Phenomenological implications of nonlocal electrodynamics

Raoul Serao
Università Degli Studi Di Salerno, Salerno, Italy

In recent years many phenomena, ranging from the strong CP problem, particle mixing and oscillations, matter-antimatter asymmetry, to the nature of dark matter and dark energy, as well as the lack of a quantum theory of gravity, have lead to the development of theories beyond the Standard Model (SM) of particles. An example of a phenomenon which cannot be described within the SM may be represented by the muon magnetic moment anomaly. The successful prediction of the magnetic moment of the charged leptons is one of the most celebrated accomplishments in Quantum Field Theory. The Dirac theory predicts a g-factor $g_{Dirac} = 2$, whereas the radiative corrections shift the actual value slightly above 2. This allows one to define the anomalous magnetic moment α as the difference between the quantum field theoretic prediction and the Dirac value $\alpha = g - 2 /2$. For the electron, the anomalous moment $\alpha_e = (g-2)_e/2$ computed from Quantum Electrodynamics matches with the experimental value up to a striking precision of 10^{-12} . However recently, new experimental results from the Muon g-2 collaboration have confirmed a discrepancy between the observed value of the muon anomalous moment α_μ and the standard model prediction. The combined data from the Brookhaven and the Fermilab Muon g-2 experiments lead to a 4.2σ discrepancy $\Delta\, \alpha_\mu = \alpha_{\mu,EXP} - \alpha_{\mu,SM} = (251 \pm 59) \times 10^{-11}$. The discrepancy has fueled the discussion upon the need for new physics, since, if confirmed, it would be a clear indication of physics beyond the SM. Many speculations about the origin of this discrepancy have been made in the last years. On the other hand, nonlocal theories have proliferated since the seminal work of Yukawa. Nonlocal theories of gravity have been developed as an extension of general relativity. Here nonlocal (i.e. non-polynomial) form factors in the gravitational action can help to solve the problem of ghosts as well as to improve the ultraviolet behavior of the quantized theory. In particle physics, nonlocal theories are closely tied to string theories, as well as noncommutative field theories. Recently, a nonlocal extension of the standard model has been proposed. In this work we speculate about the possibility that the g−2 discrepancy for the muon be induced by a string-field-theory inspired nonlocal theory. We compute the lowest order nonlocal correction to the anomalous magnetic moment α_{NL}, and we find that it depends in a simple fashion on the nonlocality scale M_f and the fermion mass m_f as $\alpha_{NL} \propto m_f^2/M_f^2$. We then compare the known experimental anomaly $\Delta\, \alpha_\mu$ with the nonlocal prediction $\alpha_{\mu,\mathrm{NL}}$ in order to find a lower bound on the nonlocality scale. Our results indicate that the nonlocal theory might explain the discrepancy observed in the muon moment, and then $\alpha_{\mu,\mathrm{NL}}$ might represent an important contribution to $\Delta\alpha_\mu$. Moreover the nonlocal contribution provides a very high discrepancy in the tau moment. In addition we discuss some preliminary results about the phenomenological impact of nonlocality in atomic spectra.