Awesome universal chirp

In 1978, while I was an undergraduate student, Kip Thorne came to Stanford University to give a seminar on a proposed search for gravitational waves. The auditorium quickly filled with experts and inquisitive students like me. As Thorne described a quest for these ripples in space-time, the audience grew palpably skeptical. Albert Einstein had predicted the existence of gravitational waves based on his theory of general relativity, but even he was doubtful that they would ever be detected because they were anticipated to be so weak. Listening to Thorne propose an approach for measuring such waves, I had no idea that he and his colleagues were about to begin a 40-year journey to discover what Science now recognizes as the 2016 Breakthrough of the Year. The announcement that gravitational waves had indeed been detected opens up a new window into the universe (see the News story on p. 1516).

The planning and experimentation that led to the Laser Interferometer Gravitational-Wave Observatory (LIGO), the apparatus that detected the gravitational waves, illustrate how the interplay between theory and experiment can provide the impetus for building remarkable new tools. LIGO depends on measuring changes in length that amount to a small fraction of the diameter of an atomic nucleus over a distance of several kilometers. After many years of construction, and just after the completion of a substantial upgrade, LIGO observatories situated in Hanford, Washington, and Livingston, Louisiana, detected a “chirp” lasting about a tenth of a second on 14 September 2015. The detailed features of this chirp could be fit by Einstein’s equations with impressive accuracy. The original paper describing this discovery is a joy to read,* even without understanding the technical details. Two black holes, each with about 30 solar masses, circled one another and then coalesced into a single black hole. In this process, the energy associated with these three masses was released in the form of gravitational waves. Although this discovery is a singular event, its importance lies in the observations yet to come. An additional, but smaller, black hole merger has already been observed, and more are expected, particularly with the sophisticated detectors that are in development. More measurements of events across the space and time of the universe may lead to theories and observations of other phenomena that will need explanation.

Science’s runners-up include many exciting discoveries that can be divided (somewhat arbitrarily) into two categories. Some breakthroughs were primarily technological advances, spanning a range of fields. These include remarkable progress in artificial intelligence; DNA sequencers based on passing DNA strands through nanopores; coaxing stem cells to form eggs capable of producing viable mammals; the construction of novel small-scale lenses; and programs that can design proteins and protein assemblies with predetermined structures. This category also contains Science’s People’s Choice for the Breakthrough of the Year—the ability to grow human embryos in culture for nearly 2 weeks, much longer than had been achieved previously, opening up new research opportunities but also raising important ethical questions.

Other breakthroughs represent more conceptual advances. These include the discovery of an exoplanet only 4 light-years from Earth; a genomic analysis that supports the notion that all modern human beings derive from a single migration out of Africa; new insights into the similarities between human and ape minds; and the demonstration that clearing mice of senescent cells can slow the aging process.

Selection of the Breakthrough of the Year should be viewed not only as a competition for top positions, but as a celebration of the remarkable scientific advances that are published over the course of a year. It is a pleasure to compile and think through all of the exciting results that have been published, and a challenge to winnow the field down to a final list.

–Jeremy Berg


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