arXiv:gr-qc/0207007 v1 1 Jul 2002

Stueckelberg Redux:

How Classical Gravity Can Induce Changes in Particle Lifetimes

Eric Lewin Altschuler, M.D., Ph.D.

University of California, San Diego

La Jolla, CA 92093-0109

email: ealtschuler@ucsd.edu

Abstract

ECG Stueckelberg (1905-1984) often published important theories years before those who would receive the Nobel Prize for their discovery. Perhaps other jewels may remain the work of this prescient genius. In a short paper in 1957--coming shortly on the heels of the suggestion and experimental confirmation of parity non-conservation by the weak force--Stueckelberg noted that since there exist completely antisymmetric four-tensors (e_{abcd}) with covariant derivative zero, non-parity conserving forces can readily be accomodated by general relativity as the product of such a tensor and the non-parity conserving terms. Stueckelberg also pointed out that in classical general relativity the covariant derivative, D, of e_{abcd} is $De_{abcd} = (-g)^{½}?[e_{abcd}(-g)^{-½}] = 0$, where g is the determinant ! of the metric tensor, and ∂ is an ordinary derivative. Since g is non-zero, if g is constant, e is a constant and mean particle lifetimes are constant. I point out that Stueckelberg's paper has three further deep and important implications. (1) We see how gravitymattercan influence particle lifetimesby forcing the e tensor to be non-constant to have to "adjust" so that $\partial[e_{abcd}(-g)^{-½}]$ is zero, and we can get some quantitative feel for the magnitude of this effect. (2) If any differences in the lifetimes of particles and antiparticles are to occur, in the absence of Lorenz invariance violation, it would be in regions where ∂g is non-zero. (3) If indeed, differences in particle and antiparticle lifetimes are found, before they can be ascribed to effects of quantum gravity, supersymmetry, or string theory, the effects of classical gravity need! to be accounted for.

ECG Stueckelberg (1905-1984) (refs. 1 and 2 refs. therein) was one of the most brilliant but enigmatic theoretical physicists of all-time: He independently arrived at a theory of the strong force similar to Yukawas, but did not publish it because of objections by his advisor W. Pauli. He did publish, or submit for publication a number of the most important theories in Twentieth Century physics, including renormalization of quantum electrodynamics and the renormalization group, often years before those who would be awarded Nobel Prizes for their discovery. He is the unchallenged originator of the idea of baryon number conservation, and he left a legacy of numerous papers in remarkably diverse branches of physics and even physical chemistry. It is not completely clear why Stueckelbergs work was not more completely recognized, but factors may include writing papers in languages other than English or German (e.g., French), an opaque writ! ing style peppered with an idiosyncratic use of mathematical symbolism, or simply "being ahead of his time." Given the prescient nature of Stueckelbergs work, one wonders if there are still not jewels relevant to today to be found in his papers. In a short (less than one page) paper of Stueckelbergs from the forerunner of these LETTERS in 1957 [3] I have found a mathematical, but intuitively simple, and experimentally testable description of how classical gravity might induce changes in particle mean proper lifetimes.

In 1956 Lee and Yang [4] pointed out that there was no experimental evidence that the weak force did not violate parity and that the possibility of non-conservation of parity by the weak force should be investigated. This bold suggestion was rapidly confirmed experimentally by three groups [5]. Not only was the weak force found to violate parity, but it did so maximally. At the time, and even now, parity non-conservation seems non-intuitive to many scientists, including physicists. The motivation for Stueckelbergs paper [3] was to respond to the perception that parity non-conservation was "unnatural." He pointed out that since there exist completely antisymmetric four-tensors with covariant derivative zero, then non-parity conserving forces can readily be incorporated into the field equations for general relativityand thus into the rest of physicsby adding a term which is the product of such an antisymmetric four-tensor with parity non-co! nserving terms. Indeed, as the field equations of general relativity symmetry allow such a term, it would almost be a surprise if they were not found in Nature.

Also in his paper Stueckelberg points out that following from the principle of general covariance of general relativity the covariant derivative D of a function f,

$Df = (-g)^{½} ?[f(-g)^{-½}]$, where g is the determinant of the metric tensor, and ∂ is an ordinary derivative. So, for the completely antisymmetric tensor e_{abcd}, $De_{abcd} = (-g)^{½} ?[e_{abcd}(-g)^{-½}] = 0$. Stueckelberg points out that g is non-zero, and for regimes where special relativity applies g is a constant, so that e_{abcd} must also be a constant. As Stueckelberg notes, this implies that mean proper lifetimes of unstable particles are then the same (by symmetry) in all Lorenz frames, even when parity non-conserving forces are included.

Now, there is a very important principle in particle physics, the CPT theorem [6], derived using quantum mechanics and special relativity which shows that the equations of quantum field theory are invariant to the simultaneous inversion of charge, parity, and time. One consequence [7] of the CPT theorem is that particles and antiparticles should have the same mean lifetimes. By the CPT theorem a particle and its antiparticle have the same lifetime when gravity is excluded. But by Stueckelbergs paper we see that when there are large gravity gradients, $∂g ≠ 0$, in order for $∂[e_{abcd}(-g)^{-½}]$ to equal zero then e_{abcd} can no longer be a constant, and we might then expect that mean particle lifetimes will not be the same in all places.

Stueckelbergs paper [3] then gives, in fact, a number of deep, but still somewhat intuitive results: (1) We see how gravitymattercan influence particle lifetimesby forcing the e tensor to be non-constant to have to "adjust" so that $∂[e_{abcd}(-g)^{-½}]$ is zero, and we can get some quantitative feel for the magnitude of this effect. (2) If any differences in the lifetimes of particles and antiparticles are to occur, in the absence of Lorenz invariance violation, it would be in regions where ∂g is non-zero. (3) Recently, experiments meant to search for CPT violations have been discussed [8]. If indeed, differences in particle and antiparticle lifetimes are found, before they can be ascribed to effects of quantum gravity, supersymmetry, or string theory, the effects of classical gravity need to be accounted for.

References

1.S.S. Schweber, *QED and the Men Who Made It* (Princeton University Press, Princeton, 1994).

2.R.P. Crease and C.C. Mann, *The Second Creation: Makers of the Revolution in Twentieth-Century Physics* (Rutgers University Press, New Brunswick, 1996).

3.E.C.G. Stueckelberg, Physical Review **106**, 388 (1957).

4.T.D. Lee and C.N. Yang, Physical Review **104**, 254 (1956).

5.Wu, Ambler, Hayward, Hoppes and Hudson, Physical Review **105**, 1413 (1957); Garwin, Lederman and Weinrich, Physical Review **105**, 1415 (1957); J.I. Friedman, J.I. and V.L. Telegdi, Physical Review **105**, 1681 (1957).

6.G. Lüders, Kgl. DAnske Videnskab. Selkab, Mat.-fys. Medd. **28**, No. 5 (1954).

7.G. Lüders and B. Zumino, Physical Review **106**, 385 (1957).

8.S.K. Lamoreaux, Nature **416**, 803 (2002).