ACES, the Definition of the Second, and the Interpretation of Time Dilation

ACES - Atomic Clock Ensemble in Space

Author: Franc Rozman • Contact: fr.rozman@gmail.com

ESA is conducting the ACES measurement, which, if successfully completed, will represent a turning point in our understanding of the universe. [3]

The ACES (Atomic Clock Ensemble in Space) experiment [3] compares an atomic clock on the International Space Station (ISS) with a clock on Earth. It tests whether gravity and the speed of the ISS influence the rate of the clock.

They are checking whether the clock behaves as prescribed by the definition of the second, or as predicted by the theory of relativity.

The ACES system was installed on the ISS in April 2025; we are awaiting the measurement results. [3]

We measure time in seconds. The General Conference on Weights and Measures (CGPM) has defined the second in such a way that all ideal clocks run identically, regardless of circumstances. On the basis of this definition, we expect the clocks on Earth and on the ISS to run at the same rate. [1]

In the past, several measurements have been carried out in which researchers attempted to detect differences in the rate of clocks at different altitudes and speeds. The results of such experiments are usually interpreted within the framework of the theory of relativity. [2] At the same time, we must ask how the results of these measurements are compatible with the definition of the second. [1][2]

ACES is a decisive, though not final, measurement for assessing the theory of relativity. This experiment is followed by an independent measurement of the wavelength of light with a standard metre. [4] The measurement shows that the wavelength of light does not depend on the motion of the source or the observer [4]; only the frequency depends on it.

Different interpretations of the frequency and wavelength of light lead to different conclusions about whether the speed of light is always the same or can depend on circumstances. Supporters of the theory of relativity interpret such phenomena in one way; the measurements, however, suggest that the same data could also be read differently.

In the ACES experiment it will be important to interpret the results as neutrally as possible – as data that can either confirm existing models or show where they need to be refined. [3] It is natural to expect that the ACES measurement will make it possible to reach an unambiguous judgment between the theory of relativity and the definition of the second. [1][3]

In everyday life, the theory of relativity has no direct influence and does not hinder our daily tasks. The current understanding of an always constant speed of light is, however, an obstacle to understanding the universe, especially the distant universe where dark matter appears. We can therefore expect the ACES measurement to open up new horizons in this field. [1][3]

The ACES measurement offers an opportunity to test our basic assumptions about time and the speed of light and thereby broaden our view of the universe.

References

[1] BIPM. *The International System of Units (SI)*, 9th ed., 2019 (latest update of version 3.0, 2023/2025). Bureau International des Poids et Mesures, Sèvres.

[2] Hafele, J. C., & Keating, R. E. “Around-the-World Atomic Clocks: Observed Relativistic Time Gains.” *Science* 177(4044), 168–170 (1972). DOI: 10.1126/science.177.4044.168.

[3] ESA/ACES technical descriptions (PHARAO/SHM, microwave and laser links MWL/ELT), e.g. ACES Factsheet and accompanying technical documentation (2011–2024).

[4] Franc Rozman, *The Light from Space*, 2025.