Invited talk

Spectroscopy of Antihydrogen: The ALPHA experiment at CERN

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The ALPHA experiment at CERN is unique in its demonstrated ability to study the internal structure of antihydrogen – the antimatter equivalent of the simplest atom. Such studies are motivated by the apparent absence of antimatter in the observable universe, and they probe the fundamental symmetries that underlie current theory. For example, the Standard Model requires that hydrogen and antihydrogen have the same spectrum. The possibility of applying the *precision* measurement and manipulation techniques of atomic physics to an antimatter atom makes antihydrogen a very compelling testbed for symmetries such as CPT and the Weak Equivalence Principle of General Relativity. To study antihydrogen, it must first be created, trapped, and then held for long enough to make a measurement – typically using very few anti-atoms. I will discuss the latest developments in antihydrogen physics, including the state-of-the art of spectroscopic studies using the ALPHA-2 machine. In ALPHA-2, we have studied several laser and microwave driven transitions and demonstrated laser cooling of trapped antihydrogen[1]. Very recently, we have shown that it is possible to accumulate more than 10^4 anti-atoms in a single day. I will illustrate the techniques necessary to achieve these many milestones and consider the future of antihydrogen studies, including gravitational measurements using antimatter[2].

[1]Laser cooling of antihydrogen atoms (ALPHA Collaboration) *Nature* **592**, 35–42 (2021).
[2]Observation of the effect of gravity on the motion of antimatter (ALPHA Collaboration) *Nature* **621**,716–722 (2023).