[original idea]

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Spacetime is entangled in a Bell state

Open Physics Collaboration^{*†}

February 29, 2020

Abstract

We propose a connection for the Minkowski's invariant proper time and one of the Bell states.

keywords: special relativity, invariant proper time, quantum Bell states

Preamble

1. *The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.* [1]

Hermann Minkowski

^{*}All authors with their affiliations appear at the end of this paper.

[†]Corresponding author: mplobo@uft.edu.br | Join the Open Physics Collaboration

Proper Time

2. Minkowski showed that space and time are inseparable and unified by a unique and invariant quantity called the *proper time* (τ) [1, 2].

3.

$$\tau^2 = t^2 - x^2$$

4. t is the time interval from two events in a given inertial frame.

5. x is the space interval from two events in a given inertial frame.

Spacetime entanglement

6. One of the Bell states is

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|00\rangle - |11\rangle),$$

where $|0\rangle$ and $|1\rangle$ are quantum states.

7. Note the resemblance between (3) and (6).

8. One can assume that quantum spacetime is entangled in the following Bell state

$$|\tau\tau\rangle = \frac{1}{\sqrt{2}}(|tt\rangle - |xx\rangle).$$

9. $|t\rangle$ is the quantum state that **originates time** in the classical scale.

10. $|x\rangle$ is the quantum state that **originates space** in the classical scale.

11. This notation suggests the following tensor products.

12.

$$|\tau\tau\rangle \equiv |\tau\rangle_1 |\tau\rangle_2 \equiv |\tau\rangle_1 \otimes |\tau\rangle_2$$

13.

$$|xx\rangle \equiv |x\rangle_1 |x\rangle_2 \equiv |x\rangle_1 \otimes |x\rangle_2$$

14.

$$|tt\rangle \equiv |t\rangle_1 |t\rangle_2 \equiv |t\rangle_1 \otimes |t\rangle_2$$

15. $|x\rangle_1$ and $|x\rangle_2$ are the **entangled quantum states of position** in *different regions*.

16. Similarly, $|t\rangle_1$ and $|t\rangle_2$ are the **entangled quantum states of time** in *different periods*.

Momentum and energy

17. A similar approach can be done with the magnitude of *momenergy* [2],

$$E^2 - \vec{p}^2,$$

which is Lorentz invariant.

Final Remarks

18. **Time** and **space** can be assembled as a **qubit** in the very quantum realm, like in the Planck scale, for instance.

19. A lot of further investigation need to be done regarding (8).

20. Other discussions on time that are related to this article can be found here [3–5].

Open Invitation

Review, add content, and co-author this paper [6, 7]. *Join* the **Open Physics Collaboration**. Send your contribution to mplobo@uft.edu.br.

Ethical conduct of research

This original work was pre-registered under the OSF Preprints [8], please cite it accordingly [9]. This will ensure that researches are conducted with integrity and intellectual honesty at all times and by all means.

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The Open Physics Collaboration

Matheus Pereira Lobo (lead author, mplobo@uft.edu.br),^{1,2}

João Marcos Costa da Silva,¹ Suel Sousa Ribeiro¹

¹Federal University of Tocantins (Brazil); ²Universidade Aberta (UAb, Portugal)