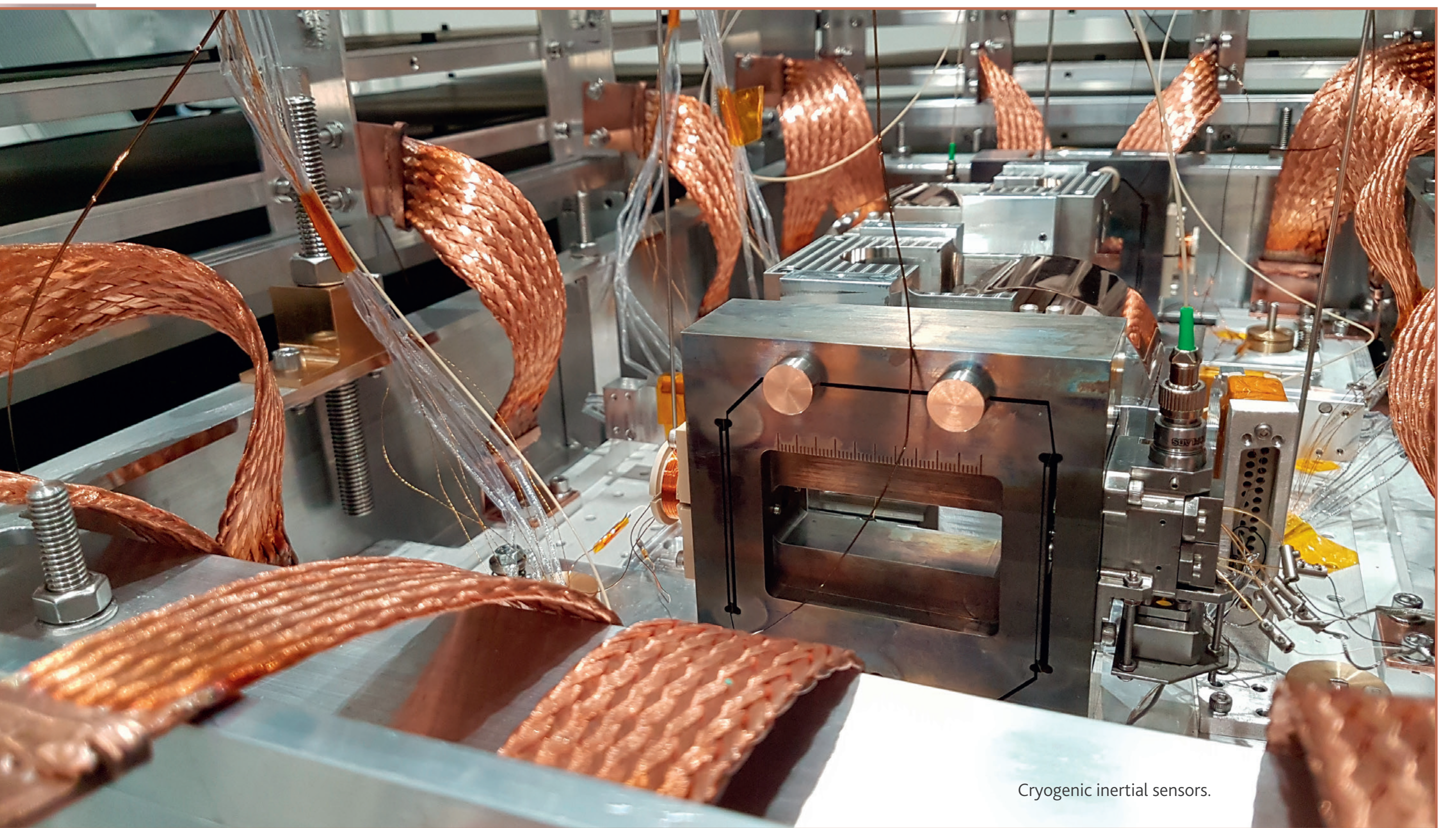


Cryogenic inertial sensors.

A platform for **detecting gravitational waves**

Gravitational waves were first directly observed in 2015 and over 100 more have since been detected. The next generation of detectors are now under development, with researchers in the SILENT project developing a platform to isolate the Einstein telescope from background disturbance and increase sensitivity at low frequencies, as **Professor Christophe Collette** explains.

The Einstein telescope is designed to detect gravitational waves at a higher level of sensitivity than currently possible, helping scientists identify the merger of black holes far out in space and opening up new insights into the origins of the universe. The telescope itself is set to be located deep underground when it enters operation, to minimise disturbance from ground motion of the earth. "Because of the seismic activity of the Earth some disturbances or waves are generated at the surface, which leads to a degree of motion, around the order of a micron," explains Professor Christophe Collette, head of the Precision Mechatronics Laboratory at the University of Liege. A second major factor behind the decision to locate the instrument underground is the goal of minimising disturbance from Newtonian noise, which is caused by fluctuations in the Earth's gravitational field. "If the distance between the mirror in the Einstein telescope and the mass surrounding it changes, then the force which is applied by this body on the mirror is also going to change. This in turn is going to induce some motion of the mirror," says Professor Collette.

"In the project we aim to **develop instrumentation** and **control strategies** to **boost the performance** of the **Einstein telescope** at low frequencies."

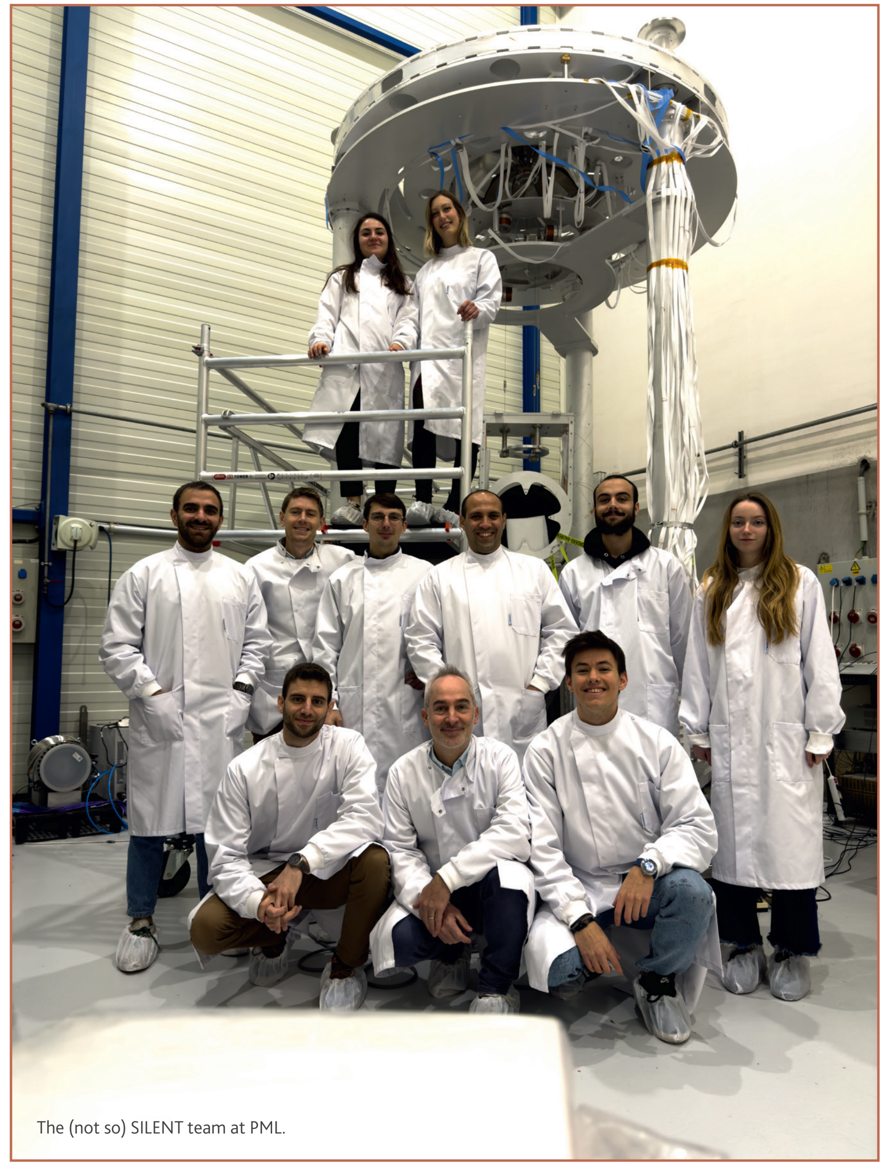
SILENT project

This represents a powerful set of reasons for putting the telescope underground, with two main sites currently being considered, one on the island of Sardinia and another in the area around the border between Germany, the Netherlands and Belgium. Controlling the movement and vibration of the telescope will help enhance its sensitivity to gravitational waves, a topic central to Professor Collette's work as Principal Investigator of the ERC-backed SILENT project. "In the project we aim to develop instrumentation and control strategies to boost the performance of the Einstein telescope at low frequencies," he outlines. The SILENT team is developing a platform to essentially isolate the telescope from these sources of disturbance and so increase measurement sensitivity. "We have basically developed two platforms in the project. One is very much modular, designed with certain technical challenges in mind," says Professor Collette. "Then, based on the lessons learned with this platform, we have developed and built a second. This platform is now in operation, it's performing pretty effectively, and we are currently working to improve the performance."

Assembly of the radiative cryostat.

The platform itself is designed to support the mirrors within the Einstein telescope, which are a key part of the instrument as a whole. In current gravitational wave detectors like LIGO, Virgo and KAGRA, light is split using a beam splitter, which then travels down two perpendicular arms in a vacuum tube to mirrors, before the light bounces back and recombines. "The interference of these two reflected beams can then be analysed to detect gravitational waves," explains Professor Collette. While the exact design of the Einstein telescope is still to be finalised, Professor Collette says the key role of the SILENT platform will be to isolate the mirrors in the instrument. "There is nothing to isolate inbetween these mirrors, in the vacuum tube. However, the mirrors have to be extremely stable, and to achieve that we need to develop an effective suspension system," he continues. "The SILENT platform will provide an environment which is much quieter than the ground, down to frequencies around 10 mHz. Below that, we want the mirror to move together with the ground."

This platform is now being used in a prototype mirror called E-TEST, which will give scientists the opportunity to test and refine different technologies. The E-TEST prototype is a single, full-scale mirror, cooled down to cryogenic temperatures and isolated from seismic motion at low frequencies. "One key feature of the next generation of gravitational wave detectors like the Einstein telescope is that they will use cryogenic mirrors which work at very low temperatures, close to absolute zero. These mirrors will be much larger and the internal noise of the instrument will be pushed down, so the sensitivity will be increased," outlines Professor Collette. It is hoped this increased sensitivity will enable the next generation of detectors to detect more gravitational waves than currently possible. "About 100 gravitational waves have been detected with existing instruments since 2015, when the first was detected by LIGO," continues Professor Collette. "We expect to measure something like 100,000 gravitational waves a year with the Einstein telescope."



The (not so) SILENT team at PML.

Gravitational waves

The main priority with the Einstein telescope is to detect the merger of black holes, which

Installation of the SILENT prototype at PML.

SILENT

Seismic IsoLation of Einstein Telescope

Project Objectives

The EU-funded SILENT project will develop a new platform, controlled by optical seismometers, liquid inclinometers and a gravimeter. It will float in the inertial space and feature new optical inertial sensors and efficient controllers; moreover, it will allow developing accurate models of the Newtonian noise.

Project Funding

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 866259).

Project Partners

There are a total of 16 partner institutions and private companies participating in the SILENT project. Please see the below web link for full details:
http://www.pmlab.be/meet the team

Contact Details

Project Coordinator,
Professor Christophe Collette
Precision Mechatronics Laboratory
Bât. B52/3 Active aerospace structures and advanced mechanical systems
Quartier Polytech 1
Allée de la Découverte 9
4000 Liège
Belgique
T: +32 4 3669152
E: Christophe.Collette@uliege.be
W: http://www.pmlab.be

Professor Christophe Collette

Christophe Collette received an M.Sc. in physics engineering from the University of Liège in 2001 and Ph.D. degree in mechatronics engineering from the Université Libre de Bruxelles in 2007. He is currently full professor at University of Liège, and part time professor at the Université Libre de Bruxelles. He is founder and director of the Precision Mechatronics Laboratory (PML).

Precision Mechatronics Laboratory (PML) is developing instrumentation and strategies for actively measuring and controlling the vibrations of structures, with a particular interest for high precision control of large instruments dedicated to experimental physics, including gravitational wave detectors, particle colliders, segmented ground and space telescopes, satellites and light sources.

Precision Mechatronics Laboratory

generate large distortions of spacetime, as predicted by Einstein in his general theory of relativity. These extremely heavy bodies approach each other at a fraction of the speed of light, then orbit around each other, before merging and generating gravitational waves, essentially ripples in spacetime. "This is the main kind of event that will be detected with the Einstein telescope. But it will also be able to detect other types of events, like the merger of neutron stars," says Professor Collette. During the merger of neutron stars signals are emitted in the electromagnetic domain, which Professor Collette says opens up new possibilities in research. "We can observe these events not only with gravitational wave detectors, but also through a traditional telescope, from their electromagnetic signature," he explains. "This dual observation is called multi-messenger astronomy, and it gives us a much deeper understanding of bodies such as neutron stars. This is something that we would like to continue to do in future with the Einstein telescope."

The Einstein telescope will help researchers to localize merger of neutron stars, and point electromagnetic telescopes accordingly. The Einstein telescope could also complement space-based instruments, which are sensitive in much lower frequency ranges than those on the ground. "It would be very interesting if we could have an overlapping window, so that we have continuous observation over a large frequency range. That is another objective with the Einstein telescope," continues Professor Collette. The SILENT project will play an important role in increasing the sensitivity of the telescope, while Professor Collette says their research also holds wider relevance to other fields beyond astronomy. "Vibration isolation is also necessary for other scientific instruments, like particle colliders and synchrotrons for example, as well as in medicine and microscopy. There are many fields in which vibration isolation is necessary," he says.

The team at the Precision Mechatronics Laboratory are keen to explore these other potential applications of their research into vibration control, part of a commitment to working hand-in-hand with industry. Quantum computers for example will require an extreme level of vibration isolation, and Professor Collette says the knowledge gained in the project will be highly valuable in this and other respects. "Our research in SILENT is definitely transposable to other fields," he says. The current priority in the SILENT project however is to improve the platform, looking towards its eventual application in the telescope. "We have developed the platform, the inertial sensors, and the control strategy. They are performing very well, and we are working to improve them," continues Professor Collette. "We aim to continue to improve the control strategy, in order to make better use of the inertial sensor and improve the level of isolation at low frequencies. We are also involved in several other projects, in which we will continue to work specifically on control strategies."

> "The Einstein telescope is designed to **detect gravitational waves** at a **higher level of sensitivity** than currently possible, helping scientists identify the **merger of black holes** far out in space and **opening up new insights** into the **origins of the universe."**

Chiara's final touch on the interferometer.