PRESS RELEASE

MAX PLANCK INSTITUTE
FOR THE SCIENCE OF LIGHT

AI finds new ways to observe the most extreme events in the universe

ERLANGEN, 14 APRIL 2025

Extreme cosmic events such as colliding black holes or the explosions of stars can cause ripples in spacetime, so-called gravitational waves. Their discovery opened a new window into the universe. To observe them, ultra-precise detectors are required. Designing them remains a major scientific challenge for humans. Researchers at the Max Planck Institute for the Science of Light (MPL) have been working on how an artificial intelligence system could explore an unimaginably vast space of possible designs to find entirely new solutions. The results were recently published in the journal ›Physical Review X‹.

More than a century ago, Einstein theoretically predicted gravitational waves. They could only be directly detected in 2016 because the development of the necessary detectors was extremely complex. Dr. Mario Krenn, head of the research group ›Artificial Scientist Lab‹ at MPL, in collaboration with the team of LIGO ("Laser Interferometer Gravitational-Wave Observatory"), who built those detectors successfully, called ›Urania‹ to design novel interferometric gravitational wave detectors. Interferometry describes a measurement method which uses the interference of waves, i.e. their superposition when they meet. Detector design requires optimizing both layout and parameters. The scientists have converted this challenge into a continuous optimization problem and solved it using methods inspired by modern machine learning. They have found many new experimental designs which outperform the best known next-generation detectors. These results have the potential to improve the range of detectable signals by more than an order of magnitude.

Nonconformist and creative: that's what ›Urania‹ discovered

In the algorithm's solutions, the researchers rediscovered numerous known techniques. ›Urania‹ also proposed unorthodox designs which could reshape our understanding of detector technology. "After roughly two years of developing and running our AI algorithms, we discovered dozens of new solutions that seem to be better than experimental blueprints by human scientists. We asked ourselves what humans overlooked in comparison to the machine," says Krenn. The researchers expanded their scientific approach to understand the AI-discovered tricks, ideas, and techniques. Many of them are still completely alien to them. They have compiled 50 top-performing designs in a public ›Detector Zoo‹ and made them

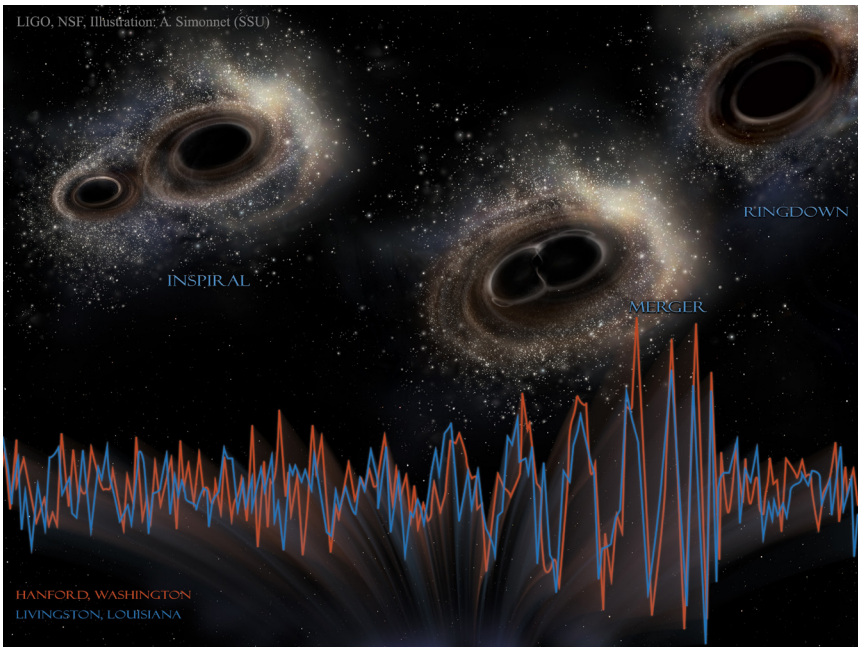

Illustration of the first gravitational wave event observed by LIGO. The detected wave forms from LIGO Hanford (orange) and LIGO Livingston (blue) are superimposed beneath illustrations of the merging black holes.

Max Planck Institute for the Science of Light Staudtstraße 2 91058 Erlangen Germany
Contact: Edda Fischer E-Mail: MPLpresse@mpl.mpg.de Phone: +49 (0)9131 7133 805
mpl.mpg.de PhysikDesLichts @mpi-scienceoflight.bsky.social
@physik_des_lichts @MPI_PhysikDesLichts

available to the scientific community for further research.
The recently published work shows that AI can uncover novel detector designs and inspire human researchers to explore new experimental and theoretical ideas. More broadly, it suggests that AI could play a major role in designing future tools for exploring the universe, from the smallest to the largest scales. “We are in an era where machines can discover new super-human solutions in science, and the task of humans is to understand what the machine has done. This will certainly become a very prominent part of the future of science”, says Krenn.

© Stephan Spangenberg

Dr. Mario Krenn, research group leader at MPL.

Scientific Contact:
Dr. Mario Krenn
Max Planck Institute for the Science of Light, Erlangen
Research Group Leader ›Artificial Scientist Lab‹
www.mpl.mpg.de / mario.krenn@mpl.mpg.de

Original Publication in Physical Review X:
Mario Krenn, Yehonathan Drori, Rana X Adhikari. Digital Discovery of interferometric Gravitational Wave Detectors. In Physical Review X (2025).
DOI: 10.1103/PhysRevX.15.021012

Research at the Max Planck Institute for the Science of Light (MPL) covers a wide range of topics, including nonlinear optics, quantum optics, nanophotonics, photonic crystal fibres, optomechanics, quantum technologies, biophysics, and – in collaboration with the Max-Planck-Zentrum für Physik und Medizin – links between physics and medicine. MPL was founded in 2009 and is one of the over 80 institutes that make up the Max Planck Society, whose mission is to conduct basic research in the service of the general public in the natural sciences, life sciences, social sciences and the humanities.

Max Planck Institute for the Science of Light Staudtstraße 2 91058 Erlangen Germany
Contact: Edda Fischer E-Mail: MPLpresse@mpl.mpg.de Phone: +49 (0)9131 7133 805
mpl.mpg.de PhysikDesLichts @mpi-scienceoflight.bsky.social
@physik_des_lichts @MPI_PhysikDesLichts