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SCIENTIST OF THE YEAR

Gabriela González, Ph.D.

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SCIENTIST OF THE YEAR

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Dr. Gabriela González is an experimental physicist who has successfully led the LIGO Scientific Collaboration (LSC) for the past five years. LIGO stands for Laser Interferometer Gravitational Wave Observatory, and it consists of two detectors located in Livingston, Louisiana and Hanford, Washington. The LSC is a group of more than 1000 scientists worldwide who have joined together in the search for gravitational waves. Their successful detection of a wave created by two colliding black holes, more than 1.3 Billion light years away, has been hailed across the scientific community as a historical turning point as significant and game-changing as the moment Galileo first pointed his telescope to the sky.

Since 2011, Dr. González' job description has consisted of one line: lead the Collaboration, ensure its proper functioning, and represent the LSC to the external world. This role has been the crowning achievement of a remarkable career dedicated to the discovery of gravitational waves and to the emergence of a new astronomy based on observations of these waves. It's also the culmination of a life-long love affair with science.

"It was when I was just a girl and began learning about atoms, about how protons, electrons, and neutrons all interacted, that a light went on in my mind," she recalls exuberantly. "I realized that everything was made of atoms, and that you could explore everything from atoms all the way to the whole universe, and you could do it all within the spectrum of physics. That was fascinating to me."

Her research has eventually focused on experimental gravitational wave science, specifically on the development of techniques for suspended mass interferometers. She is an expert in her field, and she's published several papers on improving the sensitivity of the detectors in interferometers. Her role in the commissioning of the large-scale interferometer at the Livingston, Louisiana observatory has been major.

Since going online, Dr. González and her group have taken significant responsibility for instrumental characterization and calibration of the data collected, and she's led the LSC's data analysis groups searching for binary systems, namely pairs of neutron stars or black holes in close orbits around each other. But it's been her dedication to leading the LSC collaboration as the Spokesperson – a role she was elected to by an overwhelming majority of the collaboration scientists in 2011 – where's she's really distinguished herself. Her decisive leadership has been instrumental in this multi-decade effort's historic achievements. While the work of LIGO and the LSC goes back decades, the confirmation of the existence of gravitational waves is an achievement 100 years in the making.

In his theory of General Relativity, published in 1916, Albert Einstein advanced an entirely new model of the universe, one where space and time are interwoven in a four dimensional fabric Einstein christened 'space-time.' In this model, gravity isn't a force that one large object imposes directly onto smaller objects, as Isaac Newton first proposed. Instead, gravity is the warping of the geometric structure of space-time around an object because of its mass. Smaller objects get caught into the orbit of these larger objects when they fall into the invisible "grooves" in space-time this warping creates – like a ball riding the rim of a roulette wheel.

Einstein then made a series of predictions about how cosmic phenomena would behave in his new model of the universe. One of the most audacious predictions was the existence of gravitational waves. His math showed that sudden, massive liberations of energy in a given corner of the cosmos would ripple through the fabric of space-time – not unlike the ripples in a still pond disrupted suddenly by a pebble. If these energy releases were immense enough, those ripples would emanate across multiple light years of distance and would distort space-time around the Earth briefly.

A question then arose. Could these distortions be measured and detected directly? Ironically, Einstein had doubts. Not because he lacked confidence in his math, of course, but because even a mind as brilliant as his could not conceive of a way to engineer the kind of technology we would need to detect such a small effect.

That all began to change in the 1960s, when physicists like Joseph Weber and Rainer Weiss demonstrated how Einstein's waves might be detected, and then tested early prototypes of the instruments to do so. The degree of precision and sensitivity that would be required were orders of magnitude beyond the technical limits of the time, and technological breakthroughs across many scientific disciplines would be required to reach them. But the concepts were proven, and an entirely new field of scientific endeavor had been opened.

It was this brave new world that a wide-eyed graduate student from Argentina discovered when she arrived at Syracuse University in the 1990s to pursue a PhD in physics. "I had studied theoretical physics and General Relativity in college and didn't learn much about gravitational waves other than that Einstein had predicted them," Dr. González recalls. "I fully expected to continue with General Relativity, but then this new professor, Peter Saulson, joined the department. He was working on this new "LIGO" project that no one knew much about, and as I learned more about the detectors they were developing to measure and detect these waves, I just thought it was the coolest thing one could do."

"These detectors didn't exist yet," she continues. "It was all theoretical and experimental, different universities testing and prototyping the technology. So that's what I began doing, first on small experiments for my thesis at Syracuse, and later at MIT, Penn State and LSU."

Dr. González spent the next 20 years working on teams tasked with turning these prototype instruments and techniques into full scale working interferometers that today can detect disturbances in the fabric of space-time on the order of a fraction of the diameter of a proton. These instruments are engineering masterpieces in their own right, and they've enabled the LIGO team to make the most precise measurements of anything, ever. And because they are so sensitive, you need at least two of them far enough apart to ensure that what you're detecting isn't terrestrial in origin.

The interferometers accomplish this by splitting a laser beam of the purest light possible, and directing them down 4-kilometer, perfectly vacuum-sealed and suspended tubes arranged in a large "L" formation. These half-laser beams bounce between mirrors at either end of their respective tunnels, before they're recombined at the base and aimed at a photo detector.

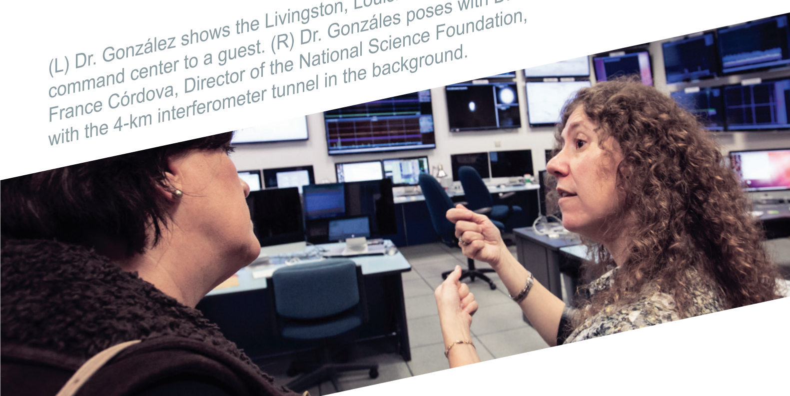
When space-time around us is stable, the two beams line-up perfectly when they're recombined, effectively cancelling each other out. In this scenario, no light reaches the photo detector. But when a gravitational wave passes through the Earth, it disturbs space-time briefly. This disturbance squeezes and stretches the long tubes of the interferometers ever so slightly, altering the distance between the mirrors and the frequency of the laser beams. And when the split beams are recombined, they fail to cancel-out and the photo detectors record the difference.

Finally, on September 14, 2015, it happened, and it was almost too good to be true. The interferometer in Louisiana detected a wave form with oscillations that indicated it was indeed a gravitational wave. 7 milliseconds later, a nearly identical wave form was detected at the site in Washington, increasing the probably that this was the real deal.

"There were certain data plots we made that were so good, so clear! It looked exactly like a gravitational wave was supposed to look. We almost couldn't believe it," Dr. González remembered. "We were still testing certain aspects of the instruments with simulated waves, so our first suspicion was that this strong wave was a simulation. But we quickly realized it wasn't, and many of us at that moment began to believe we had done it. Of course it took a lot of time and analysis to confirm it, but many of us were confident we had it."

It's been said that Galileo gave humankind the eyes with which to see the universe. The scientists and engineers involved with LIGO have now given us the ears with which to hear the universe. "The frequency of the waveforms is within the human hearing range. So we can now hear the universe talking to us," Dr. González proudly proclaimed. This new ability to 'hear' the universe has blown open the doors to new fields of study.

Asked about the significance of proving the last of Einstein's predictions on the theory of General Relativity, Dr. González demurs a bit. She seems inspired more by what's coming next than what's come before. "That's what excites me most," Dr. González concludes. "I can't wait to see what the next generation of theorists can do with General Relativity now!"



(L) Dr. González shows the Livingston, Louisiana Interferometer command center to a guest. (R) Dr. Gonzáles poses with Dr. France Córdova, Director of the National Science Foundation, with the 4-km interferometer tunnel in the background.