

MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (A2)
Gravity and Fundamental Physics (1)

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RELATIVISTIC REDSHIFT PROBE USING BALLOONS

Abstract

The continuous improvement of optical atomic clocks offers a unique opportunity to check the redshift predicted by General Relativity using stratospheric balloons. The concept has been under study at CNES and was presented two years ago. Here we report the work done in the mean-time. Carrying an optical clock to an altitude of 40 km and comparing its signal to the one of a sister clock on the ground allows an improvement over current knowledge, and a check on a possible violation if it is observed by the ACES mission in the next three years. The challenges of the experiment are recalled. The capabilities of a clock accurate at the 10^{-16} level flying at 400 km: the case of the PHARAO atomic clock within the ACES payload, can only be matched by a 10^{-17} accuracy clock is flying “only” at 40 km. We decide to set a goal of $5 \cdot 10^{-18}$ for margin. To be consistent with this goal, the altitude of the clock must be known to better than 5 cm as the earth potential typically creates a relative shift of 10^{-18} per cm. The relation between altitude and gravitational potential must be known accordingly. We report the choice of a GPS receiver, its environment test and the results of an actual flight in a stratospheric balloon launched from Canada during the summer 2015. More flights may follow as we want to fully qualify the device before the actual experiment. Another challenge is the frequency transfer device associated with the experiment. Current advanced microwave device may be up to the task, but would require several hours of averaging to reach the required frequency resolution. In contrast, coherent laser link promises to do so in much less than an hour and would not limit the clock comparison. We will explore the possibility of using experimental balloon flights to test these devices as well. Finally, optical atomic clocks continue to improve at their own pace in terms of stability ($3 \cdot 10^{-16}$ at one second), accuracy ($2 \cdot 10^{-18}$) and reliability (reaching days of continuous operations). Several initiatives to make them transportable exist. The first flight may take place in 2019/2020 time frame.