HIGHLY PRECISE CLOCKS TO TEST FUNDAMENTAL PHYSICS

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ABSTRACT. Highly precise atomic clocks and precision oscillators are excellent tools to test founding principles, such as the Equivalence Principle, which are the basis of modern physics. A large variety of tests are possible, including tests of Local Lorentz Invariance, of Local Position Invariance like, for example, tests of the variability of natural constants with time and with gravitation potential, tests of isotropy of space, etc. Over several decades, SYRTE has developed an ensemble of highly accurate atomic clocks and oscillators using a large diversity of atomic species and methods. The SYRTE clock ensemble comprises hydrogen masers, Cs and Rb atomic fountain clocks, Sr and Hg optical lattice clocks, as well as ultra stable oscillators both in the microwave domain (cryogenic sapphire oscillator) and in the optical domain (Fabry-Perot cavity stabilized ultra stable lasers) and means to compare these clocks locally or remotely (fiber links in the RF and the optical domain, femtosecond optical frequency combs, satellite time and frequency transfer methods). In this paper, we list the fundamental physics tests that have been performed over the years with the SYRTE clock ensemble. Several of these tests are done thanks to the collaboration with partner institutes including the University of Western Australia, the Max Planck Institut für Quantenoptik in Germany, and others.

TESTS OF LOCAL POSITION INVARIANCE

M. Niering et al.,
Measurement of the Hydrogen 1S-2S Transition Frequency by Phase Coherent Comparison with a Microwave Cesium Fountain Clock.
Phys. Rev. Lett. 84, 5496 (2000).

H. Marion, et al.,
Search for Variations of Fundamental Constants using Atomic Fountain Clocks.
Phys. Rev. Lett. 90, 150801 (2003).

M. Fischer et al.,
New Limits to the Drift of Fundamental Constants from Laboratory Measurements.
Phys. Rev. Lett. 92, 230802 (2004).

N. Ashby et al.,
Testing Local Position Invariance with Four Cesium-Fountain Primary Frequency Standards and Four NIST Hydrogen Masers.
Phys. Rev. Lett. 98, 070802 (2007).
Note: SYRTE contributed to this test through primary calibrations of the Interntational Atomic Time (TAI).

S. Blatt et al.,
New Limits on Coupling of Fundamental Constants to Gravity Using ^{87}Sr Optical Lattice Clocks.
Phys. Rev. Lett. 100, 140801 (2008).

C. G. Parthey et al.,
Improved Measurement of the Hydrogen 1S-2S Transition Frequency.
Phys. Rev. Lett. 107, 203001 (2011).

TESTS OF LOCAL LORENTZ INVARIANCE

P. Wolf P. et al.,
Tests of Lorentz Invariance using a Microwave Resonator.,
Phys. Rev. Lett. 90, 060402, (2003).

P. Wolf P. et al.,
Whispering Gallery Resonators and Tests of Lorentz Invariance.,
Gen. Rel. and Grav. 36, 2351 (2004).

P. Wolf P. et al.,
Improved test of Lorentz invariance in electrodynamics.,
Phys. Rev. D 70, 051902(R)(2004).

P.L. Stanwix et al.,
Test of Lorentz Invariance in Electrodynamics Using Rotating Cryogenic Sapphire Microwave Oscillators.,
Phys. Rev. Lett. 95, 040404 (2005).

P. Wolf P. et al.,
Cold Atom Clock Test of Lorentz Invariance in the Matter Sector.,
Phys. Rev. Lett. 96, 060801 (2006).

P.L. Stanwix et al.,
Improved test of Lorentz invariance in electrodynamics using rotating cryogenic sapphire oscillators.,
Phys. Rev. D74, 081101(R) (2006).

H. Müller et al.,
Tests of Relativity by Complementary Rotating Michelson-Morley Experiments.,
Phys. Rev. Lett. 99, 050401 (2007).

M. E. Tobar et al.,
Testing local Lorentz and position invariance and variation of fundamental constants by searching the derivative of the comparison frequency between a cryogenic sapphire oscillator and hydrogen maser.,
Phys. Rev. D81, 022003 (2010).