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Archimedes: how much does the vacuum weigh?

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The cosmological constant problem enfolds one of the most long-standing issues in physics: the incompatibility between Quantum Field Theory and General Relativity. Within this background, the Archimedes experiment aims to investigate the relationship between zero-point quantum fluctuations of the electromagnetic field and gravity. Using a highly sensitive suitably designed beam-balance, Archimedes will measure the force exerted by gravitational field on samples hanging from the balance arms. Vacuum energy is modulated inside the samples by exploiting superconductive transition, which turns them in a stack of Casimir cavities, expelling not-allowed EM modes. If vacuum energy interacts with gravity, an upward force will act on the samples and could be interpreted as the missing weight of the ejected EM modes, in similarity with the Archimedes buoyancy of fluid. The expected signal in torque generated with this modulation is of the order of $10^{-13} Nm/\sqrt{Hz}$. To minimize environmental disturbances, Archimedes is installed in the SarGrav Laboratories at the Sos-Enattos site, in Sardinia (Italy) which is seismically very quiet and, for this reason, candidate for hosting the third-generation Gravitational Waves detector Einstein Telescope. The tilt sensitivity of Archimedes prototype, installed in the same laboratory, is currently thermal-noise limited, and has been measured to be below $10^{-12} Nm/\sqrt{Hz}$ in the frequency band 20 mHz - 70 mHz, which makes it one of the most sensitive beam-balance in the world in this frequency range. Besides demonstrating the correctness of the design, measurements on the prototype also showed that it is capable to investigate other kind of fundamental physics aspects, such as the interaction with dark B-L photons. The final setup of the Archimedes experiment is now fully installed, the first sensitivity measurement in vacuum is expected by the end of 2024, while the final measurement of the vacuum fluctuations' weight is forecast to be performed within 2026.

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