Position, Momentum, and the Standard Model Fermions

Carl A. Brannen

8500 148th Ave. NE #T-1064,
Redmond, WA USA,
carl@brannenworks.com

Abstract. Measuring the position of a free electron gives it an unknown momentum. A second measurement will give a new position far away. On the other hand, consecutive measurements of spin give the same result. In this talk we attempt to unify these very different behaviors.

Position and momentum are complementary observables. An eigenstate of position has no information about momentum and vice versa. For an N-dimensional Hilbert space we say that two bases $|a_j\rangle$, and $|b_k\rangle$ are "mutually unbiased" if all their transition probabilities are equal: $|\langle a_j|b_k\rangle|^2 = 1/N$. Position and momentum are similar to mutually unbiased bases, but for an infinite dimensional Hilbert space.

Svetlichny discovered that Feynman's (position) path integral can be interpreted as a sum over products of mutually unbiased bases. This raises the question "what happens when we compute spin-1/2 path integrals over mutually unbiased bases?" There are three pairwise mutually unbiased bases for spin-1/2. We compute the long term propagators of spin path integrals and show that a natural description of the three generations of elementary particles results. We discuss mixing matrices, lepton and hadron masses, and the weak hypercharge and weak isospin quantum numbers.

Keywords: MUBs, path integral, spin, emergent, weak
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REFERENCES

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