A WINDOW OPENS TO THE UNIVERSE

LSU PHYSICIST INSTRUMENTAL IN ONE OF THE LARGEST SCIENTIFIC DISCOVERIES OF OUR TIME

SINCE THE BEGINNING OF CIVILIZATION, HUMANS HAVE LOOKED TO THE SKY FOR guidance, whether charting a destination by the stars, measuring time by the sun, or attempting to determine what lies beyond our planet. On Feb. 11, 2016, the scientific community took another leap forward when researchers announced the first-ever detection of gravitational waves, predicted by Albert Einstein's 1915 general theory of relativity, ushering in a new era of cosmic observation.

BY TAMARA MIZELL AND ALISON SATAKE | PHOTOS BY LSU STRATEGIC COMMUNICATIONS

Einstein hypothesized that massive objects could warp or bend spacetime. So, for example, a pair of black holes orbiting near one another would eventually collide, forming a single, more massive black hole. Part of their combined mass is converted to energy, following Einstein's formula, E=mc2. This energy is emitted as a burst of gravitational radiation, which travels outward like ripples on a pond. These ripples, or gravitational waves, are what researchers hoped to measure – and they succeeded. In this first-ever physical detection of gravitational waves, scientists were able to conclude that the collision and subsequent merger of two black holes happened approximately 1.3 billion years ago.

LSU Department of Physics & Astronomy Professor Gabriela González has played a central role in this groundbreaking discovery. She has served as the spokesperson for the large, international scientific collaboration that detected gravitational waves called the LIGO Scientific Collaboration, or LSC. She is also an experimental physicist whose research involves the reduction of noise to enhance the sensitivity of the gravitational wave detectors at the Laser Interferometer Gravitational-wave Observatories, or LIGO, as well as calibration of the detectors and analyzing the data.

The U.S. has two LIGO detectors. One is in Livingston, La. and the other is in Hanford, Wash. LIGO Livingston is the only detector within driving distance to a major research university – LSU.

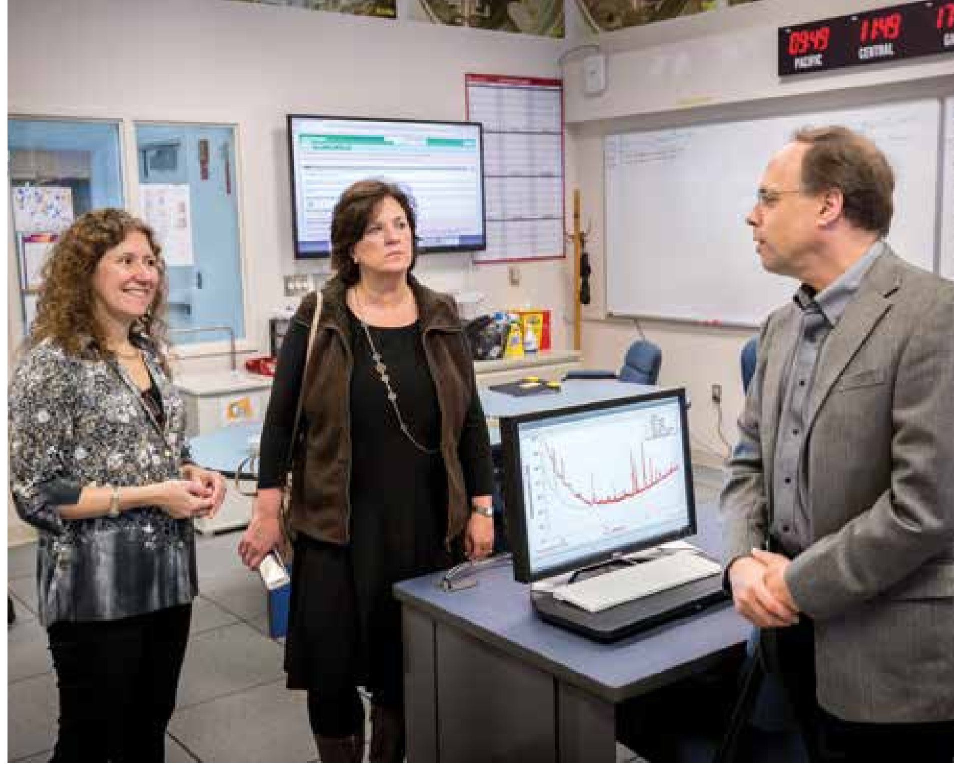
"LSU has had a very unique partnership with LIGO because we are so close to the Livingston observatory. I'm a professor at LSU, but my work became very important for the field because of the work that I do at LIGO Livingston. That's how I became spokesperson, eventually. And that's true of our students who are also considered critical pieces of this enterprise. They've been able to have that kind of contribution much better and more efficiently than students at other institutions, because they're here," González said.

She has served as spokesperson of the 1,000 member international LIGO Scientific Collaboration, or LSC, for the past five years and is the longest serving elected LSC spokesperson. She has received accolades for her work from around the world including being named as one of the top 10 scientists in the world by the scientific journal Nature, Scientist of the Year by Great Minds in STEM, and one of the top 100 Leading Global Thinkers by Foreign Policy magazine for the LSC. On behalf of the LSC, she received the 2016 Breakthrough of the Year from Physics World for "their revolutionary, first-ever direct observations of gravitational waves."

González was born and raised in Córdoba, Argentina. She studied physics at the University of Córdoba, where she earned her undergraduate college degree. She recently was awarded the highest distinction from the Senate of Argentina, the Honorable Domingo Faustino Sarmiento award.

She came to the U.S. to pursue and attain her Ph.D. from Syracuse University. Her doctorate focused on Brownian motion and gravitational waves. Her work took her to universities across the U.S. including MIT, Penn State, and LSU.

France Cordova, director of the National Science Foundation, left, with Gabriela González at LIGO-Livingston. NSF has invested about $1.1 billion in this project over the past forty years to cover research and development, student education, facilities construction, and staffing. It provides about $50 million per year for research. LIGO Livingston's annual budget is $6-9 million per year and is fully funded by NSF.



Top photo: LSU Physics & Astronomy graduate students celebrate the detection of gravitational waves at LIGO-Livingston. LSU student researchers have been a part of the LIGO Scientific Collaboration work. Bottom photo: With other leaders and founders of the LIGO effort, Gabriela González made the official statements and took questions starting at the National Press Club in Washington, D.C., before gathered national science press. The announcement was also live-streamed online. "This detection is the beginning of a new era. The field of gravitational wave astronomy is now a reality," González said.

Gabriela González, left with College of Science Dean Cynthia Peterson and Joseph Giaime, professor of physics & astronomy and head of LIGO-Livingston.

WHAT'S MORE EXCITING IS THAT THE FUTURE IS NOW HERE. WE NOW KNOW THAT WE'LL BE DETECTING MORE OF THESE, AND WE REALLY HAVE AN OBSERVATORY. THE GOAL WAS NOT TO DETECT THE FIRST GRAVITATIONAL WAVE; IT WAS TO DETECT GRAVITATIONAL WAVES - PLURAL.

THE LIGO SCIENTIFIC COLLABORATION

A century after Einstein predicted the existence of gravitational waves, representatives from the National Science Foundation, or NSF, which funds LIGO, along with researchers from Caltech, MIT, LSU, and the LSC took to the podium in Washington, D.C., to announce their findings at a National Press Club press conference.

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The LIGO Livingston observatory is located on LSU property, and LSU faculty, students, and research staff are major contributors to the fifteen-nation, international LSC. More than 1,000 scientists from universities across the U.S. and fourteen other countries conduct LIGO research as members of the LSC. More than ninety universities and research institutions in the LSC develop detector technology and analyze data; about 250 students are contributing members of the collaboration.

LSU's investment in gravitational wave detection spans more than four decades, and is among the longest of the institutions contributing to the present discovery. LSU faculty, students, and scholars have had leading roles in the development of several generations of gravitational wave detectors, in their commissioning and operation as well as the collaborations formed. This achievement is in part an outcome of LSU's long-term vision and commitment to high-risk, high-potential scientific research.

PICKING UP THE SIGNAL: GW150914

While the announcement came in February, the waves were actually detected on Sept. 14, 2015, at 4:51 a.m. CST by both of the twin LIGO detectors in Louisiana and Washington state. González and other top LIGO researchers woke up to text messages and emails from scientists who were analyzing data from an engineering run, during which systems were being tested prior to the planned observational run. Since the universe never sleeps, researchers got an early wakeup call that day.

"Even in the beginning, for the first few hours, I thought somebody had made a mistake and that this was a test. So it took some time – a few hours for me, a few weeks for others – to convince ourselves that this was not a test, that this was a candidate," González said.

Once the suspected waves were detected, teams sprang into action to execute detection procedures: first, more data had to be taken and analyzed; then it had to be reviewed for errors or inconsistencies; and a paper had to be written and submitted for review to outside referees who would further analyze the findings. Once the results were confirmed by outside referees, the LSC team announced them to the world.

The analysis of the full data taken with LIGO detectors between September 2015 and January 2016 revealed another detection of gravitational waves on Dec. 26, also from the merger of a different pair of smaller black holes. When announced in June, it proved the beginning of a new era for gravitational wave astronomy.

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From this breakthrough, we will be able to learn more about gravity near a black hole, where spacetime is warped, but that's only the beginning. LSC scientists continue to conduct research on the existing data and expect to detect more astronomical events as the LIGO detectors and technology become more sensitive, and the European gravitational wave detector, VIRGO, located in Cascina, Italy, begins to collect data. They anticipate detecting other events, including neutron stars in our galaxy, other black holes, and supernova explosions.

"I actually have been saying for a long time that I wasn't looking forward to the first detection, I was looking to get past the first detection," González said. "What's more exciting is that the future is now here. We now know that we'll be detecting more of these, and we really have an observatory. The goal was not to detect the first gravitational wave; it was to detect gravitational waves – plural."

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Q&A WITH GABRIELA GONZÁLEZ

What has been the most exciting moment, for you, through this process from the first detection until now?

G It was seeing the reactions of people, the questions we had, how everybody was watching and reacting to this so favorably after the announcement. I was kind of expecting some more skeptical questions and people saying, "Well, we should wait and see." But everybody was so excited about this, and the general public wanted to know more. And it's been like that since then; it hasn't died down. It's been a steady stream of excitement.

Average Americans may not understand what this discovery means to their everyday lives. How would you simplify this accomplishment in a way that makes it relevant and understandable?

G Well, we have no idea—and, in general, scientists have no idea—which discoveries will later turn out to be useful for technology. So we have to keep making them. But I think that there are two aspects of this that gets everybody inspired: one is that this proves, not just with math equations from Einstein but from measurements, that the spacetime in which we all live is moving around. We measured this here on Earth. It's moving around; it's not static. You think that the distance between you and me, if we don't move, is set, but it's not. And that just changes the way you think about the universe. The universe is a very, very dynamic place. The other thing that I have learned that inspires everybody, more than I thought, is that we are always looking at the sky, and we want to understand what's out there. So, in this instance, you're looking at the sky and these ripples are coming to you from so, so long ago. So it's like we're beginning to hear the universe, instead of just seeing it.

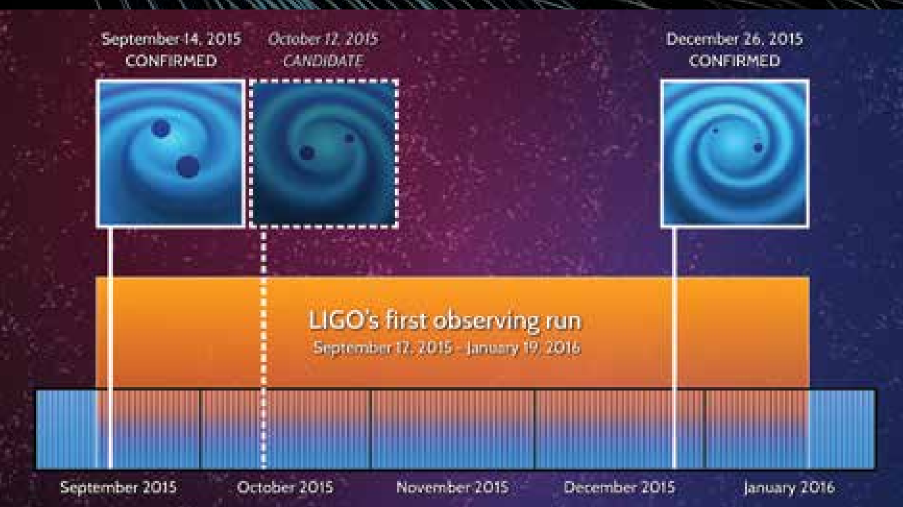
We all know that we need lasers for everything now – in medicine, in movies, and so on – but when lasers were invented, people didn't believe they had any application and said, "Oh, this is a solution looking for a problem." And even with relativity, we tend to think about this as a mathematical way of describing the universe, but it's more real than that; you have to use relativity to get GPS right. So now, relativity is essential to our lives; we all use GPS.

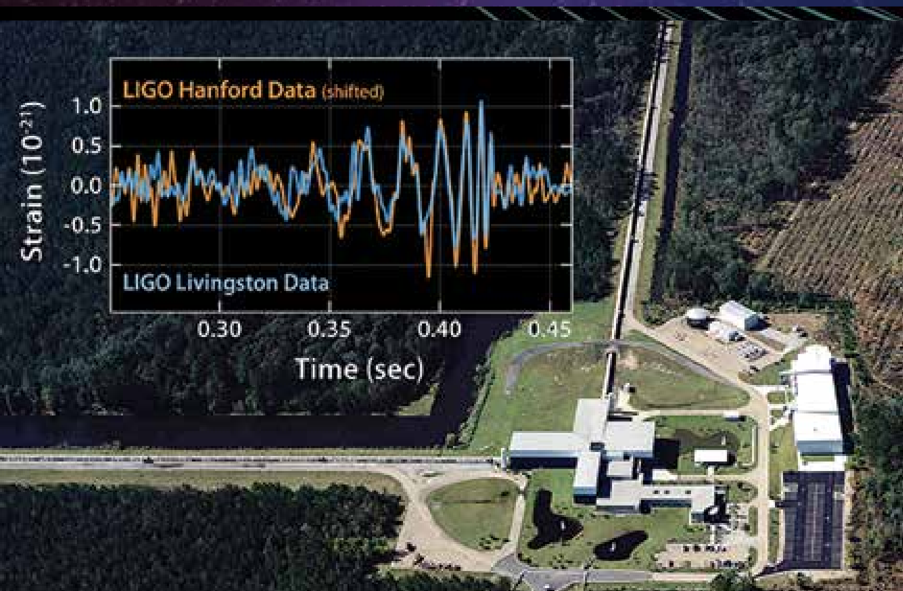
What do you say to people who believe this discovery indicates that time travel is now possible?

G This doesn't have anything to do with time travel. It does have to do with time being part of spacetime. When we say that distances get stretched and squeezed, it's actually spacetime—so time gets stretched and squeezed too. We knew that, but now we've measured it. But that's not the same as time travel. You can go faster or slower towards the future, but not back in time...yet.

What advice would you give to young people, particularly to young women, who want to go into scientific fields?

G Ask questions! Ask questions of everybody. And when people say they don't know—because you have to ask questions to people who know the answers, and sometimes you don't know who knows the answers—keep asking. Now, with social media, with the Internet, you can email anybody. We receive questions from lots of people all the time, and we love them. So, ask questions; that's how you learn.





From top: 1. Gabriela González was invited to testify before the U.S. Congress on the 2015 detection of gravitational waves, and the role of the LIGO Scientific Collaboration she leads. She and colleagues presented a full committee hearing titled "Unlocking the Secrets of the Universe: Gravitational Waves to the Committee on Science, Space & Technology." 2. This illustration shows the dates for two confirmed gravitational wave detections by LIGO, plus one candidate detection, which was too weak to unambiguously confirm. All three events occurred during the first four-month run of Advanced LIGO, the upgraded, more sensitive version of the observatories. The three events are GW150914 (Sept. 14, 2015), LVT 151012 (Oct. 12, 2015), and GW151226 (Dec. 26, 2015). 3. Years of research and hard work came to fruition with the detection of a single ripple in the fabric of space-time on Sept. 14, 2015. At 4:50:45 a.m., the LIGO Livingston Observatory in Livingston, La., detected a signal of a gravitational wave. Nearly seven milliseconds later, another identical signal reached the LIGO Hanford facility in Hanford, Wash., confirming the signal and the presence of gravitational waves in the universe.

KEY TERMS

What is spacetime?

In its simplest form, spacetime is the combination of the three-dimensional world of space, which we see all around us, plus time. This gives us the four-dimensional spacetime, a warped fabric that tells how masses move.

What are gravitational waves?

Gravitational waves are ripples in the fabric of spacetime that radiate outward from a cataclysmic astronomical event.

How does the interferometer work?

Both the Livingston and Hanford observatories have L-shaped arms that are 2.5 miles, or 4 kilometers, long and 4 feet in diameter. Lasers are sent in two beams down the arms under a near-perfect vacuum. The beams of light are used to monitor the distance between mirrors at the end of the arms, carefully isolated from the ground motion. According to Einstein's theory, the distance between the mirrors would change by an infinitesimal amount when a gravitational wave passes by the detector. A change in the lengths of the arms smaller than one-ten-thousandth the diameter of a proton can be detected. The near-simultaneous detection by the two observatories is necessary to confirm that an event is real.