LIGO Fact Sheet

NSF and the Laser Interferometer Gravitational-Wave Observatory

In 1916, Albert Einstein published the paper that predicted gravitational waves – ripples in the fabric of space-time resulting from the most violent phenomena in our distant universe, such as supernovae explosions or colliding black holes. For 100 years, this prediction has stimulated scientists around the world, who have been seeking to directly detect gravitational waves.

Approximately 50 years ago, the National Science Foundation (NSF) joined this quest and began funding the science and technological innovation that would ultimately lead to direct detection of gravitational waves. More importantly, it would also lead to a scientific capability to observe and study our universe in new ways, much like the advent of radio astronomy or even when Galileo first used a telescope to view the night skies.

NSF's funding of LIGO and the science behind its operation and research began in the 1970s, and the NSF's continued support through many years of scientific and technical development yielded an extraordinary success. In September 2015, the newly commissioned Advanced LIGO detectors observed gravitational waves that resulted from merging black holes approximately 1.3 billion light-years away and 1.3 billion years ago. This watershed achievement earned three of LIGO Laboratory's founding members the 2017 Nobel Prize in Physics. In the first three observing runs from 2015 through 2020, LIGO continued to add to our knowledge of the nature of sources of gravitational waves: the first detection and localization of gravitational waves from a BNS collision, coincident with a gamma ray burst (GRB) was followed by observation of the stars' dying remnant across the electromagnetic (EM) spectrum ; the first neutron star - binary black hole (NSBH) coalescence; and the first direct evidence of intermediate mass black hole (IMBH) formation. Some 90 signals have now been confidently detected.

What is LIGO?

LIGO consists of two widely separated interferometers within the United States—one in Hanford, Washington, and the other in Livingston, Louisiana— each a laser interferometer inside an L-shaped ultra-high vacuum tunnel and operated in unison to detect gravitational waves. The California Institute of Technology and Massachusetts Institute of Technology led the design, construction and operation of the NSF-funded facilities.

What are gravitational waves?

Gravitational waves are emitted when masses accelerate (e.g., neutron stars, colliding black holes). This can be compared in some ways to how accelerating charges create electromagnetic fields and radio waves that antennae detect. Gravitational wave detectors are also a sort of “receiver.” Gravitational waves travel to Earth almost like ripples in a pond. However, these ripples in the space-time fabric carry information about their violent origins and about the nature of gravity – information that cannot be obtained from other astronomical signals.

How does LIGO work?

Einstein himself questioned whether we could create an instrument sensitive enough to capture this phenomenon. Inside the vertex of the L-shaped LIGO vacuum systems, a beam splitter divides a single entering laser beam into two beams, each travelling along a 4 km long arm of the L. The beams reflect back and forth between precisely positioned and exquisitely configured mirrors that are suspended, like a child in a swing, near each end and near the vertex on either side of the beam splitter.

As a gravitational wave passes by, the lengths of the paths that the divided laser beams take along each arm will actually stretch the laser beam ever-so slightly –by only 1/10,000th of the diameter of a proton. It's this signal change – occurring at both interferometers -- within 10 milliseconds of one another -- that indicates a gravitational wave. And from that minute change, scientists are further able to identify the wave's source and very broadly where it the universe it originated.

Worldwide commitment to world-class research

The LIGO Scientific Collaboration (LSC), which carries out the scientific interpretation of the signals and helps advance the LIGO detector science, is a group of some 1500 scientists at universities around the United States and in some 20 countries. The LSC network includes the LIGO interferometers and the GEO600 interferometer, a project located near Hannover, Germany, designed and operated by scientists from Max Planck Institute for Gravitational Physics, along with partners in the United Kingdom funded by the Science and Technology Facilities Council (STFC). Additionally, a new node of the LIGO network in India may be operational in the late 2020's.

The LSC works jointly with the Virgo Collaboration — which designed and constructed the Virgo interferometer, with 3 km long arms and located in Cascina, Italy. Virgo and LIGO observe and analyze data together, allowing the position of sources in the sky to be resolved. KAGRA, a Japanese detector, is also joining both the observation with LIGO and Virgo and in the interpretation of the data.

International partners have contributed equipment, labor and expertise to LIGO, including Britain's Science and Technology Facilities Council supplying the suspension assembly and some mirror optics; the Max Planck Society of Germany providing the high-power, high-stability laser; and an Australian consortium of universities supported by the Australian Research Council offering systems for initially positioning and measuring in place the mirror curvatures to better than nanometer precision.

NSF investment

LIGO is one of the largest experiments the agency has ever funded. It was the biggest NSF investment ever when the National Science Board gave the go-ahead to fund initial construction in 1990. At this point, NSF has invested approximately $1.4 billion in construction and upgrades, in operational costs, and in research awards to individual scientists, who study LIGO data to learn more about our universe.

Maximizing what we learn from LIGO

NSF supports basic research that drives innovation and innovators that transform our future. Basic research offers no promises and is often risky but is also potentially revolutionary. LIGO is no exception. The direct detection of gravitational waves is not only an historic moment in science, it also has already spawned other scientific innovations. For example, a laser developed by LIGO Scientific Collaboration scientists has many applications. The same technique used to stabilize LIGO's sensitive laser frequencies also helps to build the semiconductors in our computers and cell phones. Other spin-offs are being realized in areas such as measurement science, seismic isolation, vacuum technology, mirror coatings and optics.

As is often the case with research in fundamental science, few would have invested in it from the beginning. However, this discovery significantly changes what we can learn about the universe. With plans to further increase LIGO's sensitivity in the coming years and the potential addition of other countries' interferometers to the network, LIGO provides an opportunity to detect more gravitational waves and also hone in more precisely on the whereabouts of the universe's most violent phenomena.