Gravitational Wave Astronomy: Individual Sources

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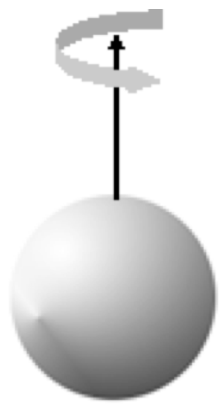
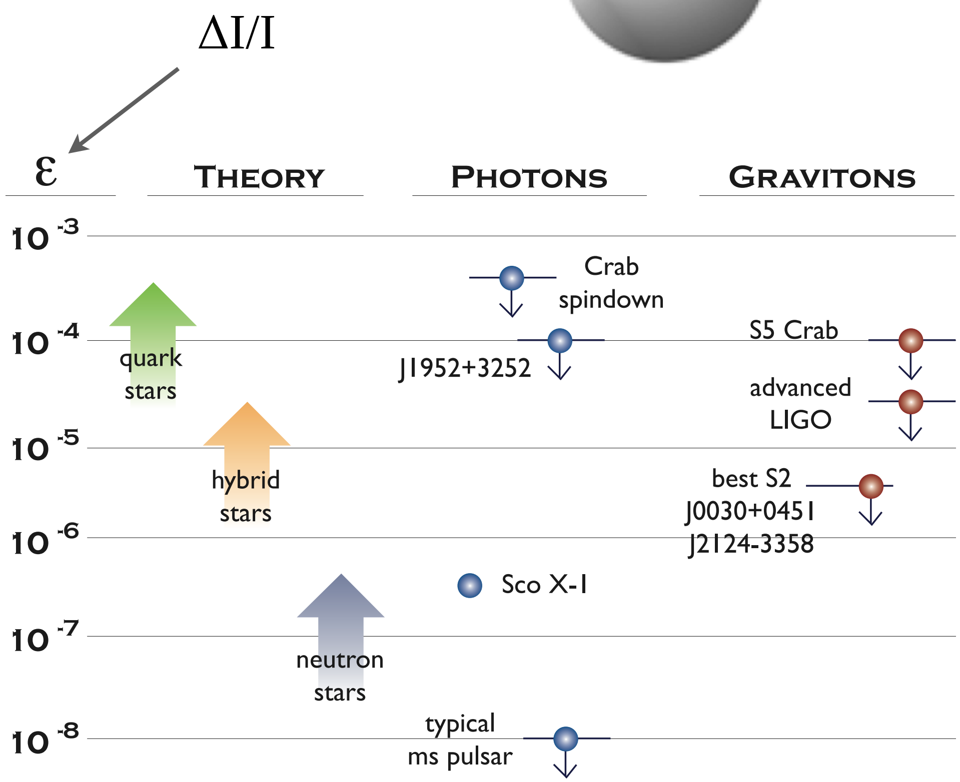
Gravitational wave sources and signature science

Radiation amplitude from rapidly rotating neutron stars is limited by the equation of state of cold nuclear matter

Radiation arises from rotating non-axisymmetry



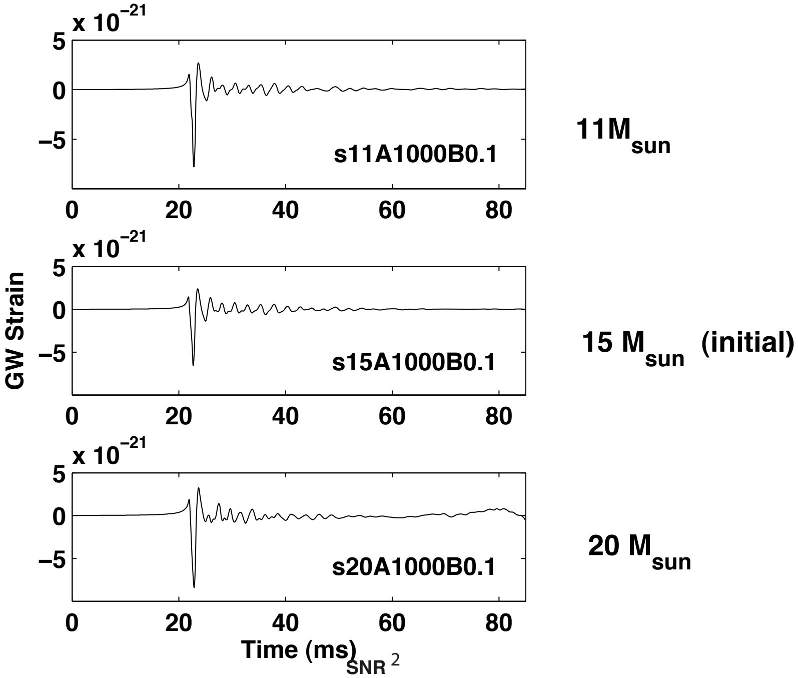
"Mountain" height is bounded by stress crust can support

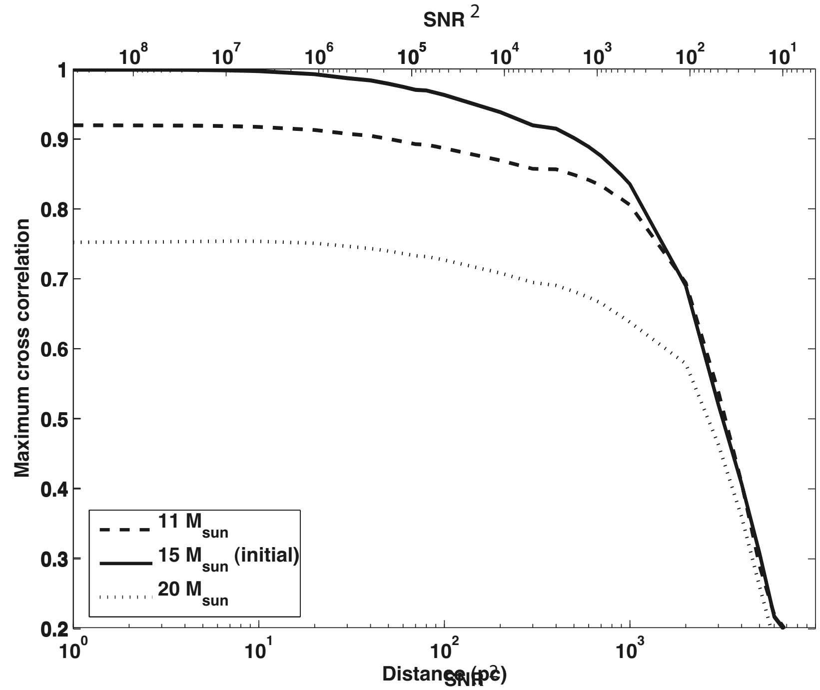


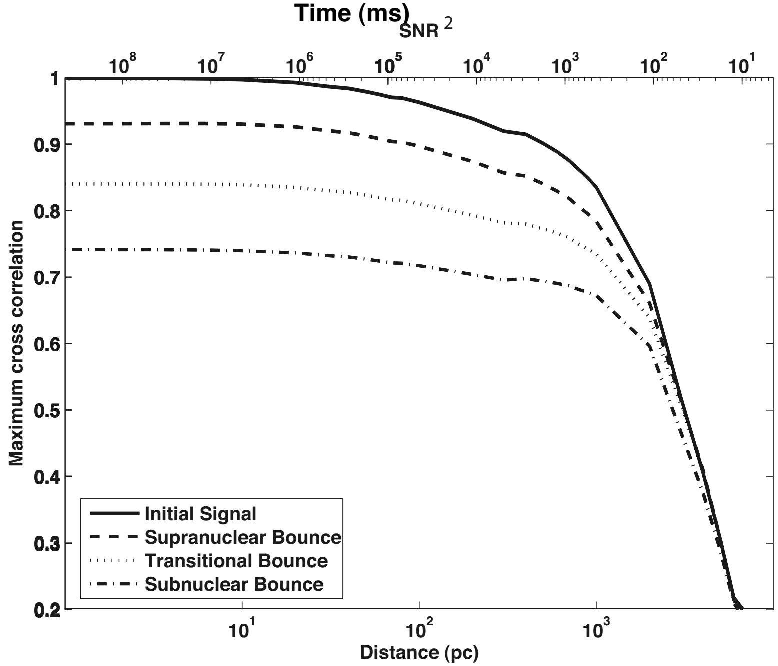
Maximum crust strain is determined by nuclear equation of state

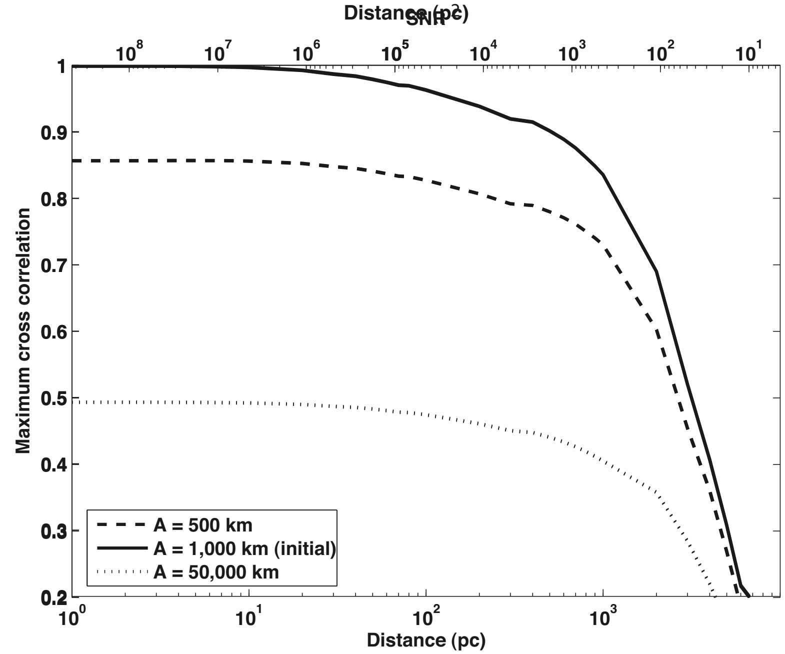
Observation of radiation corresponding to "too large" a stress rules-out an EOS

Gravitational waves from stellar core collapse carry evidence of progenitor star, collapse characteristics









Compact binary coalescence signature includes component masses, orbital inclination, absolute luminosity distance

$$
\begin{aligned}
h_+ &= \frac{2\mathcal{M}}{d_L}\left(1+\cos^2 i\right)\left(\pi f \mathcal{M}\right)^{2/3}\cos\Phi(t)\\
h_\times &= \frac{4\mathcal{M}}{d_L}\cos i\left(\pi f \mathcal{M}\right)^{2/3}\sin\Phi(t)\\
f &= \frac{1}{\pi\mathcal{M}}\left(\frac{5}{256}\frac{\mathcal{M}}{T-t}\right)^{3/8}\\
\Phi &= -2\left(\frac{T-t}{5\mathcal{M}}\right)^{5/8}\\
\mathcal{M} &= \left(\mu^2 M^3\right)^{1/5}
\end{aligned}
$$

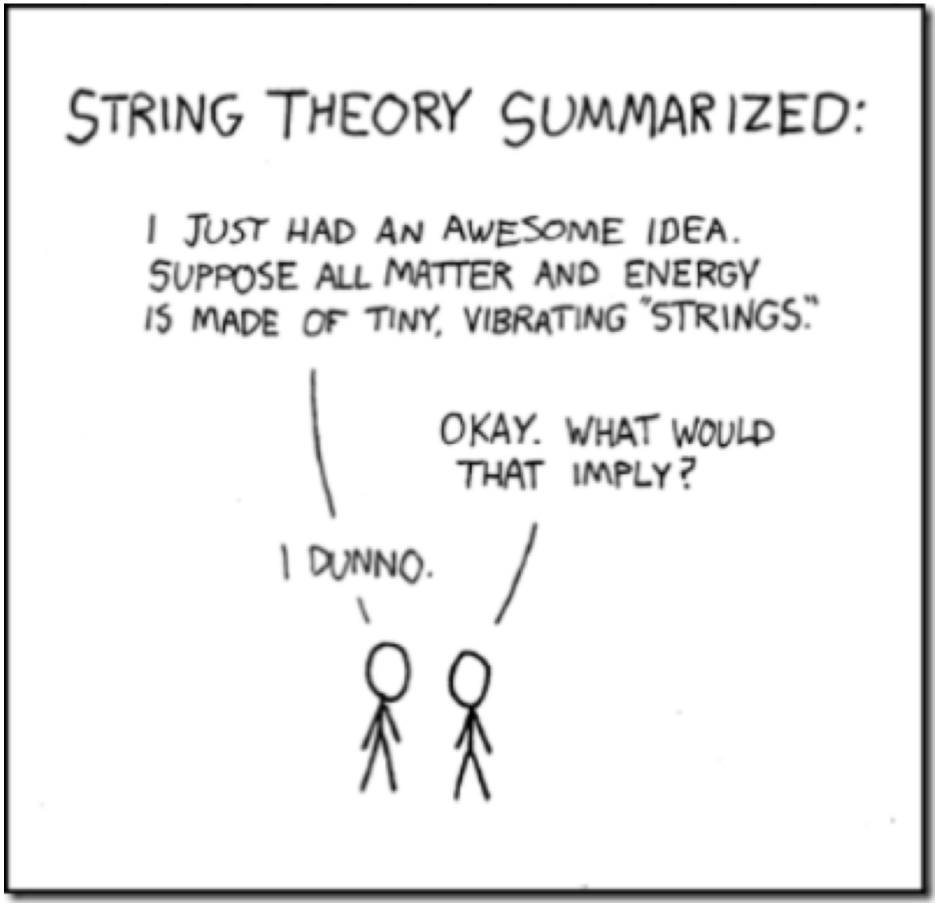
Inspiral rate bounds component masses

Higher-order corrections allow individual masses, spins to be disentangled

Polarization determines orbital plane inclination

These plus location on sky determines luminosity distance

Quantum gravity corrections to general relativity affect gravitational wave propagation



String theory consistency requires GR quantum correction

- Affects only gravitation sector
- Affects propagation: a wavenumber dependent birefringence amplifies one polarization, suppresses the other

LISA will observe cosmological sources up to z~30

- Bound/measure form-factors associated with CS correction

c_g can be measured by timing the gravitational wave signal arriving from a CWDB or a rapidly rotating neutron star

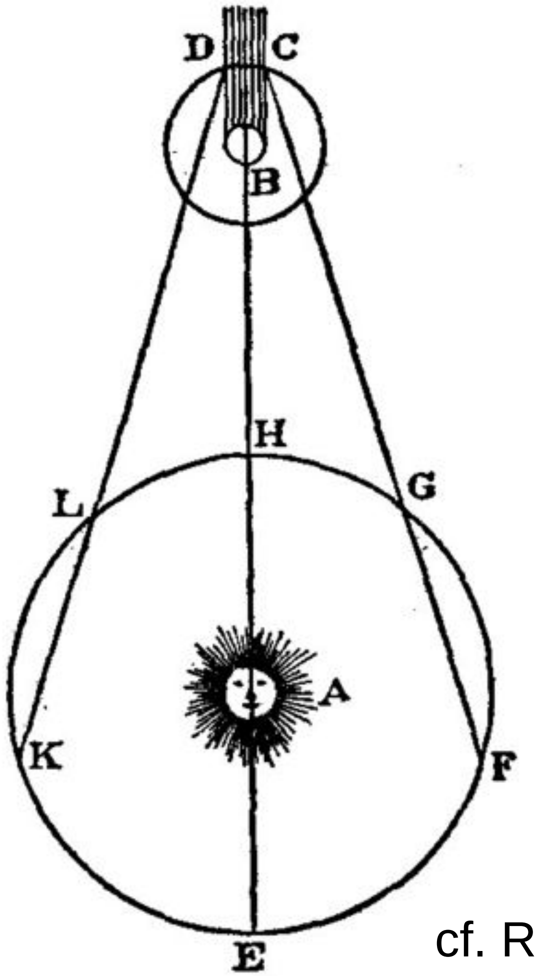


FIG. 70.

cf. Roemer Journal des Sçavans 7 Dec 1676, pg 233-6

1676: Roemer measures *c* from "Galilean Clock" arrival timing residuals over Jovian synoptic year

GW observation of a pulsar, or binary measures c_g:

$$c_g = \frac{8\pi}{\Delta\Phi_{\rm PP}} \frac{R \sin\theta}{P_{\rm NS}}$$

LISA + WD Binary: $\frac{\Delta c_g}{c} < 10^{-3}$

LIGO + Pulsar: $\frac{\Delta c_g}{c} < 10^{-6}$

General relativity can be tested by observing black hole formation

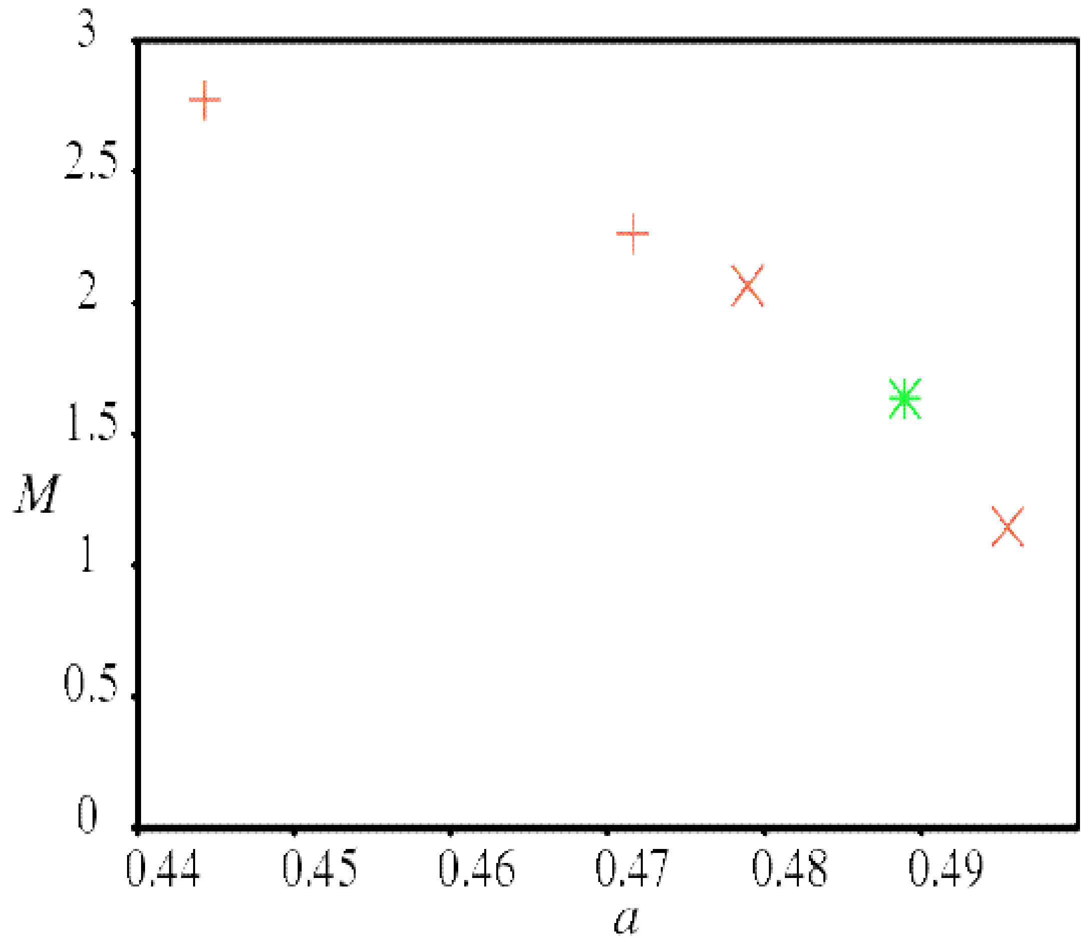
Black holes "ring"

"No-hair" theorem: frequency, damping time set by black hole mass, spin

$$h \sim \sum \exp(-t/\tau_k) \sin 2\pi f_k t$$

Observe ringing

(f_k, t_k) pairs must be consistent with single (M, a) pair



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