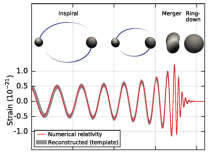


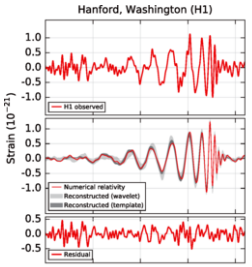
Probing the nature of compact objects with gravitational waves

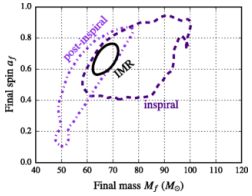
Ka Wa Tsang, Laura van der Schaaf, Archisman Ghosh, Chris Van Den Broeck

Tests of general relativity in the first observation run of Adv-LIGO

PRL **116**, 061102 (2016); PRL **116**, 221101 (2016)

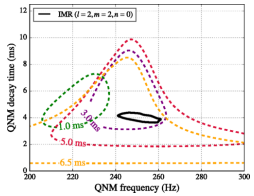
Residual of the data after subtracting the best-fit waveform is statistically consistent with detector noise at other times when no signal is present.



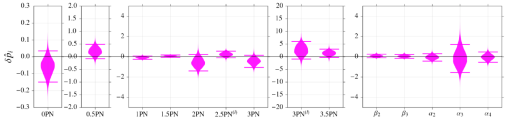


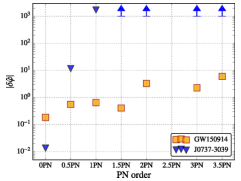
Mass and spin of the remnant object estimated from the inspiral and merger-ringdown parts agree with each other given GR predictions.

The ringdown is consistent with the presence of a least-damped quasinormal mode of a remnant black hole.



Allowing coefficients in waveform models to deviate from their GR values, the deviation parameters do not show any departure from their GR values.





The $\left(\frac{v}{c}\right)^3$ coefficient measured to $\mathcal{O}(10\%)$

Dynamical self-interaction of spacetime

Spin-orbit interaction

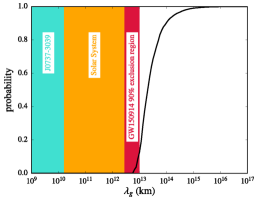
First-ever measurement of orbital dynamics beyond leading order in v/c.

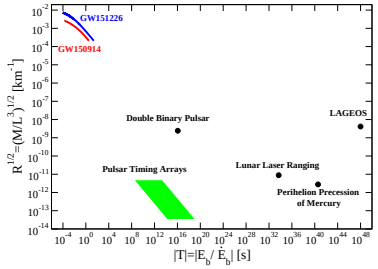
First probes into the dynamical regime of strong field general relativity.

Absence of dispersion in the wave propagation → Best dynamical bound mass of the graviton.

Yunes *et al* (2016)

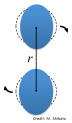
$$m_g \leq 1.2 \times 10^{-22} \mathrm{eV}/c^2$$





Black holes of general relativity or exotic compact objects?

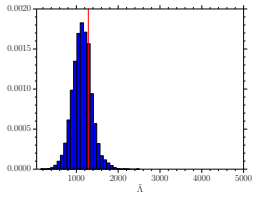
Testing for tidal effects during inspiral:

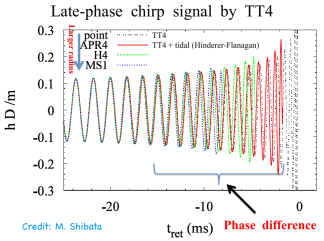


Neutrons stars in binaries are tidally deformed.

Have a measurable effect on the orbital motion.

Lackey *et al* (2014)



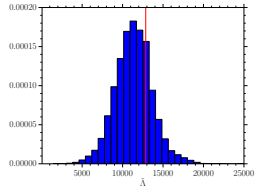


Signature in gravitational wave signal will enable constraints on the elusive neutron star equation of state.

One of the most important problems in astrophysics.

Boson stars, dark matter stars, gravastars

Exotic compact objects mimicking black holes will also exhibit tides, which can be larger than that of NS.

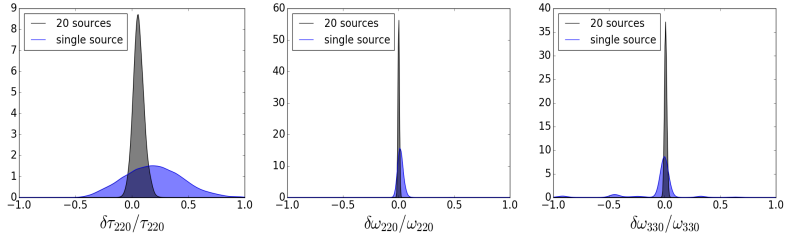


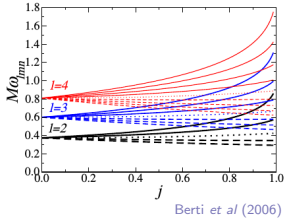
Testing the no-hair theorem with quasinormal modes:

No-hair theorem: A stationary black hole geometry in Einstein's general relativity is described only by its mass and spin.

During ringdown, the quasinormal mode frequencies and damping times will depend only on the mass and spin of the remnant black hole, which can be obtained from linearized Einstein equations on Kerr background.

⇒ Test for dependences $\omega_{lmn}(M_f, J_f)$, $\tau_{lmn}(M_f, J_f)$.





Berti *et al* (2006)

Even where it is not possible to measure the ω_{lmn} and τ_{lmn} directly, by combining information from multiple events, systematic departures in $\delta\omega_{lmn}$ $\delta\tau_{lmn}$ can be constrained.

Meidam *et al* (2014)

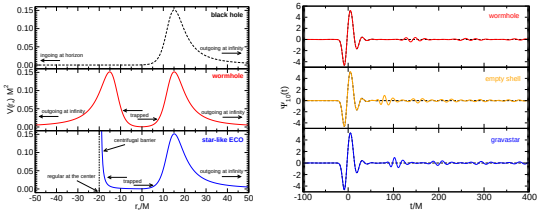
Search for "echoes" after the merger:

Planck-scale modifications → "echoes".

$$\Delta t = nM \log(M/l)$$

n=8: wormholes
n=6: thin-shell gravastars
n=4: empty shell

Cardoso *et al* (2016)



For an event like GW150914, $\Delta t = \mathcal{O}(1\mathrm{ms})$, at aLIGO design can hope to see first few echoes.

Independent of detailed models, can search for repeating bursts of radiation immediately following the binary-merger detection.