Dedication of Advanced LIGO

19 May 2015

The Advanced LIGO Project, a major upgrade that will increase the sensitivity of the Laser Interferometer Gravitational-wave Observatories instruments by a factor of 10 and provide a 1,000-fold increase in the number of astrophysical candidates for gravitational wave signals, will be officially dedicated in a ceremony to be held on Tuesday, May 19, at the LIGO Hanford facility in Richland, Washington.

LIGO was designed and is operated by Caltech and MIT, with funding from the National Science Foundation (NSF). Advanced LIGO, funded by the NSF with important contributions from the UK Science and Technology Facilities Council (STFC), the Max Planck Society of Germany, and the Australian Research Council (ARC), is now being brought online, with the first searches for gravitational waves planned for the fall of 2015.

The ceremony will feature remarks from speakers including Caltech president Thomas F. Rosenbaum, the Sonja and William Davidow Presidential Chair and professor of physics; Professor of Physics B. Thomas Soifer, the Kent and Joyce Kresa Leadership Chair of Caltech's Division of Physics, Mathematics and Astronomy; Kirk Kolenbrander, MIT vice president; and France Córdova, director of the National Science Foundation.

"We've spent the past seven years putting together the most sensitive gravitational-wave detector ever built. Commissioning the detectors has gone extremely well thus far, and we are looking forward to our first science run with Advanced LIGO beginning later in 2015. This is a very exciting time for the field," says Caltech's David H. Reitze, executive director of the LIGO Project.

"Advanced LIGO represents a critically important step forward in our continuing effort to understand the extraordinary mysteries of our universe," says NSF director Córdova. "It gives scientists a highly sophisticated instrument for detecting gravitational waves, which we believe carry with them information about their dynamic origins and about the nature of gravity that cannot be obtained by conventional astronomical tools."

Predicted by Albert Einstein in 1916 as a consequence of his general theory of relativity, gravitational waves are ripples in the fabric of space and time produced by violent events in the distant universe—for example, by the collision of two black holes or by the cores of supernova explosions. Gravitational waves are emitted by accelerating masses much in the same way as radio waves are produced by accelerating charges, such as electrons in antennas. As they travel to Earth, these ripples in the space-time fabric bring with them information about their violent origins and about the nature of gravity that cannot be obtained by other astronomical tools.

Although they have not yet been detected directly, the influence of gravitational waves on a binary pulsar system (two neutron stars orbiting each other) has been measured accurately and is in excellent agreement with the predictions. Scientists therefore have great confidence that gravitational waves exist. But a direct detection will confirm Einstein's vision of the waves and allow a fascinating new window into cataclysms in the cosmos.

LIGO was originally proposed in the 1990s as a means of detecting these gravitational waves. Each of the 4-km-long L-shaped LIGO interferometers (one each at LIGO Hanford and at the LIGO observatory in Livingston, Louisiana) use a laser split into two beams that travel back and forth down long arms (which are beam tubes from which the air has been evacuated). The beams are used to monitor the distance between precisely configured mirrors.

According to Einstein's theory, the relative distance between the mirrors will change very slightly when a gravitational wave passes by. The original configuration of LIGO was sensitive enough to detect a change in the lengths of the 4-km arms by a distance one-thousandth the size of a proton; Advanced LIGO, which will utilize the infrastructure of LIGO, will be 10 times more sensitive.

"To achieve this improvement, we took many lessons learned from initial LIGO, put them together with the results of worldwide R&D, and made a complete redesign and replacement of the detectors," says David Shoemaker of MIT, the project leader for Advanced LIGO.

Included in the upgrade were changes in the lasers (180-watt highly stabilized systems), optics (40-kg fused-silica "test mass" mirrors suspended by fused-silica fibers), seismic isolation systems (using inertial sensing and feedback), and in how the microscopic motion (less than one billionth of one billionth of a meter) of the test masses is detected.

The change of more than a factor of 10 in sensitivity also comes with a significant increase in the sensitive frequency range and the ability to tune the instrument for specific astrophysical sources. This will allow Advanced LIGO to look at the last minutes of the life of pairs of massive black holes as they spiral closer, coalesce into one larger black hole, and then vibrate much like two soap bubbles becoming one. It will also allow the instrument to pinpoint periodic signals from the many known pulsars that radiate in the range from 500 to 1,000 Hertz (frequencies that correspond to high notes on an organ).

Advanced LIGO will also be used to search for the gravitational cosmic background—allowing tests of theories about the development of the universe only 10^-35 second after the Big Bang.

LIGO research is carried out by the LIGO Scientific Collaboration (LSC), a group of some 950 scientists at universities around the United States and in 15 other countries. The LSC network includes the LIGO interferometers and the GEO600 interferometer, a think thank and test bed for advanced detector techniques. GEO600 is located near Hannover, Germany, and designed and operated by scientists from the Max Planck Institute for Gravitational Physics and Leibniz Universität Hannover, along with partners in the United Kingdom funded by the Science and Technology Facilities Council (STFC). The LSC works jointly with the Virgo Collaboration—which designed and constructed the 3-km-long Virgo interferometer located in Cascina, Italy—to analyze data from the LIGO, GEO, and Virgo interferometers.

"The world will be watching the Advanced LIGO detectors begin to take data later this year, joined next year by Virgo and in the future by other detectors in an international network," says Gabriela González, professor of physics and astronomy at Louisiana State University and LSC spokesperson. "The LSC is preparing for analyzing data from gravitational wave detectors thoroughly and promptly to advance astrophysics, expecting significant results in a few years."

"I have been involved in the experimental search for gravitational waves for many years and, on the basis of my personal experience, I can state that these days are crucial for the whole international community, which is pursuing the goal of the first direct detection," says Virgo spokesperson Fulvio Ricci, professor of experimental physics at Sapienza University of Rome. "The beginning of the Advanced LIGO operation is the most important step in the process leading to the deployment of an international network of advanced detectors. Virgo and LIGO previously collected data and produced interesting physics results. Now the time is mature for a discovery and for writing a new chapter in fundamental physics and astronomy books."

Several international partners provided significant contributions of equipment, labor, and expertise:

The UK partners supplied the suspension assembly and some optics for the mirrors whose movements register the passage of the gravitational waves; this has been funded via Britain's STFC.

"I am delighted that the precision fused-silica suspensions, developed from those in the GEO600 detector and upgraded to carry 40-kg mirrors, have been successfully integrated into the Advanced LIGO detectors," says Ken Strain, deputy director of the Institute for Gravitational Research at the University of Glasgow and principal investigator of the Advanced LIGO project team in the UK. "This opens the way for observing to start in the near future."

The German contribution was the high-power, high-stability laser whose light measures the actual movements of the mirrors; this has been funded via the Max Planck Society in Munich and the VolkswagenStiftung. The laser system was developed at the Albert Einstein Institute and the Laser Zentrum Hannover.

"I am very pleased that our custom-made high-power lasers are among the core measurement technologies of Advanced LIGO," says Karsten Danzmann, director of the Max Planck Institute for Gravitational Physics (Albert Einstein Institute/AEI), and director of the Institute for Gravitational Physics at the Leibniz Universität Hannover. "It is an exciting moment to see Advanced LIGO going online with key technologies developed and tested at the AEI and the British-German GEO600 Observatory. We are now a large step closer to the first direct detection of gravitational waves."

An Australian consortium of universities, led by the Australian National University and the University of Adelaide, and supported by the Australian Research Council, contributed the systems for initially positioning the optics and then measuring in place the optics curvature to nanometer precision.

"It is inspiring to be part of a collaborative worldwide effort that has built the most sensitive detector ever, now 'listening' for the weakest signals in the universe generated by its most violent events," says David McClelland, professor of physics and head of the Department of Quantum Science at the Australian National University. "It has been exciting to see LIGO mature as a research endeavor, and as each year has passed, the generation of new knowledge and technology has become more and more significant," adds Aidan Byrne, chief executive officer of the Australian Research Council. "The ARC…wishes the LIGO Scientific Collaboration the best with the ongoing hunt for elusive gravitational waves."

The University of Florida and Columbia University assumed specific responsibilities for the design and construction of Advanced LIGO.

Provided by California Institute of Technology