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【16】Spectroscopy of trapped antihydrogen atoms

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Precision studies of antihydrogen might shed light on one of the most tantalizing mysteries in today's Physics: the asymmetry of matter-antimatter abundance in the Universe. In this presentation, we review the developments in the experiments ATHENA and ALPHA, housed at CERN's Antiproton Decelerator, leading to the first production of low-energy anti-atoms [1] and later the first trapping of antihydrogen atoms [2]. These exotic atoms can be held for over 15 minutes in the trap [3], thus allowing for a new era of high precision measurements of antimatter. Among the initial measurements, we have put new limits on a possible electrical charge of the anti-atom [4] that, together with independent measurements, put new limits on a possible charge anomaly of the positron. Microwaves can induce spin-flipping transitions [5] and allow for the measurement of the hyperfine constant. The main goal of a high precision two-photon laser spectroscopy on the 1s-2s transition has just been started with the observation of the laser excitation [6], and it should evolve into 2017 with a first spectrum leading to comparisons of parts in 10¹² between these transitions in antihydrogen and its charge conjugate atom. There are prospects for reaching parts in 10¹⁵ and beyond [7], and those will require further cooling of the anti-atoms [8] and the possibility to trap hydrogen in the same trapping environment as the antihydrogen [9]. Whether the CPT (charge-parity-time) symmetry will hold true at these levels of precision or whether gravity acts the same way –probed firstly by "red shifts" on the transition frequencies –on antimatter atoms, only nature has that answer. As experimenters with this exotic species at hand it is our duty to properly inquire nature's responses on all these issues.

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[4] M. Ahmadi, et al. (ALPHA Coll.) "An improved limit on the charge of antihydrogen from stochastic acceleration", Nature 529, 373 (2016)
[5] C. Amole, et al. (ALPHA Coll.), "Resonant quantum transitions in trapped antihydrogen atoms", Nature 483, 439(2012)
[6] M. Ahmadi et al. [ALPHA Coll.], Observation of the 1S–2S transition in trapped antihydrogen, Nature 541, 506 (2017)
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