Spacetime ripples from dying black holes could help reveal how they formed

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This artist's concept shows a galaxy with a supermassive black hole at its core. The black hole is shooting out jets of radio waves. Image credit: NASA/JPL-Caltech

(Phys.org)—Researchers from Cardiff University have discovered a new property of black holes: their dying tones could reveal the cosmic crash that produced them.

Black holes are regions of space where gravity is so strong that not even light can escape and so isolated black holes are truly dark objects and don't emit any form of radiation.

However, black holes that get deformed, because of other black holes or stars crashing into them, are known to emit a new sort of radiation, called gravitational waves, which Einstein predicted nearly a hundred years ago.

Gravitational waves are ripples in the fabric of spacetime that travel at the speed of light but they are extremely difficult to detect.

Kilometer-sized laser interferometers are being built in the US, Europe, Japan and India, to detect these waves from colliding black holes and other cosmic events. They are sensitive to gravitational waves in roughly the same frequency range as audible sound waves, and can be thought of as a microphone to gravitational waves.

Two black holes orbiting around each other emit gravitational waves and lose energy; eventually they come together and collide to produce a black hole that is initially highly deformed. Gravitational waves from a deformed black hole come out not in one tone but in a mixture of a number of different tones, very much like the dying tones of a ringing bell.

In the case of black holes, the frequency of each tone and rate at which the tones decay depend only on the two parameters that characterize a black hole: its mass and how rapidly it spins.

Therefore scientists have long believed that by detecting the spacetime ripples of a black hole and measuring their frequencies one can measure the mass and spin of a black hole without going anywhere near it.

Ioannis Kamaretsos, Mark Hannam and B. Sathyaprakash of Cardiff University used Cardiff's powerful ARCCA cluster to perform a large number of computer simulations of a pair of black holes crashing against each other, and found that the different tones of a ringing black hole can actually tell us much more.

The team's findings will appear in the *Physical Review Letters*.

"By comparing the strengths of the different tones, it is possible not only to learn about the final black hole, but also the properties of the original two black holes that took part in the collision," explained Ioannis Kamaretsos, who performed the simulations as part of his PhD research.

He added, "It is exciting that the details of the late inspiral and merger are imprinted on the waves from the deformed final black hole. If General Relativity is correct, we may be able to make clear how very massive black holes in the centres of galaxies have shaped galactic evolution.

We never guessed it would be possible to weigh two black holes after they've collided and merged," said Dr Mark Hannam.

"We might even be able to use these results to test Einstein's general theory of relativity. We can compare the waves we observe from the orbiting black holes with the waves from the merged black hole, and check whether they are consistent," he added.

Professor B Sathyaprakash, who has spent his whole career studying gravitational waves commented: "It is quite remarkable. As in any new research, our finding opens up new questions: how accurately can we measure the parameters of the progenitor binary, whether our results hold good for more generic systems where initial black hole spins are arbitrarily oriented, etc. We will be addressing these questions in the coming years.

"Advanced gravitational wave detectors that are currently being built will provide us an opportunity to test our predictions in the coming decade."

Their research opens up a new avenue for studying the properties of the binary that produced the final black hole even when the binary itself is not visible to a gravitational wave detector. Future gravitational wave detectors should be able to study black holes far heavier than what was thought possible before and hence enhance their science reach.

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