GEO600 as Part of a Worldwide Interferometer Network

GEO600 is part of a worldwide network of gravitational wave detectors. The network includes the two U.S. LIGO detectors and the Italian-French-Dutch Virgo project near Pisa. The GEO Collaboration is also involved in the development of gravitational wave detectors in Japan and India.

The networking of detectors has two reasons: if a gravitational wave is detected, it is only possible to discriminate it from local disturbances by cross-checks with the data from other distant detectors. Additionally, at least four widely spaced detectors are necessary to obtain information about the location of the source of the gravitational wave signals, the polarization of the waves and how the signals evolve over time. This is why all detectors share their data.

The Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

Scientists at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) do research into the entire spectrum of general relativity and beyond: from the huge dimensions of outer space to the tiny scales of strings. The AEI has two sub-institutes, one in Hannover and one in Potsdam. Some scientists at the AEI in Potsdam work toward developing a theory which will unify quantum field theory and Albert Einstein's theory of general relativity. Other scientists examine the structure of gravitational waves which are emitted by neutron stars and black holes – by analytically and numerically finding solutions to Einstein's field equations they compute the possible waveforms. Others again are probing the mathematical fundamentals of space-time and gravitation expanding on Einstein's theories.

The AEI in Hannover operates the German-British gravitational wave detector GEO600 in Ruthe near Hannover. It also plays a leading role in the space-based project LISA Pathfinder and the development of new gravitational wave detectors for use on the ground and in space. The institute also develops and employs modern mathematical data analysis methods needed to filter out gravitational wave signals from the data streams generated by the gravitational wave detectors.

The Max Planck Society for the Advancement of Science e.V.

is an independent, non-profit research organization. It operates over 80 Max Planck Institutes, which conduct fundamental research in the service of the general public in the natural sciences, social sciences and the humanities.

Max Planck Institutes focus on research fields that are too innovative or too inter-disciplinary to fit into the research structures of universities, or too demanding in terms of funding or time requirements for a university. Thus, the Max Planck Institutes ideally complement the research work done at universities.

MAX-PLANCK-GESELLSCHAFT

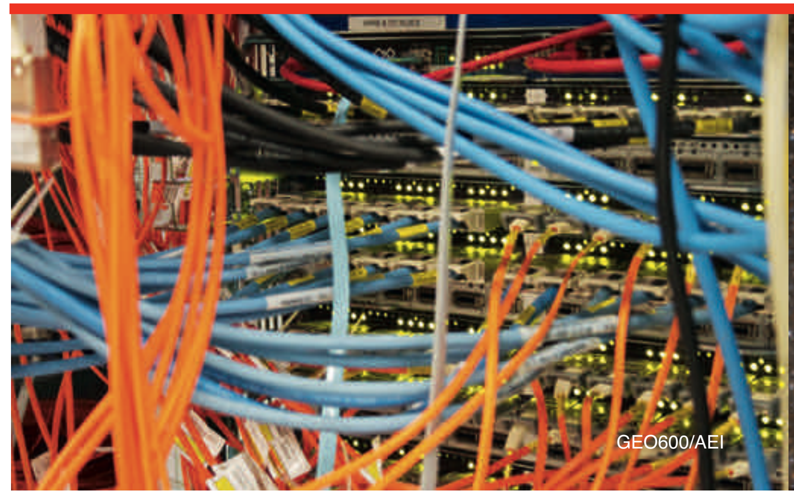
Operation and Financing

GEO600 is jointly operated by the Max Planck Institute for Gravitational Physics (Albert Einstein Institute), the Leibniz Universität Hannover, and British researchers at the Universities of Cardiff and Glasgow. It is financed by the German Federal Ministry of Education and Research, the State of Lower Saxony, the Max Planck Society, the British Science & Technology Facilities Council (STFC) and the Volkswagen Foundation.

Einstein@Home

The coordinating center for the distributed computing project Einstein@Home is at the Albert Einstein Institute in Hannover. Einstein@Home volunteers all around the world donate their computer's and smartphone's idle compute time to the search for gravitational waves. In return they get detailed insights into the world of advanced scientific research.

einsteinathome.org


GEO600/AEI


Simulating eXtreme Spacetimes project


AEI

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GEO600 in Ruthe near Hannover

- From Hannover: B6 (Messeschnellweg) southbound, exit "Sarstedt/Heisede" on the right.
- Take a right turn to "Heisede", then turn left at "Schulenburg/Ruthe"
- In Ruthe, turn right. After crossing the river Leine, turn right at "Universität Hannover/Versuchsgelände" or "Schäferberg"
- Follow the road all the way to the end of the apple orchard and the fence
- Public Transport: Stadtbahn Line 1 to Sarstedt, then Bus Line 201 to Ruthe/Mitte. Follow the Street "Schäferberg". 15 Minutes on foot.

Visiting the detector
GEO600 can be visited.
To book a group tour please contact:
Dr. Benjamin Knispel
Press Officer AEI Hannover
Phone:+49 511 762-19104
benjamin.knispel@aei.mpg.de

Websites:
www.aei.mpg.de
www.ligo.org
www.cascina.virgo.infn.it
www.lisamission.org

www.geo600.org

AEI/Simulating eXtreme Spacetimes project/Airborne Hydro Mapping GmbH

GEO600

Gravitational Wave Detector

Think Tank for New Technologies

The GEO600 Gravitational Wave Observatory

For thousands of years, we humans have observed the stars, and for hundreds of years we have been constructing ever more powerful telescopes.

With existing astronomical methods only a part of the Universe can be observed. This leaves many questions to be answered:

- What happens inside exploding stars?
- What are the compact remnants of these supernovae made of?
- How do black holes grow and coalesce?
- What happened just after the Big Bang? And what is the mysterious Dark Matter?

Gravitational waves can help us to answer all these questions. They are messengers from the darkest and most remote parts of the universe.

New Astronomy

On September 14, 2015, gravitational waves have directly been measured for the first time ever: the LIGO detectors in the USA detected the signal of two merging black holes. The German-British gravitational wave detector GEO600 plays a large part in this, as it is here that essential technologies are developed and tested, which were implemented in the LIGO detectors and crucial for the measurement in September 2015.

The first direct detection of gravitational waves has opened an entirely new window to our universe. The era of gravitational wave astronomy has now begun.

Think Tank GEO600

Technologies developed at GEO600 are now being used in all the current gravitational wave detectors. They are also being applied in geodesy, climate research and in the aerospace industry.

GEO600 is not just a part of the worldwide detector network, but also a think tank for new technologies.

Gravitational Waves – Ripples in Space-time

In 1915, Albert Einstein portrayed a completely new picture of our world in his general theory of relativity: In contrast to what Newton believed, gravitation is not a force, but a consequence of the geometry of space and time.

Large masses such as stars and galaxies deform space-time around them. If other objects move through such areas, they are diverted from their original path, apparently attracted by the larger mass. What in fact happens is that the objects just follow the path mapped out for them by the deformation of space-time.

Accelerated masses give rise to perturbations in the space-time continuum that propagate in all directions with the speed of light. These moving space-time disturbances are called gravitational waves. They alternately stretch and compress space – changing the distances between the objects in space.

Measuring Tiny Distances

However, the changes in distance caused by gravitational waves are tiny: even the gravitational wave produced by a powerful event in our vicinity, like a supernova explosion within the Milky Way, changes the distance between Earth and Sun only by about the diameter of a hydrogen atom – and that merely for a tiny fraction of a second.

For shorter distances the effect is correspondingly smaller: when measuring a distance of only one kilometre, a change of a thousandth of the diameter of a proton has to be detected to determine the passing of a gravitational wave. This is the effect the physicists have measured with the gravitational-wave detectors.

The great challenge is to get rid of the many disturbances, like air pressure and temperature fluctuations as well as seismic vibrations of all sorts, that would conceal a signal.

Detecting Gravitational Waves – How GEO600 Works

The tiny perturbations in space-time caused by gravitational waves are measured by a so-called laser interferometer. Here is how it works: a semi-transparent mirror splits an incoming laser beam into two perpendicular beams. These beams travel through the two arms of the interferometer. At the end of each arm they are reflected by mirrors, and when they reach the centre again, they are recombined and shine on a photo detector.

The interferometer is operated such that the light waves of the reflected laser beams are in opposite phase and cancel each other out: the output of the interferometer is dark.

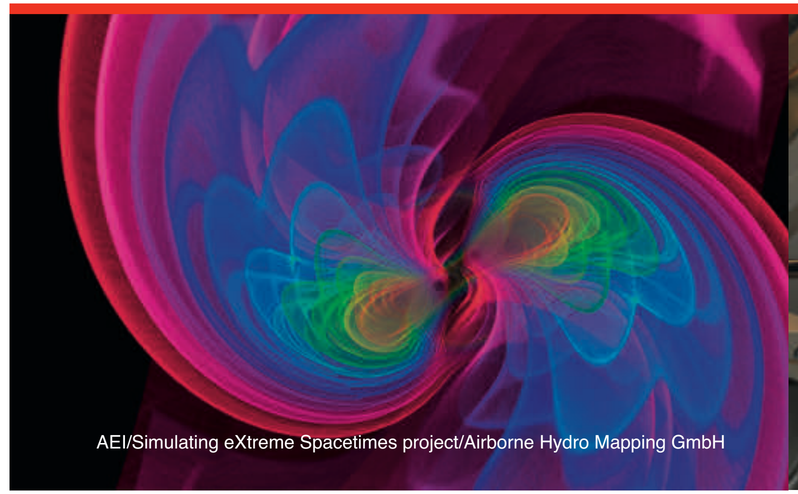
A passing gravitational wave will change the lengths of both arms simultaneously: it will stretch one arm while squeezing the other one at the same time. Now the reflected laser beams no longer cancel each other out completely and there is a signal: light at the interferometer's output.

The technologies developed and tested in GEO600 to measure the tiny ripples in spacetime are now used in all gravitational wave detectors worldwide.

High Tech Under a Tin Roof – Focussing on the Essentials

From the outside, the gravitational wave detector GEO600 does not seem like much. But, hidden in the container buildings and the two 600 metre-long trenches covered with corrugated steel are the most modern of technologies. The focus here is on the essentials, and the simple exterior covers a first-rank scientific experiment. Technology here is being driven to its limits and then developed further: laser stabilization, absorption-free optics, vibration damping and data processing were given many new impulses by the GEO600 scientists.

One example of the advanced technologies used at GEO600 is the so-called "signal recycling" A special mirror at the interferometer output reflects the interference beam back into the interferometer so that the part of the laser light containing the expected gravitational wave signal is amplified. Even the laser light which is used has been improved past what nature usually would allow: GEO600 has a squeezed light source, where the quantum mechanical noise in the light is modified to make the interferometer more sensitive. GEO600 scientists also developed a novel way of suspending the mirrors on glass fibres.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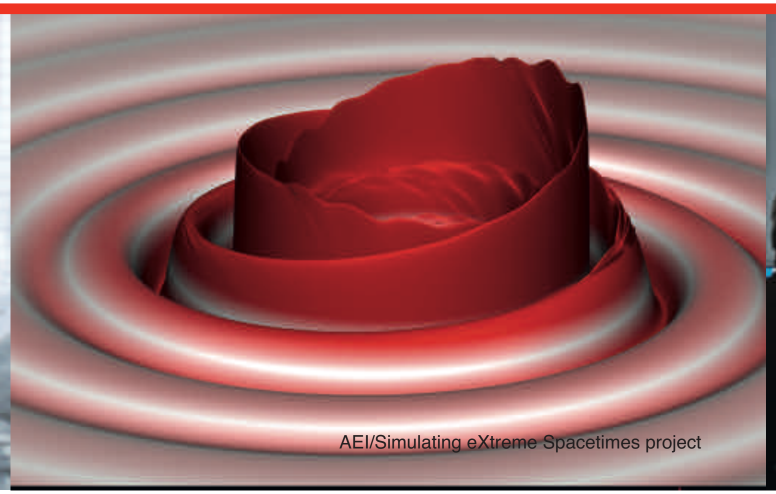
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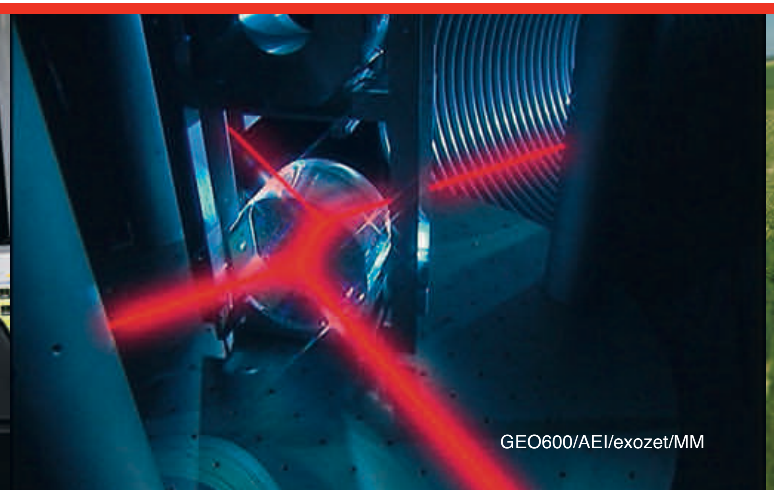
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