My group studies binary systems composed of black holes and/or neutron stars. Einstein’s theory of gravity, General Relativity (GR), was formulated in 1916 and passed many stringent experimental tests [1]. According to the theory, binary systems lose orbital energy to gravitational waves and get closer to each other (“inspiral”) until they finally coalesce in a violent merger. For example the double pulsar J0737-3039, discovered in 2003, will merge in about 85 million years.

Coalescing binaries are the most promising source of gravitational waves (GWs) to be observed by experiments such as LIGO (the largest physics experiment in the nation right now) or the planned space-based mission eLISA/NGO. Searching for these binaries requires an accurate knowledge of the GWs they emit. Analytical and numerical techniques must be used to understand the binary dynamics [2] (the figure shows a modern simulation of two coalescing black holes).

GW observations of these binaries will shed light on several open problems in theoretical physics and astrophysics: is Einstein’s theory correct? How can we reconcile it with quantum mechanics? Are the compact objects we see at galactic centers black holes, and how did they get there? What is dark energy?

CREDITS: NASA Goddard Numerical Relativistic Astrophysics Group; Visualization: Chris Henze, NASA/Ames

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Einstein’s GR is an extremely successful theory of gravity and a pillar of modern physics, but there are strong theoretical and experimental motivations to go beyond GR:

1) Study black hole collisions near the speed of light in four and higher dimensions: TeV-gravity scenarios, cosmic censorship, gauge/gravity duality.
2) Probe strong-field gravity using astrophysical observations of merging compact binaries or compact stars.
3) Investigate alternative theories, look for “corrections” to GR in astrophysics: hints to unify GR and quantum mechanics?

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