Testing Gravitational Redshift through Simulation based on the China Space Station Laser Timing Experiment.

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One of the major purposes of the Laser Timing (LT) experiment is to test gravitational redshift (GRS). The LT experiment is based on satellite laser ranging (SLR) technology and employs specialized space equipment to accurately record the arrival times of laser pulses in space. In October 2022, the China Space Station (CSS) was launched, equipped with a set of high-precision atomic frequency standards and LT experiment instruments, to the Mengtian module. These standards include hydrogen, cooled atom microwave, and optical atomic clocks with stabilities of 2×10^{-15}, 2×10^{-16}, and 3×10^{-17} @ day, respectively. Additionally, the LT payload is equipped with a novel single photon detector with a timing stability of $< 1 \times 10^{-12}$ @ 300 s and an event timer with RMS precision of $< 8 \times 10^{-12}$. The CSS operates at an altitude of about 400 km, with an orbital inclination of 41.47 degrees. This configuration allows it to contribute effectively to the CSS missions' scientific and research capabilities, including fundamental physics, space astronomy and astrophysics, geodesy, Earth science, and various other applications. Through simulations, based on the optical two-way laser time transfer (TWLTT) links, this study aims to test the GRS. The simulated observations include the recordings of the laser signal emission time at ground station toward the CSS, the arriving time of the signal at CSS, and the receiving time of the returning signal from CSS at ground station. We expect that testing the gravitational redshift using the TWLTT approach in the LT experiment may achieve an accuracy of 10^{-6}, better than the present accuracy in the world. This demonstrates the exceptional precision achievable with optical atomic clocks on the CSS. This work highlights the potential of laser timing experiments to significantly advance our understanding of fundamental physics and contribute to space-based scientific research. This study is supported by the National Natural Science Foundations of China (NSFC) (Grant Nos. 42030105, 42388102, and 42274011) and the Space Station Project (2020-228).

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