Precision spectroscopy of H_2^+ and antiprotonic helium atoms. Theory.

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In recent years several experiments on precision spectroscopy of three-body light atomic and molecular systems become available [1, 2]. That is a great challenge to theorists, since the QED theory for the few-body bound state problem is not that well elaborated as for atoms comprised of two particles.

In our contribution we would like to make an outlook of the present status of theoretical calculations based on the Nonrelativistic QED effective theory. Numerical results for the relativistic and radiative corrections up to (and partially including) $m\alpha^6$ order can be found in [3] for the antiprotonic helium atom and in [4] for the hydrogen molecular ion.

Calculations of the remaining $m\alpha^6$ contribution have been recently carried out in the nonrecoil limit (results are presented on Figure below).

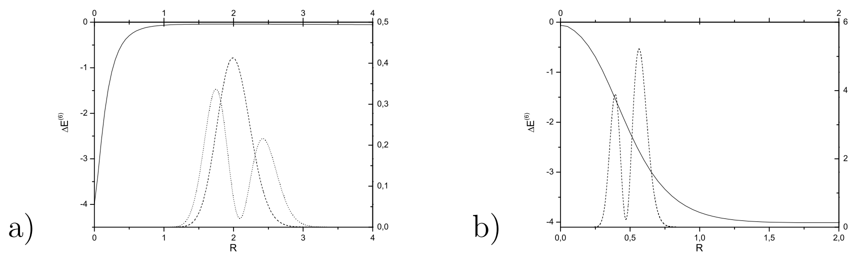

Figure 1: The effective adiabatic potential for the relativistic $m\alpha^6$ order correction: a) $z_1 = z_2 = 1$; b) $z_1 = 2$, $z_2 = -1$. Dashed lines are the radial wave function for: a) the ground and first vibrational S-states of H_2^+; b) the $(36, 34)$ state of the $^4He^+\bar{p}$ atom.

Analysis of the antiprotonic helium atom spectroscopy allows to determine the $m_{\bar{p}}/m_e$ ratio with a 2 ppb precision and confirms a 1 σ agreement with the CODATA02 recommended value. Below is a comparison of theoretical calculations for the HD^+ ion for the $(v, L): (0, 2) \to (4, 3)$ rovibrational transition with the most recent measurement [2] (PRL):

$$E_{\rm exp} = 214\,978\,560.6(5)\ \text{MHz}$$
$$E_{\rm th} = 214\,978\,560.88(7)\ \text{MHz}$$

[1] M. Hori, *et al.* Phys. Rev. Lett. **96**, 243401 (2006); and references therein.

[2] B. Roth, J.C.J. Koelemeij, H. Daerr, and S. Schiller, Phys. Rev. A **74**, 040501(R) (2006); J.C.J. Koelemeij, *et al.* Phys. Rev. Lett. **98**, 173002 (2007).

[3] V.I. Korobov, Phys. Rev. A **67**, 062501 (2003); V.I. Korobov, Proceedings of EXA-05, IMEP, Vienna, Austria, 491 (2005).

[4] V.I. Korobov, Phys. Rev. A **74**, 052506 (2006).