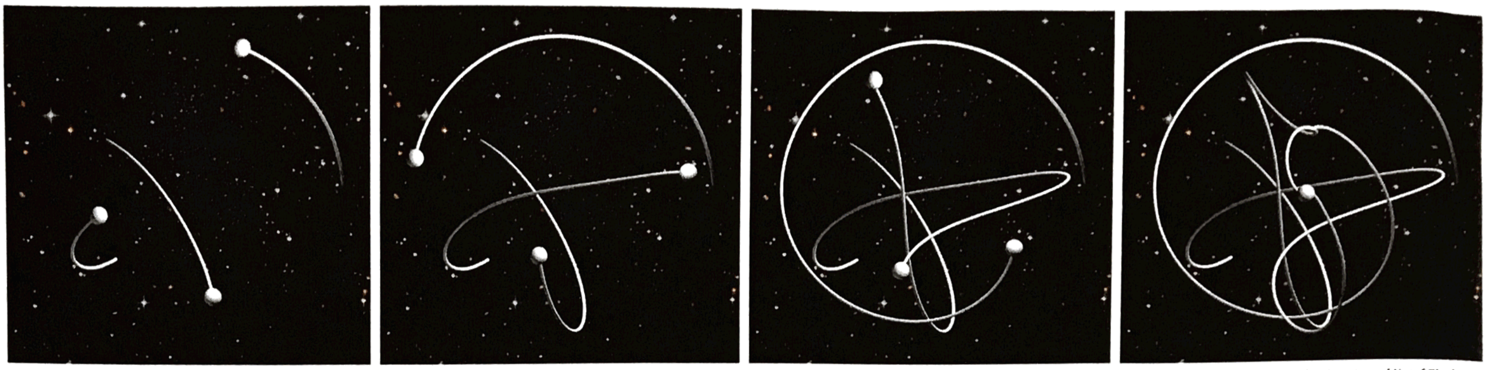

Visualization by Hans-Peter Bischof. Simulation by Manuela Campanelli, Carlos Lousto and Yosef Zlochower

A scientific visualization of the inspiral and merger of three black holes and their trajectories done by CCRG researchers.

RIT scientists have long reached for the stars

BY SUSAN GAWLOWICZ

Scientists who built their careers on Einstein's general theory of relativity rejoiced when the biggest discovery in a century confirmed his predictions.

For them, the February announcement of the first detection of gravitational waves by the Laser Interferometer Gravitational-wave Observatory, or LIGO, was not just a validation of their life's work. It was the launch of a whole new field of physics scholarship, as they immediately got to work compiling results and publishing papers, more than a dozen so far.

Four RIT faculty and their research team contributed to LIGO's breakthrough discovery, which detected signals emitted from a black-hole collision 1.3 billion light years away. RIT's LIGO team is preparing for the first-ever black-hole census when LIGO begins its second operational run this summer.

But the seeds for their current success were planted a long time ago by something in their lives that drew them to become scientists.

Manuela Campanelli

From an early age, Manuela Campanelli was fascinated by black holes. Her curiosity was sparked by Carl Sagan's television program *Cosmos* and other documentaries she watched growing up in Biel, Switzerland. Her parents encouraged her passion for math and physics and her pursuit of a career in science.

Her education took her to the University of Perugia in Italy and then back to Switzerland for graduate work at the University of Bern, a town where Einstein developed his famous theory.

While working on her Ph.D. in 1991, she attended a black hole conference in Sicily. There she met Carlos Lousto, also a scientist. The couple married and accepted a series of post-doctoral fellowships that took them to the University of Utah in Salt Lake City, the Max Planck Institute in Germany and then to the University of Texas at Brownsville. While at UT, they formed a group of young faculty wrestling with Einstein's equations on supercomputers.

In Campanelli, Einstein's theories met their match. Her landmark 2005 research simulated the merger of two black holes on a supercomputer and the gravitational waves that flowed from it like ripples in water. The work coincided with different solutions revealed that year by two other teams. Those predictions were confirmed in 2015 when the signal detected by LIGO matched the numerical model of the waveform produced by Lousto and James Healy, a postdoctoral fellow at the RIT center.

Today, Campanelli is a professor in RIT's School of Mathematical Sciences and founder and director of the Center for Computational Relativity and Gravitation. She joined RIT in 2007 with her co-authors Lousto and Yosef Zlochower.

For Campanelli, the exciting part of the LIGO discovery was seeing how closely her 2005 mathematical predictions of gravitational waves mirrored the natural phenomenon.

"I couldn't believe it the first time I saw what LIGO had detected and how close it looked to the waveform we had modeled on a supercomputer," she said. "That was mind-blowing to me. It was almost unreal."

Campanelli's current research models the dynamics of extreme astrophysical scenarios.

She is simulating black holes that eject jets of hot gas and the disks of matter that surround and feed them. She is eager to explore multimessenger astronomy—a hybrid approach that will combine information collected from gravitational waves and from the electromagnetic spectrum.

"Multimessenger astronomy will give us new insights and broaden our understanding of the universe," Campanelli said. "We expect surprises."

Carlos Lousto

The Latin American media has turned Buenos-Aires-born Carlos Lousto into a rock star. The astrophysicist's interviews have appeared in numerous prominent Spanish-language papers and on television and radio news programs. Popular Argentine Senator and former Formula-One race car driver Carlos Reutemann even recognized Lousto and his Argentine colleagues for their fundamental contributions to the discovery of gravitational waves.

Lousto feels strongly about communicating science to the public. He says he does it out of personal responsibility and in gratitude for his education.

Lousto's parents made sacrifices for his education in difficult economic circumstances. His father operated equipment at a steel mill and ensured that his only son went to school. Lousto commuted two hours by train to attend the public university, rising at 5 a.m. and returning after 10 p.m. His hard work and commitment paid off. He earned the highest grades and became the university's representative at national celebrations. Educational opportunities in Argentina, France and Germany would follow.

Lousto and Campanelli have made the pursuit of gravitational waves and binary black holes a shared passion. The inclusion of their numerical relativity research strengthened the LIGO data analysis and confirmed their prediction of the signal's appearance emitted by colliding black holes, Lousto said.

"It is not only that we have detected gravitational waves accurately," Lousto said. "In addition, this waveform could have been from anything, but it happened to be exactly what we predicted for the collision of black holes."

The signal and the black holes that created it tested the core predictions of Einstein's theory.

"It was a pass-or-fail test. Now general relativity is as well established as the other forces that allow us to describe the universe as we know it."

In Lousto's opinion, the question now shifts to describing the behavior of matter in extreme astrophysical conditions, such as the collisions of black holes and neutrons stars.

"It's exciting for the next generation of researchers and students," Lousto said. "They have a clear path in the future with ground and space technology that is in line for the next 20 years. They are the ones who will become the new gravitational wave astronomers."

Richard O'Shaughnessy

Richard O'Shaughnessy's wide-ranging interest in science found a sharp focus when he took his first class in general relativity during his junior year at Cornell University.

"I realized—Wow!—general relativity is fantastic," O'Shaughnessy said. "I suddenly understood many other things better than I did before because of the way that Einstein thinks about gravity and matter interactions is an incredibly beautiful and simple thing, if you look at it in the right way."

In graduate school at Caltech, O'Shaughnessy studied under Kip Thorne, one of the early proponents of LIGO's search for gravitational waves.

"Kip makes sure his students are broadly trained and able to master theory and extract information from the real world," O'Shaughnessy said. "That meant in addition to doing general relativity, I was doing LIGO experimental design, figuring out how to make LIGO as sensitive as it could be."

Years later, O'Shaughnessy's role on RIT's LIGO team focuses on the astrophysical implications. He predicts what LIGO will see and interprets what it observes. He asks himself, "What did we learn that we didn't know before?"

The avalanche of data produced early in LIGO's first operational run took O'Shaughnessy and his colleagues by surprise.

"We thought we had a few more months to get things organized," he said. "It was a bit of a hectic rush to get everything done in time."

O'Shaughnessy is expecting several times more information from the second operational run, jumpstarting an "explosion of discovery" as the detectors' sensitivity ramps up over the next few years.

"This is only the tip of the iceberg," O'Shaughnessy said. "I think we're on the cusp of a revolution in our understanding of how massive stars evolve, of how all the gold in the universe is formed—neutron stars are probably responsible for the process that made gold. And I expect to see a lot more black holes."

John Whelan

John Whelan, associate professor in RIT's School of Mathematical Sciences, is quick to name astronomer Carl Sagan when thinking about childhood heroes. Whelan, who grew up in the Hudson Valley, in Kingston, N.Y., soaked up every episode of Sagan's television program, *Cosmos*. Later on, Whelan attended Cornell University where the famous scientist taught.

Whelan's interest in math was also fostered by an uncle who taught at East Tennessee State University and gave him books about mathematical games, spatial geometry and probability. One book, *How to Take a Chance*, by Darrell Huff, stoked Whelan's interest in statistics and probability. Those mathematical tools led to a hobby and professional endeavors.

In the late 1990s, Whelan, a self-described "college hockey geek," coded formulas to work out tiebreakers of the Eastern Collegiate Athletic Conference hockey league and selection criteria for the National Collegiate Athletic Association tournament. College Hockey News hosts his script, "You are the Committee," on its website the week before tournament selection, enabling fans to predict rankings from different outcomes of the competition.

"The problem that I've been interested in is, given the game results, how do you evaluate the teams?" Whelan said. "It's important in college sports because you're trying to compare teams that play different schedules. And you have the problem of having to decide who you send to the tournament."

The computational exercise of writing algorithms for sports statistics honed his skills for astrophysical applications. As a postdoctoral researcher at University of Texas at Brownsville in 2000, Whelan constructed the data analysis pipeline that would make some of the first searches in the LIGO Scientific Collaboration with simulated and real data.

Following faculty and research positions in LIGO groups at Loyola University New Orleans and the Albert Einstein Institute in Potsdam, Germany, Whelan brought his expertise in gravitational wave analysis to the Center for Computational Relativity and Gravitation in late 2008 and became the principal investigator of RIT's group in the LIGO collaboration.

For Whelan, using math to accurately predict a scenario is akin to solving a puzzle.

"You figure out with the math that something should work," he said. "And then you run it on the data and you see it works the way the math said it was supposed to. When it works I feel almost a sense of wonderment. Maybe it just gives you a sense of confidence that your picture of the world makes sense." ■

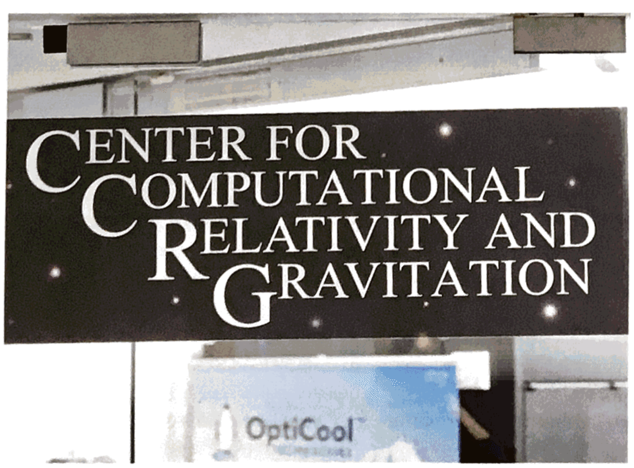

Photo by A. Sue Weisler

Photo by University of Florida / S. Barke

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From left, Center for Computational Relativity and Gravitation; an artist's impression of gravitational waves; and astrophysicist Carlos Lousto in the black hole lab.