Answering Mermin's Challenge with Conservation per No Preferred Reference Frame

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Abstract. In 1981, Mermin published a now famous paper titled, "Bringing home the atomic world: Quantum mysteries for anybody" that Feynman called, "One of the most beautiful papers in physics that I know." Therein, he presented the "Mermin device" that illustrates the conundrum of quantum entanglement per the Bell spin states for the "general reader." He then challenged the "physicist reader" to explain the way the device works "in terms meaningful to a general reader struggling with the dilemma raised by the device." Herein, we show how the physical principle of "conservation per no preferred reference frame" answers that challenge, as well as a desideratum of quantum information theorists to find "clear physical principles" for quantum mechanics.

Keywords: quantum information theory, Bell state entanglement, light postulate

There are those in quantum information theory (QIT) who have called for physical principles for quantum mechanics. Dakic and Brukner write, "Quantum theory makes the most accurate empirical predictions and yet it lacks simple, comprehensible physical principles from which the theory can be uniquely derived" [1]. And Fuchs writes [2]:

"Compare [quantum mechanics] to one of our other great physical theories, special relativity. One could make the statement of it in terms of some very crisp and clear physical principles: The speed of light is constant in all inertial frames, and the laws of physics are the same in all inertial frames. And it struck me that if we couldn't take the structure of quantum theory and change it from this very overt mathematical speak -- something that didn't look to have much physical content at all, in a way that anyone could identify with some kind of physical principle -- if we couldn't turn that into something like this, then the debate would go on forever and ever. And it seemed like a worthwhile exercise to try to reduce the mathematical structure of quantum mechanics to some crisp physical statements."

The light postulate of special relativity obtains because of "no preferred reference frame" (NPRF). Herein, we make progress on this QIT desideratum by extending NPRF to include the measurement of another fundamental constant of nature, Planck's constant h. As Weinberg points out, measuring an electron's spin via Stern-Gerlach (SG) magnets constitutes the measurement of "a universal constant of nature, Planck's constant" [3]. So if NPRF applies equally here, everyone must measure the same value for Planck's constant h regardless of their SG magnet orientations relative to the source, which like the light postulate is an empirical fact. Here the possible spin outcomes $\pm\frac{\hbar}{2}$ represent a fundamental (indivisible) unit of information per Dakic and Brukner's first axiom in their reconstruction of quantum theory, "An elementary system has the information carrying capacity of at most one bit" [1]. Thus, different SG magnet orientations relative to the source constitute different "reference frames" in quantum mechanics just as different velocities relative to the source constitute different "reference frames" in special relativity. Since NPRF leads to the "mysteries" of time dilation and length contraction in special relativity, it is perhaps not surprising that NPRF produces a "mystery" for quantum mechanics associated with the measurement of h as well. That mystery is captured nicely by the "Mermin device" for quantum entanglement arising from the Bell spin states [4]. Herein, we show how the physical principle of "conservation per NPRF" resolves the mystery of quantum entanglement to make progress on the desideratum of QIT.

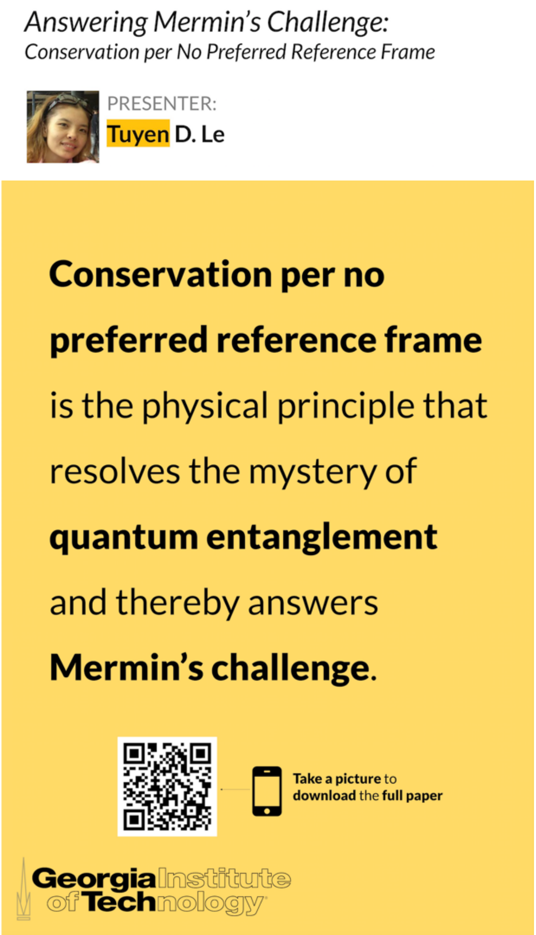

Figure 1 Poster presentation of this paper by co-author T.D. Le who is a graduate student in computer science at Georgia Tech. She will also present the paper at Q-Turn 2020. An arXiv link to the paper is in the QC code and here: https://arxiv.org/abs/1809.08231. The paper is in the "Revise and Resubmit" stage at *Scientific Reports*.

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