Strong Field QED Analysis With Bayesian Model Selection for He-Like Ions

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Abstract

Quantum Electrodynamics (QED) effects have been tested and measured in multiple systems, including free electrons, atomic and highly charged ions systems. Frequentist statistical analyses either point to a possible deviation from the theory prediction [1] of $n = 2 \to 1$ transitions energy in two-electron systems with a dependency of Z^3, Z indicating the nuclear charge, or find no disagreement [2-5]. We present a Bayesian statistical approach method using the nested sampling algorithm, implemented in the `nested_fit` code package [6], to quantitatively evaluate different deviations via probability inference from Bayesian evidence. The deviations are modeled as aZ^n and aZ^n+b functions, a and b being free parameters, for the measurements of multiple transitions on helium-like ions for $Z = 12-92$. We evaluated these modeled deviations from the current theory predictions [7, 8] for the $1s2p\,^1P_1 \to 1s^2\,^1S_0$ (w), $1s2p\,^3P_2 \to 1s^2\,^1S_0$ (x), $1s2p\,^3P_1 \to 1s^2\,^1S_0$ (y), and $1s2p\,^3S_1 \to 1s^2\,^1S_0$ (z) radiative transitions. We found that the function with highest probability corresponds to a deviation with $n \approx 4.5$, but has a marginal statistical significance of 2.7σ with respect to the zero model with no deviation from the theory. The additional analysis of the $n = 2 \to 2$ ($Z = 5-92$) transitions provided an even lesser evidence for either a constant or power model deviations. Finally, we investigated on the impact of possible future high-accuracy experiments on high-Z ions. In particular, we determine the minimum required accuracy for a meaningful test of possible deviations. We construct hypothetical measurement data in the Z region of interest, vary its uncertainty and value, and survey the behaviour of the probability distribution over the selected models for each combination. Such an analysis will allow for a better design of future experiments for the search of new QED contributions or even new physics, like milli-charged particle interactions.

References:

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