Gravitational wave detectors might be able to detect dark matter particles colliding with their mirrors

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The Laser Interferometer Gravitational-Wave Observatory (LIGO) is made up of two detectors, this one in Livingston, La., and one near Hanford, Wash. Credit: Caltech/MIT/LIGO Lab

The field of astronomy has been revolutionized, thanks to the first-ever detection of gravitational waves (GWs). Since the initial detection was made in February of 2016 by scientists at the Laser Interferometer Gravitational-wave Observatory (LIGO), multiple gravitational events have been detected. These have provided insight into a phenomenon that was predicted over a century ago by Albert Einstein.

As it turns out, the infrastructure that is used to detect GWs could also crack another astronomical mystery: dark matter. According to a new study by a team of Japanese researchers, laser interferometers could be used to look for weakly interacting massive particles (WIMPs), a major candidate particle in the hunt for dark matter.

To recap, WIMPS are a theoretical elementary particle that interacts with normal matter (baryonic) only through the "weak" force gravity. As with other elementary particles that are part of the Standard Model (of which WIMPS are not), they would have been created during the early universe when the cosmos was extremely hot.

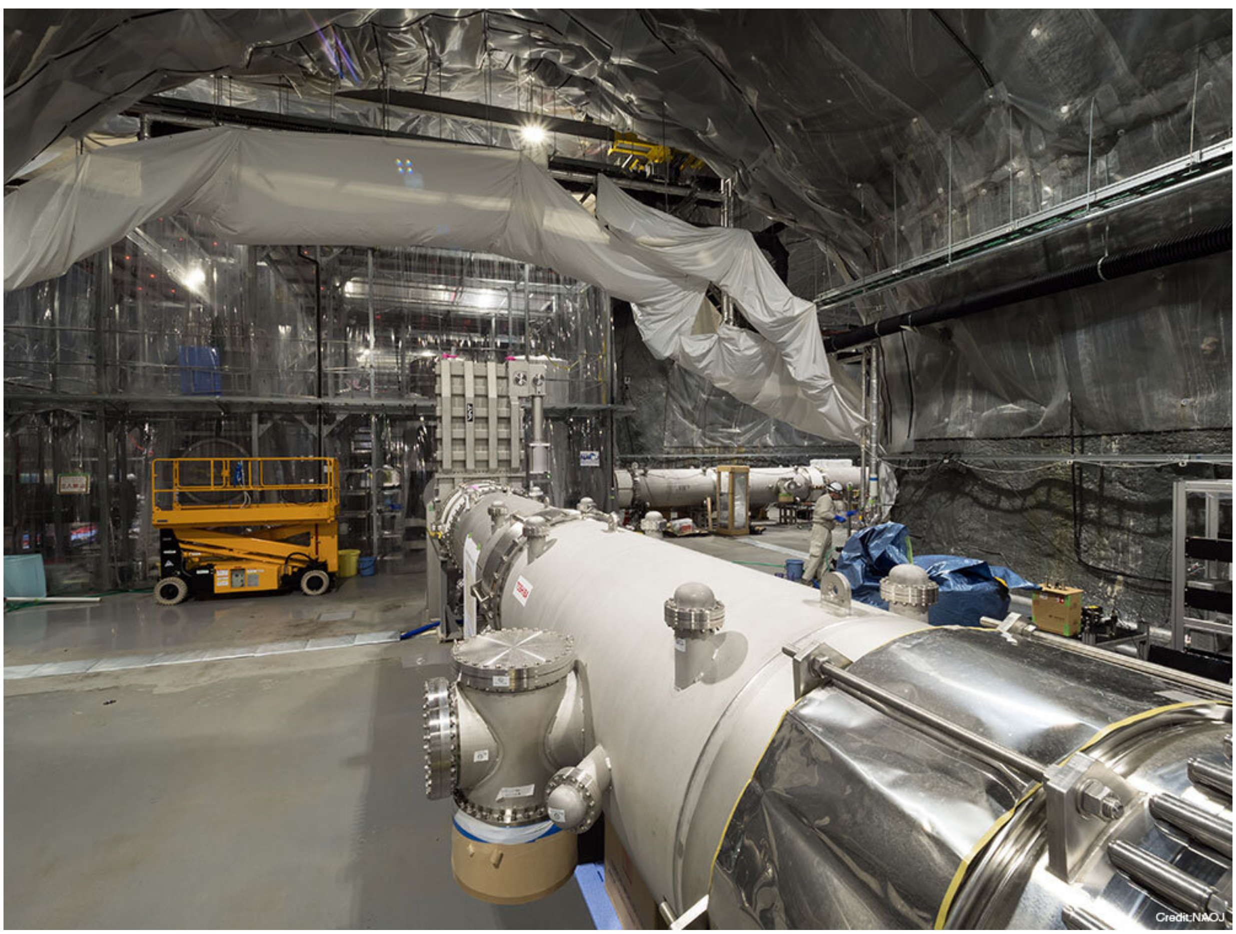
WIMPs are essentially the microscopic candidate particle, which puts them at the opposite end of the spectrum from the other major candidate—the macroscopic massive compact halo objects (MACHOs). So far, multiple experiments have been conducted to find these particles, ranging from particle collisions and indirect detections to more direct methods, but the results have been largely inconclusive.

As Dr. Satoshi Tsuchida, a professor of physics at Osaka City University and the lead author of the study, told *Universe Today* via email:

"[Most] MACHOs are believed to consist of baryonic matter, but baryons account for only 5 percent of the universe. Thus, we cannot explain the structure of the present universe if all of dark matter consists of MACHOs. On the other hand, WIMPs are non-baryonic matter, and we have no reason to exclude [them] from dark matter… Therefore, WIMPs can be promising dark matter candidates."

For the sake of their study, the research team (which includes members from Osaka University's Nambu Yoichiro Institute of Theoretical and Experimental Physics and Ritsumeikan University) propose a new search method that takes advantage of recent advances in gravity wave detection. Using the same method to detect ripples in space-time, they argue that WIMPs could also be detected for the first time.

This would constitute a "direct detection" approach using laser interferometers, a method that has been proposed in the past. However, this method has not yet been tested, in part because scientists have not yet calculated what kinds of signals will be caused by direct interactions between WIMPs and nucleons in a laser interferometer's mirror.



The KAGRA observatory undergoing upgrades. Credit: NOAJ

However, the research team argues that the motions of a pendulum and mirror in a GW detector will become excited due to a collision. The research team analyzed these motions and estimated how detectable they would be to a system of highly sophisticated sensors like those used by LIGO and other GW detectors.

From this, the team was able to provide a framework that could come in handy for future research. "Thus, our method might [provide] some new knowledge for dark matter [research]," said Dr. Satoshi. "The next-generation GW detectors have better sensitivity than current-generation ones, so the signal-to-noise ratio would be improved by some orders of magnitude."

"If we can establish a method to extract the dark matter signals on GW detector, the method could play [an] important role to elucidate the nature of WIMPs by [an] independent approach," he added. "Thus, our study might help in revealing the structure of the universe not only at present, but also in the past and future."

These include the Kamioka Gravitational wave detector, Large-scale Cryogenic Gravitational wave Telescope (KAGRA) in Japan—which is currently being upgraded—and the Einstein Telescope (ET), a third-generation European detector that is still in the design phase. When these come online and join LIGO and the Virgo observatory in Italy, they will allow for an unprecedented rate of detection.

This is not the first time that scientists have suggested other applications for GW research. For instance, an international team of scientists recently proposed that GWs could be used to study dwarf galaxies in the hopes of seeing how they are dominated by dark matter. Another proposal is using GWs to measure the expansion rate of the universe—a method that could tell us a great deal about the nature and influence of dark energy.

More information: Satoshi Tsuchida, et al. Dark Matter Signals on a Laser Interferometer. arxiv.org/abs/1909.00654 arXiv:1909.00654v2 [astro-ph.HE]

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