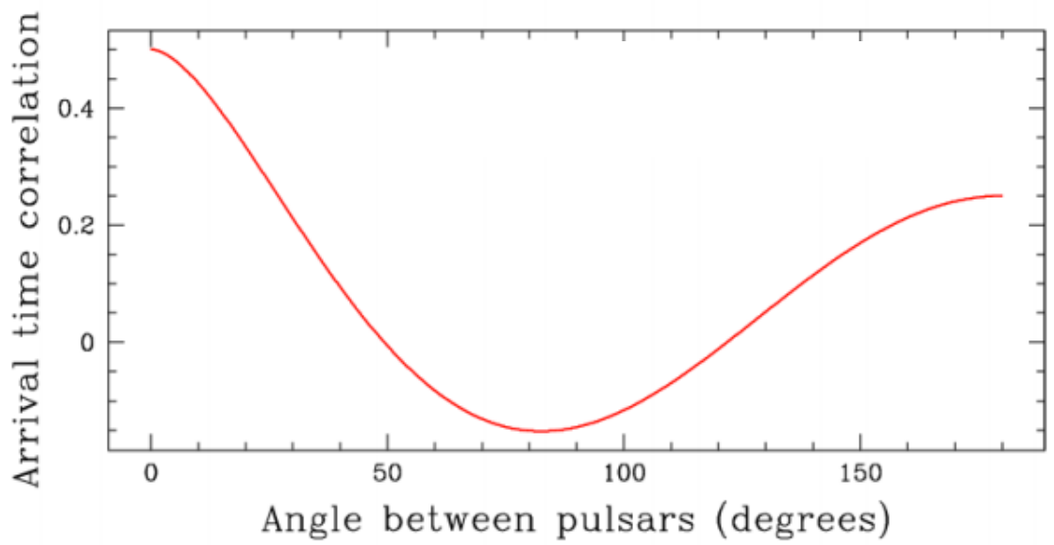
Pulsar timing



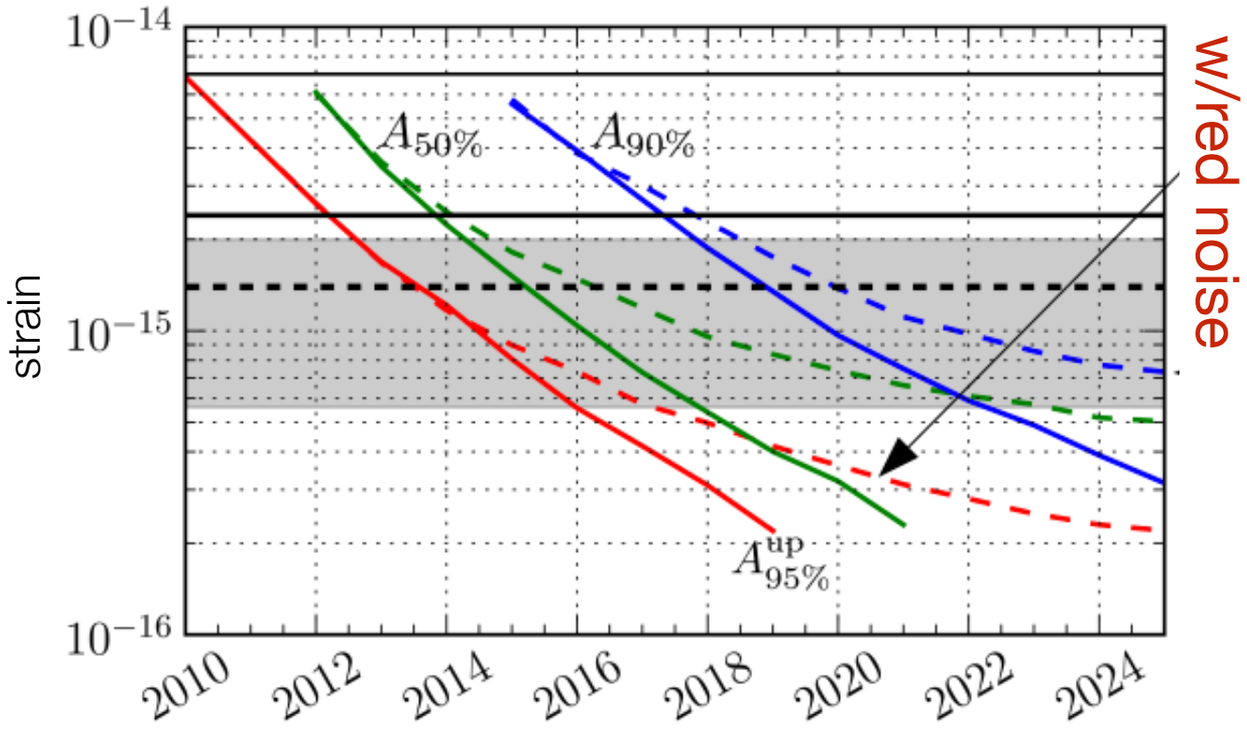
Pulsar timing array



plot: Manchester

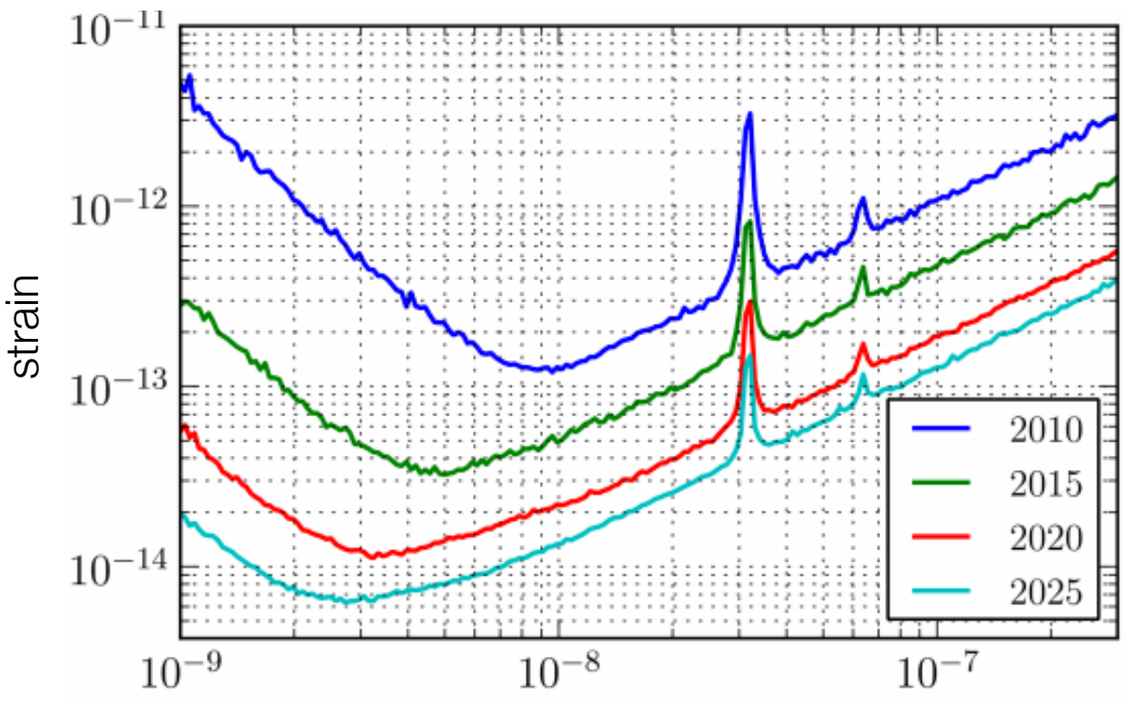


stochastic background

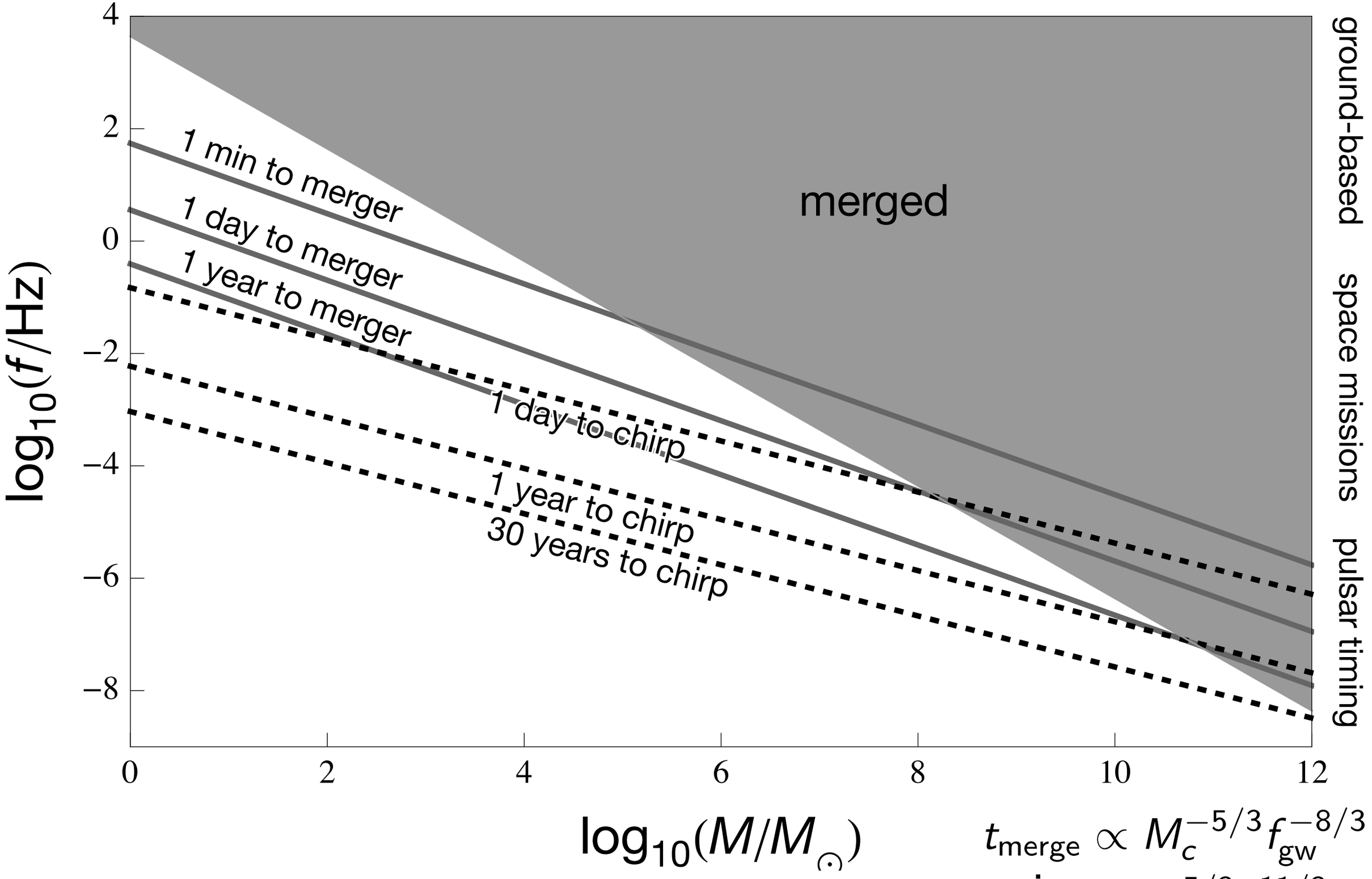


plots: NANOGrav

resolvable sources



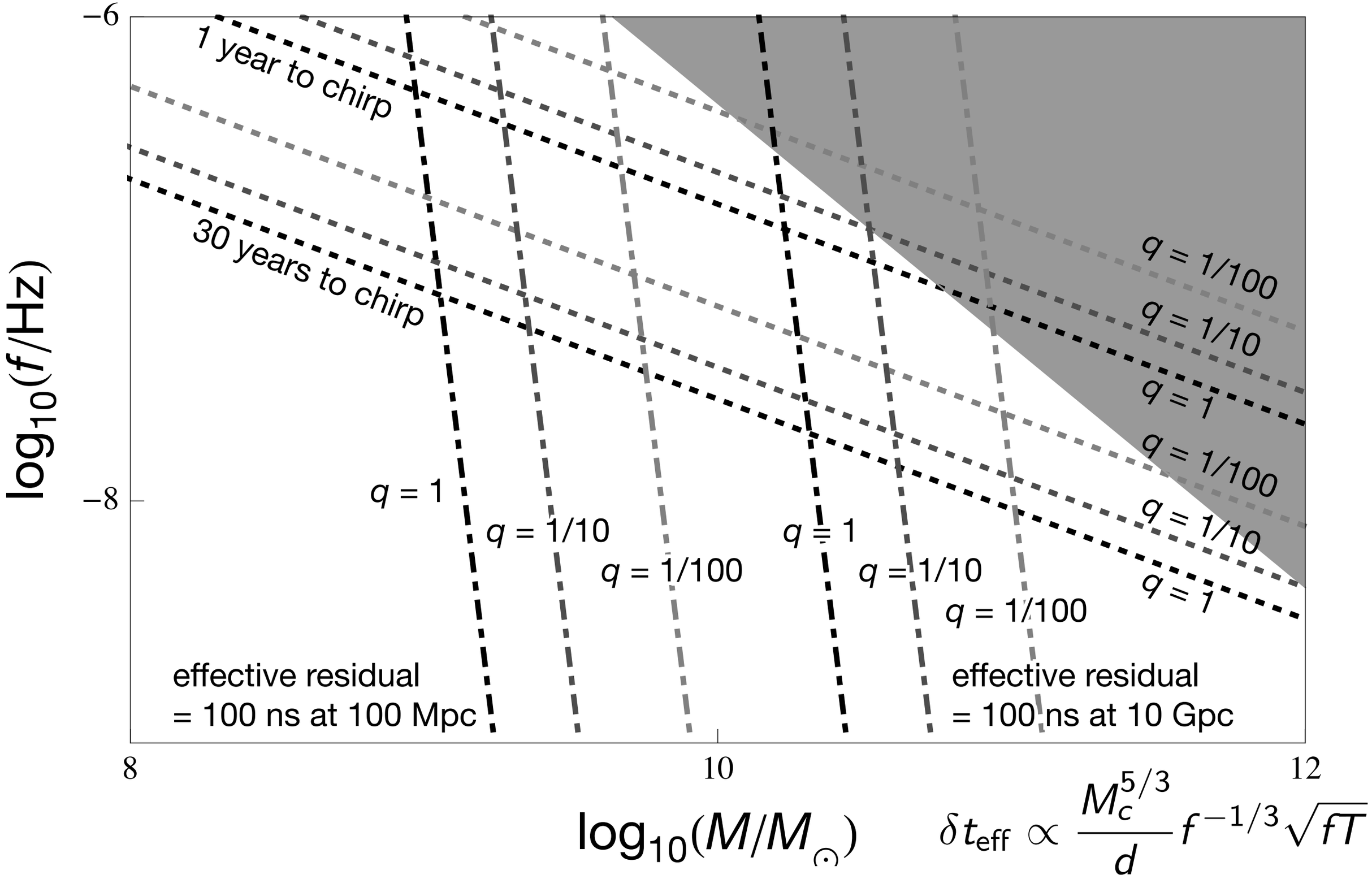
Binaries as gravitational-wave sources



$$t_{\mathrm{merge}} \propto M_c^{-5/3} f_{\mathrm{gw}}^{-8/3}$$

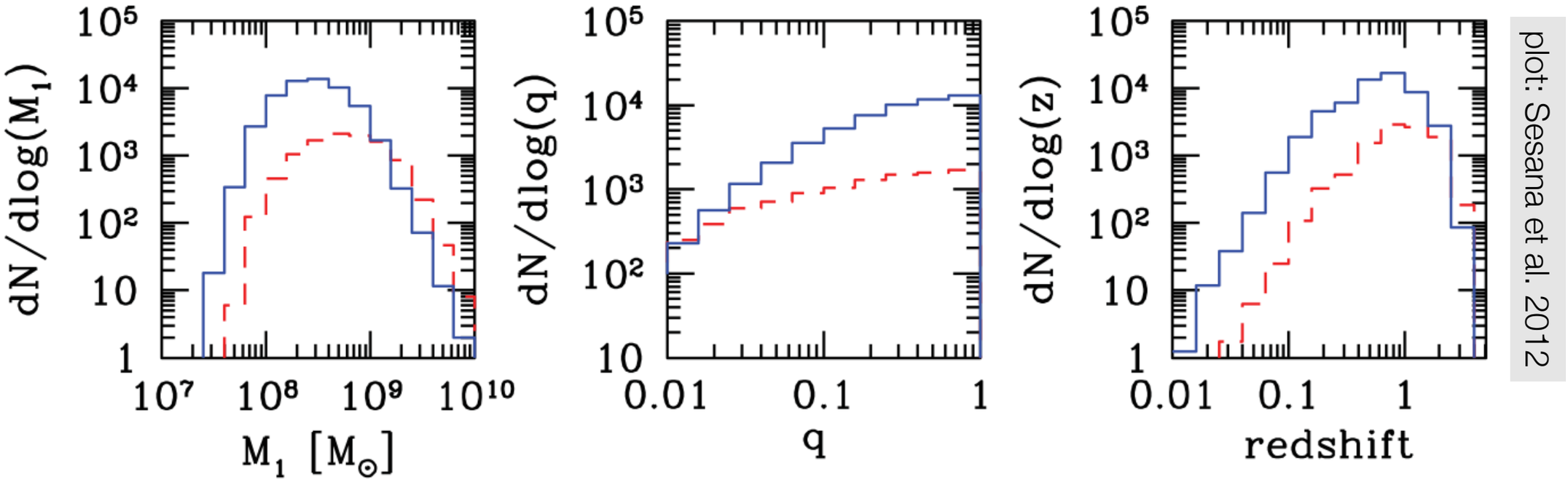
$$\dot{f}_{\mathrm{gw}} \propto M_c^{5/3} f_{\mathrm{gw}}^{11/3}$$

Binaries as gravitational-wave sources



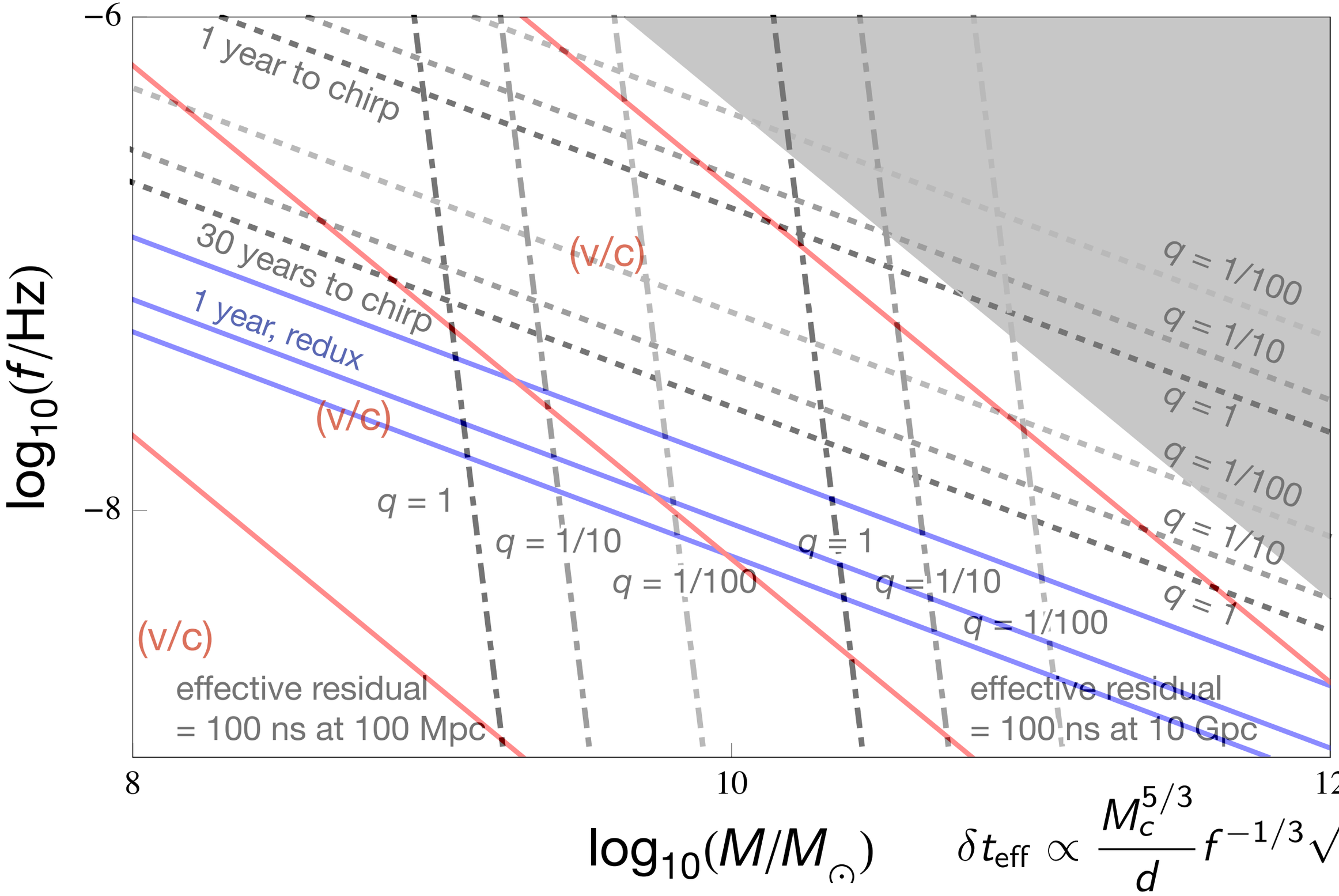
$$\delta t_{\rm eff} \propto \frac{M_c^{5/3}}{d} f^{-1/3} \sqrt{fT}$$

Binaries as gravitational-wave sources



plot: Sesana et al. 2012

Binaries as gravitational-wave sources



$$\delta t_{\rm eff} \propto \frac{M_c^{5/3}}{d} f^{-1/3} \sqrt{fT}$$

In closing, on the relevance of “Capra” dynamics

We should be able to solve the general-relativistic two-body problem for any combination of masses.

Accurate waveforms from EMRIs and IMRIs will be crucial to eLISA data analysis. (And you have time.)

For PTAs, maybe, but good old PN may be sufficient.