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Gravitational Aharonov-Bohm Effect

The original proposal for the Aharonov-Bohm (AB) effect [1] focused on the scalar and vector potentials of the electromagnetic interaction. In particular, the seminal paper of Aharonov and Bohm [1] focused mostly on the AB effect connected with the vector potential and magnetic field (vector-magnetic AB effect) rather than the scalar potential and electric field (scalar-electric AB effect). Further, the original, experimental set-up for the scalar potential-electric field AB effect involved switching the potential on and off as the electric charges entered and exited metal tubes. These tubes acted as a Faraday shell to shield the charges from the electric field but not from the electric scalar potential. Since the experimental setup for the vector-magnetic AB effect is much easier to realize, there are many experimental tests of the vector-magnetic AB effect, beginning with the first experiments by Chambers [2], to the definitive, loop-free experiments in the mid-1980s [3], and through to the present. In contrast, the best test of the scalar-electric AB effect [5] is not as clean, since it measures both scalar-electric and vector-magnetic effects together, and the charges are not completely shielded from electric fields.

In reference [4] an alternative probe of the scalar-electric AB was proposed. In the standard, ideal sca-lar-electric set-up charges are sent along different paths which had a potential difference between them (but with the charges at all times shielded from the electric fields). The observational signature of the scalar-electric AB effect was to look for a shift in the quantum interference pattern of charges. In contrast, the proposal of reference [4] placed a quantum system (Rubidium atoms) inside a Faraday cage with a time-varying scalar potential, Φe(t) (in [4] V (t) was used for the scalar potential). The observational signature highlighted in [4] was the development of energy sidebands in the spectrum of the quantum system i.e. in this alternative approach one has a shifting of energy levels as compared to a shifting of interference fringes of the standard set-up.

We apply analogously the analysis of [4] to the gravitational AB effect. There has been a recent experimental verification of the gravitational AB effect [6], which follows the standard recipe of splitting matter beams into two paths, with one path experiencing a different gravitational potential, and then looking for a shift in the interference pattern when the beams are recombined. Here we show that it is possible to apply the set-up for the analogous scalar electric AB effect given in [4] gravitational AB effect to get a cleaner confirmation of this effect, in the sense that in our proposal the quantum system will be in free fall and thus screened from the gravitational field via the equivalence principle.

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