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Breakdown of Quantum Electrodynamics in (*g*-2) – Experiments?

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Abstract

Some of the possible reasons for the presently existing statistically significant discrepancy between the experimental and the theoretical values of the electron ($g - 2$) would lead to fundamental revisions of QED.

A recent Letter [1] has again explicitly raised the question, whether there is a breakdown of quantum electrodynamics (QED). Such a breakdown seems to be a reasonable assumption in view of the existing discrepancy between the present experimental and the theoretical values of the anomalous magnetic moment of the electron. Since the announcement of the latest experimental data on the anomalous magnetic moment of the electron $a_e^{\text{exp}} = 1\,159\,652\,193(4) \times 10^{-12}$ by the University of Washington group [2], this discrepancy has led to a prevailing, sometimes controversial discussion. Since the present disagreement is nearly as big as 4 standard deviations, it is reasonable to search for systematic errors both of the experimental value and the theoretical prediction, the latter possibly implying a fundamental change, i.e., breakdown, of present QED. Samuel has put forward two possible reasons for the discrepancy, namely (i) the existence of a pseudoscalar axion, or (ii) an E_6 model with exotic leptons [1].

We wish to point out here that there are at least five further explanations – some of which, to our opinion, are certainly not less conservative as the ones proposed by Samuel:

(iii) The *perturbation series becomes asymptotic* [3] for contributions proportional to orders of the fine structure constant α higher than two. This would be an indication of a major limitation to *perturbation* QED, whereas nonperturbative methods might still be applicable.

(iv) There are large contributions from *apparatus dependencies*. Whereas there has been reached agreement on the smallness of the Casimir contribution [4] to a_e^{theor}, there are claims [5] that due to resonance effects in the microwave cavity there are shifts of a_e^{exp} which could well make up for the discrepancy between theory and experiment. Recently, some disputes in this area could be resolved by a careful consideration of physical quantities entering the definition of a_e and frequencies involved [6].

(v) By applying different *convergence acceleration methods* and inserting a very *recent value* of α, it has been suggested [7] that theory and experiment agree within 1.3 standard deviations, compared with the Letter [1] value of 4 standard deviations.

(vi) In Barut's magnetic model an upper limit for the neutrino anomalous magnetic moment of a few 10^{-9} Bohr magnetons follows. If such a value also exists for the electron, it would be of the order of the present discrepancy [8].

(vii) By considering a *fractal support of the quantized fields* it has been suggested [9] to parameterize the Hausdorff dimension of space-time. Using Samuel's theoretical new value, this dimension would be $4 - 2 \times 10^3 \times (a_e^{\text{theor}} - a_e^{\text{exp}}) = 4 - 1.21(0.29) \times 10^{-6}$.

Whereas (iv) and (v) indicate agreement of perturbative QED with experiment, (iii) allows for an agreement of nonperturbative QED. In all these three cases there would certainly not be a breakdown of QED on this level. Yet, possibilities (vi) and (vii) as well as the explanations (i) and (ii) put forward by Samuel would either introduce new parameters (such as a non-integer dimension of space–time) or change the structure of present QED.

Whether the trend of increasing differences between the theoretical and the experimental values of a_e can be substantiated in the future beyond doubt seems unclear at the moment. In view of the fact that QED is a cornerstone of our present physical description of the world, future work presents an urgent challenge both for theory and experiment.

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