Testing the Gravitational Inverse-Square Law with torsion pendulum in HUST

Shan-Qing Yang[1,*]

[1] *MOE Key Laboratory of Fundamental Physical Quantities Measurement, Hubei Key Laboratory of Gravitation and Quantum Physics, PGMF and School of Physics, Huazhong University of Science and Technology, Wuhan 430074, P. R. China.*

Driven by the two so-called hierarchy problems of gravity, a number of speculations have been proposed, which predict a deviation from the gravitational inverse-square law (ISL) in a short-range regime [1]. It is customary to parameterize these new physics by a Yukawa potential $V(r) = -Gm_1m_2(1 + \alpha e^{-r/\lambda})/r$. We have been testing Newtonian $1/r^2$ law in short range using torsion balances since 2000 [2, 3]. In 2007, we finished a null test of ISL at sub-millimeter range with a dual-modulation torsion pendulum [2], by modulating the gap between gold test masses with sizes of $\sim 19.98 \times 20.07 \times 0.202$ mm^3 from 176 μm to 341 μm. At a 95% confidence level, the result shows that the ISL holds ($|\alpha| \leq 1$) down to a length scale $\lambda = 66$ μm, and sets a unification energy scale of $M^* \geq 2.8$ TeV/c^2 for the two extra space dimensions with the size $R^* < 47$ μm. In 2012, we finished the experiment at millimeter range with gap modulation from 0.4 mm to 1.0 mm. The test masses are pure tungsten plates with sizes of $\sim 15.994 \times 15.986 \times 1.787$ mm^3. The experiment establishes the most stringent constraints on α in the ranges from 0.7 mm to 5.0 mm. In our new experiment at sub-millimeter range with separation of 295 μm between the test and source masses with sizes of $\sim 14.610 \times 0.200 \times 12.003$ mm^3, we upgrade the attractor to be 8-fold symmetric for separating the signal frequency from the drive frequency. The attractor rotates about a horizontal axis so that the Yukawa effect is in the most sensitive direction of the torsion pendulum. The "dual compensation" of the Newtonian torque is used to achieve a null experiment. This work establishes the strongest bound on α in the range of 70–300 μm, and improves the previous bounds by up to a factor of 2 at the length scale $\lambda \approx 160$ μm [4]. Now we are still putting in a great deal of effort to increase the accuracy of testing the ISL, with a larger test mass and a more symmetric attractor.

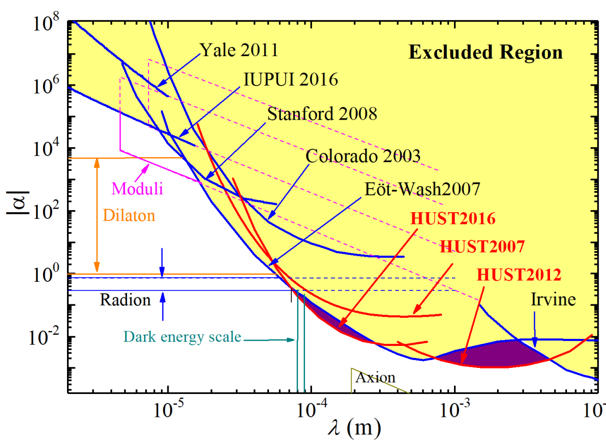

FIG. 1. Constraints on Yukawa violation of the Newtonian $1/r^2$ law. The shaded region is excluded at a 95% confidence level.

* E-mail: ysq2011@hust.edu.cn

[1] E. G. Adelberger *et al.*, *Annu. Rev. Nucl. Part. Sci.* **53**, 77 (2003).
[2] L. C. Tu *et al.*, *Phys. Rev. Lett.* **98**, 201101 (2007).
[3] S. Q. Yang *et al.*, *Phys. Rev. Lett.* **108**, 081101 (2012).
[4] W. H. Tan *et al.*, *Phys. Rev. Lett.* **116**, 131101 (2016).