Clocks with radioactive species for new physics searches

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The development of atomic clocks with systematic uncertainties in the 10^{-18} range enables searches for the variation of fundamental constants, dark matter, and violations of Lorentz invariance. I will discuss recent advances in theory of clocks based on highly-charged ions (HCIs) including the detailed investigation of optical clocks based on Cf^{15+} and Cf^{17+} [1]. Recent methodology developments and resulting capabilities of the state-of-the-art atomic methods to compute atomic properties of actinides will be presented. We significantly accelerated the computation of the valence triple excitations and included for the first time core triple excitations in the framework of the coupled-cluster approach [2]. Using a new approach, we computed energies and hyperfine constants of Th^{3+}, proposed for a nuclear clock, for an improved determination of ^{229}Th nuclear magnetic dipole and electric quadrupole moments. In another project, we developed a broadly applicable approach based on a parallel (MPI) configuration interaction code that drastically increases the ability to predict the properties of complex atoms accurately [3]. We recently used this approach to evaluate the electronic bridge process in $^{229}Th^{35+}$ for a laser excitation of a nuclear transition [4]. These methods are applicable to a broad range of atoms and ions, including superheavy elements. I will also report a release of the first version of a new online portal for high-precision atomic data and computation [5]. Future plans to add actinides and other data as well as to release computer codes are discussed.

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[2] S.G. Porsev and M.S. Safronova, in preparation.
[3] C. Cheung, M. S. Safronova, S. G. Porsev, M. G. Kozlov, I. I. Tupitsyn, and A. I. Bondarev Phys. Rev. Lett. 124, 163001 (2020).
[4] S. G. Porsev, C. Cheung, M. S. Safronova, arXiv:2105.00512, submitted to Quantum Science and Technology (2021).
[5] Parinaz Barakhshan, Adam Marrs, Bindiya Arora, Rudolf Eigenmann, Marianna S. Safronova, Portal for High-Precision Atomic Data and Computation (version 1.0). University of Delaware, Newark, DE, USA. URL: https://www.udel.edu/atom.