

Team predicts a universe crowded with black holes

June 22 2016



This is the "South Pillar" region of the star-forming region called the Carina Nebula. Like cracking open a watermelon and finding its seeds, the infrared telescope "busted open" this murky cloud to reveal star embryos tucked inside finger-like pillars of thick dust. Credit: NASA

A new study published in *Nature* presents one of the most complete models of matter in the universe and predicts hundreds of massive black hole mergers each year observable with the second generation of gravitational wave detectors.

The model anticipated the massive [black holes](#) observed by the Laser Interferometer Gravitational-wave Observatory. The two colliding masses created the first directly detected [gravitational waves](#) and confirmed Einstein's general theory of relativity.

"The universe isn't the same everywhere," said Richard O'Shaughnessy, assistant professor in RIT's School of Mathematical Sciences, and co-author of the study led by Krzysztof Belczynski from Warsaw University. "Some places produce many more binary black holes than others. Our study takes these differences into careful account."

Massive [stars](#) that collapse upon themselves and end their lives as black holes, like the pair LIGO detected, are extremely rare, O'Shaughnessy said. They are less evolved, "more primitive stars," that occur in special configurations in the universe. These stars from the early universe are made of more pristine hydrogen, a gas which makes them "Titans among stars," at 40 to 100 solar masses. In contrast, younger generations of stars consumed the corpses of their predecessors containing heavy elements, which stunted their growth.

"Because LIGO is so much more sensitive to these heavy black holes, these regions of pristine gas that make heavy black holes are extremely important," O'Shaughnessy said. "These rare regions act like factories for building identifiable pairs of black holes."

O'Shaughnessy and his colleagues predict that massive black holes like these spin in a stable way, with orbits that remain in the same plane. The model shows that the alignment of these massive black holes are impervious to the tiny kick that follows the stars' core collapse. The same kick can change the alignment of smaller black holes and rock their orbital plane.

The calculations reported in *Nature* are the most detailed calculations of

its kind ever performed, O'Shaughnessy said. He likens the model to a laboratory for assessing future prospects for gravitational wave astronomy. Other gravitational wave astronomers are now using the model in their own investigations as well.

"We've already seen that we can learn a lot about Einstein's theory and massive stars, just from this one event," said O'Shaughnessy, also a member of the LIGO Scientific Collaboration that helped make and interpret the first discovery of gravitational waves. "LIGO is not going to see 1,000 black holes like these each year, but many of them will be even better and more exciting because we will have a better instrument—better glasses to view them with and better techniques."

O'Shaughnessy is a member of RIT's Center for Computational Relativity and Gravitation where he collaborates with Carlos Lousto, professor in RIT's School of Mathematical Sciences and a member of the LIGO Scientific Collaboration.

"We feel like parents of a beautiful daughter called gravitational wave astronomy born a few months ago and seeing her grow more gorgeous by the day," Lousto said.

More information: The first gravitational-wave source from the isolated evolution of two stars in the 40–100 solar mass range, *Nature*, [nature.com/articles/doi:10.1038/nature18322](https://doi.org/10.1038/nature18322)

Provided by Rochester Institute of Technology

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