Did gravitational wave detector find dark matter?

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An aerial view of the Laser Interferometer Gravitational-wave Observatory (LIGO) detector in Livingston, Louisiana. LIGO has two detectors: one in Livingston and the other in Hanaford, Washington. LIGO is funded by NSF; Caltech and MIT conceived, built and operate the laboratories. Credit: LIGO Laboratory

When an astronomical observatory detected two black holes colliding in deep space, scientists celebrated confirmation of Einstein's prediction of gravitational waves. A team of astrophysicists wondered something else: Had the experiment found the "dark matter" that makes up most of the mass of the universe?

The eight scientists from the Johns Hopkins Henry A. Rowland Department of Physics and Astronomy had already started making calculations when the discovery by the Laser Interferometer Gravitational-Wave Observatory (LIGO) was announced in February. Their results, published recently in *Physical Review Letters*, unfold as a hypothesis suggesting a solution for an abiding mystery in astrophysics.

"We consider the possibility that the black hole binary detected by LIGO may be a signature of dark matter," wrote the scientists in their summary, referring to the black hole pair as a "binary." What follows are five pages of annotated mathematical equations showing how the researchers considered the mass of the two objects LIGO detected as a point of departure, suggesting that these objects could be part of the mysterious substance known to make up about 85 percent of the mass of the universe.

A matter of scientific speculation since the 1930s, dark matter has recently been studied with greater precision; more evidence has emerged since the 1970s, albeit always indirectly. While dark matter itself cannot yet be detected, its gravitational effects can be. For example, the influence of nearby dark matter is believed to explain inconsistencies in the rotation of visible matter in galaxies.

The Johns Hopkins team, led by postdoctoral fellow Simeon Bird, was struck by the mass of the black holes detected by LIGO, an observatory that consists of two expansive L-shaped detection systems anchored to the ground. One is in Louisiana and the other in Washington State.

Black hole masses are measured in terms of multiples of our sun. The colliding objects that generated the gravity wave detected by LIGO - a joint project of the California Institute of Technology and the Massachusetts Institute of Technology - were 36 and 29 solar masses. Those are too large to fit predictions of the size of most stellar black holes, the ultra-dense structures that form when stars collapse. But they are also too small to fit predictions for the size of supermassive black holes at the center of galaxies.

The two LIGO-detected objects do, however, fit within the expected range of mass of "primordial" black holes.

Primordial black holes are believed to have formed not from stars but from the collapse of large expanses of gas during the birth of the universe. While their existence has not been established with certainty, primordial black holes have in the past been suggested as a possible solution to the dark matter mystery. Because there's so little evidence of them, though, the "dark matter is primordial black holes" hypothesis has not gained a large following among scientists.

The LIGO findings, however, raise the prospect anew, especially as the objects detected in that experiment conform to the mass predicted for dark matter. Predictions made by scientists in the past held that conditions at the birth of the universe would have produced lots of these primordial black holes distributed roughly evenly in the universe, clustering in halos around galaxies. All this would make them good candidates for dark matter.

The Johns Hopkins team calculated how often these primordial black holes would form binary pairs, and eventually collide. Taking into account the size and elongated shape believed to characterize primordial black hole binary orbits, the team came up with a collision rate that conforms to the LIGO findings.

"We are not proposing this is the dark matter," said one of the authors, Marc Kamionkowski, the William R. Kenan Jr. Professor in the Department of Physics and Astronomy. "We're not going to bet the house. It's a plausibility argument."

More observations from LIGO and other evidence would be needed to support the hypothesis, including further detections like the one announced in February. That could suggest greater abundance of objects of that signature mass.

"If you have a lot of 30-mass events, that begs an explanation," said co-author Ely D. Kovetz, a postdoctoral fellow in physics and astronomy at Johns Hopkins. "That the discovery of gravitational waves could be connected to dark matter" is creating lots of excitement among astrophysicists, he said.

"It's got a lot of potential," Kamionkowski said.

More information: Simeon Bird et al, Did LIGO Detect Dark Matter?, *Physical Review Letters* (2016). DOI: 10.1103/PhysRevLett.116.201301

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