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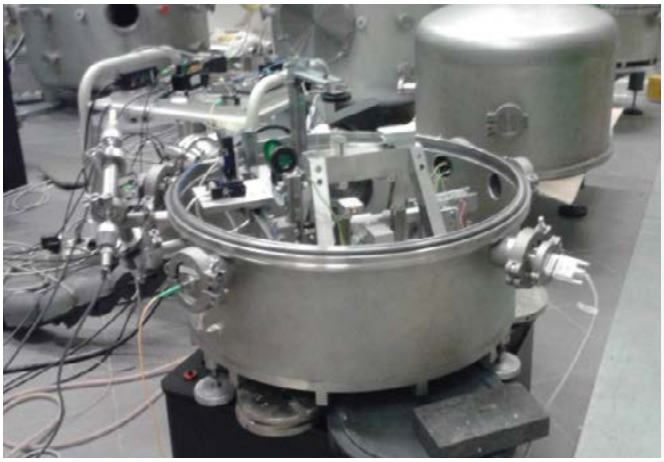

THE WEIGHT OF THE VACUUM: A STEP FORWARD FOR ARCHIMEDES

The 5-tons steel chamber, a fundamental element of the INFN Archimedes experiment, has arrived in Sardinia, the first to be installed in the SARGRAV underground laboratory in Lula, in the province of Nuoro. The scientific objective of Archimedes is to “weigh the vacuum”, i.e. to investigate the role of the interaction of vacuum fluctuations with the force of gravity, in order to help to find an answer to open questions of fundamental physics and cosmology, such as the nature of mysterious dark energy.

In quantum mechanics, Heisenberg's uncertainty principle states that the complete absence of particles and energy in a vacuum is not possible. It must therefore contain “virtual” particles that are dynamically created and then destroyed (annihilated) giving rise to continuous energy fluctuations. If we could measure the interactions between these energy fluctuations, caused by continuous annihilations, and gravity, we could say that we have "weighed the vacuum” and, therefore, created a bridge between vacuum and gravity.

But how does the Archimedes experiment work? The fundamental unit of the experiment is a super-sensitive scale with a 1 metre long arm, which will be built by the researchers of the INFN Naples division working on the experiment. The scale must be able to measure the small weight variations induced in two samples of a material that has the property of “trapping” or “expelling” vacuum energy when its temperature is changed. These two samples that constitute the "plates" of the scale are 10 cm wide and 3 mm thick discs made of a particular type of material that has the property of becoming superconductive below 100 K (-173°C), while above this temperature it behaves like an insulator. This material, called YBCO, is a superconductor and has a microscopic structure consisting of many layers (approximately one million) just a few nanometres apart: it is in the microscopic space between these layers that the so-called Casimir cavities are created, regions where the energy of the vacuum (due to

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the annihilation between particles and antiparticles) becomes lower than outside. For this reason, when it is brought below its critical temperature, YBCO becomes lighter and, by modulating the temperature of the discs around their critical temperature by irradiation, any variations in their weight can be measured and thus the interactions between vacuum fluctuations and gravity can be studied.

To be able to operate this scale at very low temperatures, cryogenics is required. The scale will therefore be installed inside a cryostat, under construction at the INFN Rome 1 division. The cryostat will consist of three steel chambers, the first of which is the 5-tons experimental vacuum chamber that has just arrived in Lula, while the second is a chamber with 4000 litres of liquid nitrogen which, like a matryoshka, will be in a third one, called the isolation chamber, where a vacuum will be created to isolate the system from the outside.

Archimedes will therefore have to carry out very high precision measurements, which is why the experiment will be installed in one of the "quietest" places in Europe: the SARGRAV underground laboratory, inside the former Sos Enattos mine. Here, in fact, seismic noises or sounds of anthropogenic origin and Newtonian noise, due to local variations in the force of gravity, are very low. For this reason, the site has been nominated to host the ambitious international Einstein Telescope (ET) project in which Italy is participating with INFN, the National Institute for Astrophysics (INAF), the Italian Institute for Geophysics and Volcanology (INGV) and the Universities of Sassari and Cagliari. ET will be an underground triangular-shaped interferometer with 10 km long arms, which will use highly enhanced technologies compared to those currently available to study gravitational waves. And, precisely in order to confirm its suitability to host the future ET telescope, Archimedes will also have the task of making very accurate measurements of the background noise of the Sos Enattos site.

Archimedes is an experiment funded by INFN. Together with the INFN divisions of Naples and Rome 1, the experiment also involves the Federico II University of Naples, La Sapienza University of Rome, the University of Sassari, the European Gravitational Observatory (EGO), the CNR National Institute of Optics (CNR-INO) and the Aix-Marseille Université. ■