# Researchers create new method for identifying black holes

June 29 2016, by Susan Gawlowicz

Rochester Institute of Technology professors have developed a faster, more accurate way to assess gravitational wave signals and infer the astronomical sources that made them.

Their method directly compares data from the Laser Interferometer Gravitational-wave Observatory to cutting-edge numerical simulations of binary black holes, including simulations performed at RIT.

In a paper available online, the LIGO Scientific Collaboration reanalyzed the first gravitational wave detections using this method. Insights from these simulations indicate that the first detected black holes were slightly more similar in mass than previously thought. RIT authors on the paper include faculty Richard O'Shaughnessy, Manuela Campanelli, Carlos Lousto, John Whelan and Yosef Zlochower; postdoctoral researcher James Healy; graduate students Jacob Lange and Yuanhao Zhang; and undergraduate student Monica Rizzo and recent graduate Jackson Henry. They are all members of RIT's Center for Computational Relativity and Gravitation and the LIGO Scientific Collaboration.

"It is the first time numerical simulations of binary black holes are used directly to estimate the parameters of a binary and, in this paper, it is proved that this can be done to the highest accuracy," Lousto said.

A validation study of the method is being done by Lange, a Ph.D. student in RIT's astrophysical sciences and technology graduate program.

"Our approach compares waveforms directly to numerical relativity simulations to reanalyze the first gravitational wave detection," he said.

Lange's research supports Lousto and O'Shaughnessy's efforts to enhance a new gravitational wave-data pipeline using targeted simulations. O'Shaughnessy presented the paper earlier this month at the Gravitational Wave Physics and Astronomy Workshop in Cape Cod, Mass.

"Most of the interesting information arrives at the end where the black hole does its most wild motions and all the cool physics of Einstein's theory really comes to the fore," said O'Shaughnessy, assistant professor in RIT's School of Mathematical Sciences. "We think by simulating the most interesting part and attaching the simple part, we'll be able to do some really interesting science that is not possible any other way."

RIT scientists played a key role in the LIGO Scientific Collaboration's landmark discovery. Their simulated signal independently verified the observed waveform produced by the black hole merger and helped confirm Einstein's general theory of relativity. This new study demonstrates the role of simulated signals in the analysis of gravitational waveforms.

"These simulations are what we have leveraged for all these years to get all the insight we have about how black holes merge and their gravitational radiation," O'Shaughnessy said. "They are the most complete and accurate models of binary black-hole coalescence."

Simulations of black holes with different masses and spins that match, or which are oddly aligned, require the complex mathematics of Einstein's strong field equations. O'Shaughnessy collaborated on the data pipeline with Lousto, a leader in the field of numerical relativity, who simulates black holes scenarios on supercomputers.

Their approach uses simulations to extract information about the black holes' properties directly from the gravitational wave data. By contrast, the initial analyses of the first gravitational waves used approximations derived from previous simulations to gain insight.

"Richard's method allow us to avoid the intermediate step and is faster and more accurate," said Lousto, professor in RIT's School of Mathematical Sciences and fellow of the American Physical Society. "The method always improves itself because with every new simulation, it adapts. It can only get better."

Lousto's simulations apply the computational techniques from the 2005 landmark research he conducted with Campanelli, director of the RIT's Center for Computational Relativity and Gravitation and a member of the LIGO Scientific Collaboration, and Zlochower, associate professor in RIT's School of Mathematical Sciences.

**More information:** arxiv.org/abs/1606.01262

Provided by Rochester Institute of Technology

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