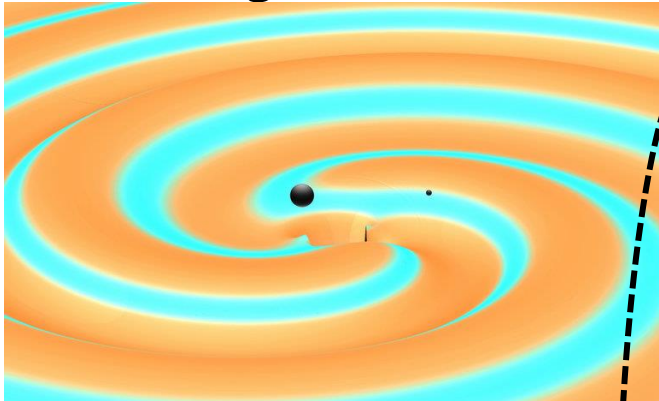


ENERGY/GRAVITATIONAL WAVES/COLLIDING FROM BLACK HOLES

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Scientists Hear a Second Chirp From Colliding Black Holes



A depiction of two black holes just moments before they collided and merged with each other, releasing energy in the form of gravitational waves.

When [astronomers announced in February](#) that they had detected the ripples in space-time known as gravitational waves from a pair of [black holes](#) colliding, the discovery was hailed as the advent of a new window on nature. It is a way of hearing the universe instead of just looking at it, as well as a long-sought vindication of Einstein's theory of gravity, general relativity. At the time, there were rumors that the discovery was not a fluke and that other gravitational-wave cataclysms had been recorded. **Now it seems that black hole collisions may be**

frequent facts of nature, with humanity at least tuned in to the darker, deeper vibrations of nature. On Wednesday, the same group of astronomers announced that they had detected a second pair of black holes that devoured each other in another cosmic cataclysm 1.4 billion years ago. In the new merger, (((black holes roughly 14 and 8 times as massive as the sun circled and combined into a single spinning black hole 21 times as massive as the sun. The collision spilled an amount of energy equivalent to the entire mass of the sun into the roiling of space-time))). After traveling

1.4 billion light years across space, those ripples shook the twin detectors of the Laser Interferometer Gravitational-Wave Observatory, or LIGO, on Dec. 26, causing it to emit a chirp about a second long. The new discovery was announced at an astronomical meeting in San Diego. The first black hole collisions, announced in February, involved black holes 36 and 29 times as massive as the sun. In a statement released by the LIGO team, Albert Lazzarini, the deputy director of the LIGO laboratory at Caltech, said that this discovery had "truly put the 'O' for Observatory in LIGO." With two detections in four months, he said, scientists could begin to make quantitative predictions on how many events they might observe and how many black holes there are in the universe.

"More gravitational-wave detectors, including one called [Virgo in Europe](#), are scheduled to come online in the near future, allowing astronomers to pinpoint the locations of these events in the sky and feel the emanations of doom ever more sensitively.

INTRODUCTION: This was the second recorded collision of two black holes in June 2016. They produced a gravitational wave of energy equivalent to the mass of one sun. Note in article the collision was between two black holes of 14 & 8 solar masses(= 22), but after collision produces a single black hole of 21 solar masses.

QUESTION: Find energy of this one solar mass equivalent gravitational wave?

HINTS: sun mass = 2×10^{30} kg. , $E = m c^2$, $c = 3 \times 10^8$ m./s.

ANSWERS: $E = \sim 1.8 \times 10^{47}$ Jouls