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Gravitational waves spotted again

On 26 December 2015, scientists from the LIGO and Virgo collaborations received an unexpected Christmas gift when the Advanced LIGO detectors recorded a new gravitational wave signal, three months after the first detection¹. And once again, the signal—a tiny distortion of spacetime—came from the final spinning 'dance' of two black holes on the point of merging, a phenomenon known as coalescence. This second observation confirms that such cataclysmic events are relatively frequent, making it likely that more will be detected from late 2016, when the Advanced LIGO (US) and Advanced Virgo (Italy) resume operation following upgrading work. This will help scientists to better understand pairs of black holes, bodies that are so dense that neither light nor matter can escape from them. The discovery, made by an international collaboration including CNRS teams, is announced on 15 June 2016 at the meeting of the American Astronomical Society in San Diego, and is published in the journal *Physical Review Letters*.

Three months after announcing the first detection of gravitational waves¹, scientists from the LIGO and Virgo collaborations have reported a second observation of the merger of two black holes, revealed by the gravitational waves emitted during the event. Although the signal is weaker than the first one, this new finding has also been confirmed with a confidence level of over 99.99999%.

Black holes are the final stage in the evolution of the most massive stars. Some of these holes form a pair, orbiting around each other and gradually getting closer while losing energy in the form of gravitational waves, until a point is reached where the process suddenly accelerates. They end up merging into a single black hole. It was this final whirling stage immediately preceding the merger that was observed on 26 December 2015, enabling scientists to infer that the mass of the black holes was between 8 and 14 times that of the Sun (as compared to 29 and 36 solar masses in the first observation on 14 September 2015). As the black holes were lighter, they moved towards each other less rapidly: the signal lasted about 1 second, as opposed to 0.2 second for the previous observation. As a result, the number of orbits observed just before the merger was considerably greater than during the first detection, making it possible to carry out a different, complementary test of Einstein's general theory of relativity. The event took place at a distance of about 1.4 billion light years from Earth, which means that the gravitational waves travelled through space for 1.4 billion years before being detected by Advanced LIGO's twin detectors, located in Louisiana and Washington State (US).

¹ [Announced on 11 February 2016](#) after several months of exhaustive analyses and verifications, it was recorded by the LIGO detectors on 14 September 2015.



This second event confirms that pairs of black holes are relatively common. A comprehensive analysis of the data collected by the LIGO detectors from September 2015 to January 2016 hints at a possible sighting of a third event of this type on 12 October 2015, although with a lower degree of certainty.

Eventually, analysis of observations of this kind may help to elucidate the origin of binary black holes: were they originally a pair of stars that both turned into black holes, or is one black hole captured by the other? To find out, a larger sample of observations will be needed, which should become possible once Advanced LIGO and Advanced Virgo resume operation in autumn 2016. As demonstrated by the first phase of data collection by the Advanced LIGO detectors, gravitational waves have now become a new way of exploring the Universe and that most fundamental of interactions, gravity.

LIGO (Laser Interferometer Gravitational-Wave Observatory) is an observatory dedicated to gravitational waves and is composed of two identical interferometers located in the US. The improved version of these detectors (Advanced LIGO) resumed operation in September 2015. The LIGO scientific collaboration was formed around these instruments. It works hand in hand with the Virgo collaboration, formed around the Virgo detector located in Pisa, Italy. Since 2007, scientists from both groups have analyzed data and published findings jointly. Advanced Virgo is planned to resume operation by the end of 2016.

LIGO research is carried out by the LIGO Scientific Collaboration (LSC), a group of more than 1000 scientists from universities around the United States and in 14 other countries. More than 90 universities and research institutes in the LSC develop detector technology and analyze data; approximately 250 students are strong contributing members of the collaboration. The LSC detector network includes the LIGO interferometers and the GEO600 detector.

VIRGO research is carried out by the Virgo Collaboration, consisting of more than 250 physicists and engineers belonging to 19 different European research groups: 6 from Centre National de la Recherche Scientifique (CNRS) in France; 8 from the Istituto Nazionale di Fisica Nucleare (INFN) in Italy; 2 in The Netherlands with Nikhef; the MTA Wigner RCP in Hungary; the POLGRAW group in Poland and the European Gravitational Observatory (EGO), the laboratory hosting the Virgo detector near Pisa in Italy.

The scientific publication of the LIGO and Virgo collaborations announcing the discovery is co-authored by 72 scientists from six teams from CNRS and associated universities:

- AstroParticule et Cosmologie laboratory (Université Paris Diderot/CNRS/CEA/Observatoire de Paris), Paris;
- 'Astrophysique Relativiste, Théories, Expériences, Métrologie, Instrumentation, Signaux' laboratory (CNRS/Observatoire de la Côte d'Azur/Université Nice Sophia Antipolis), Nice;
- Laboratoire de l'Accélérateur Linéaire (CNRS/Université Paris-Sud), Orsay;
- Laboratoire d'Annecy-le-Vieux de Physique des Particules (CNRS/Université Savoie Mont Blanc), Annecy-le-Vieux;
- Laboratoire Kastler Brossel (CNRS/UPMC/ENS/Collège de France), Paris;
- Laboratoire des Matériaux Avancés (CNRS), Villeurbanne.



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To find out more:

- [New gravitational wave detections for LIGO-Virgo](#), article in CNRS News, 15 June 2016.
- Information about the first detection of gravitational waves:
 - o [our press release](#)
 - o [Gravitational waves detected](#), article in CNRS News, 11 February 2016
 - o [Gravitational waves: a historic moment](#) video in CNRS News, 11 February 2016
- A [selection of images](#) about Virgo, from the CNRS photo library.



From left to right: the two LIGO detectors (in Hanford and Livingston, US) and the Virgo detector (Cascina, Italy).

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Bibliography

GW151226: Observation of Gravitational Waves from a 22 Solar-mass Binary Black Hole Coalescence, the LIGO Scientific Collaboration and the Virgo Collaboration. *Physical Review Letters*, on line 15 June 2016. <http://link.aps.org/doi/10.1103/PhysRevLett.116.241103>

Binary Black Hole Mergers in the first Advanced LIGO Observing Run, the LIGO Scientific Collaboration and the Virgo Collaboration. On line at ArXiv 16 June 2016.

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