The Toffoli Prize

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Derive general relativity from statistics; win $10,000.00.

A Connection Between Special Relativity and Statistics

Any system that has a predictable evolution in time may be used as a clock. Consider a diffusion clock based on a random walk in one dimension. A particle starts at the origin, and for each time step, it moves left or right with probability $\frac{1}{2}$. In the limit of long times, the width of the probability distribution for the location of the particle is proportional to $\sqrt{t}$, where t is time. Let this behavior in time serve as a clock, called a diffusion clock. Now, consider the same story but the random walk has a bias such that the probability of moving to the right (p) is larger than than the probability of moving to the left ($1-p$).

It is clear that as p approaches 1, the diffusion clock slows down, since in the case $p = 1$ the distribution is delta function moving to the right at maximum speed with no spread. But what is the mathematical relationship describing this slowing relative to a diffusion clock at rest?

The width of the moving probability distribution is proportional to $\sqrt{tp(1-p)}$. The center of the distribution for the biased random walk moves at velocity $v \equiv p-(1-p)$. We can rewrite the width of the moving probability distribution as $\sqrt{t(1-v^2)}$. Thus, the moving clock slows with respect to the stationary clock by the factor $\sqrt{(1-v^2)}$, which is identical to the time dilation relation from special relativity.

Terms of the Prize

To win the prize, one must extend this result to general relativity. As with the case of special relativity, there is an intuition which shows the correct qualitative dependence. Imagine a random walk in which more than one particle are moving in one dimension, with the rule that each spot on the line may only be occupied by one particle at a time. If every spot on the line were occupied, a diffusion clock would be frozen. The Toffoli prize will be awarded to whomever can show that a fine-grained statistical model leads to Einstein's field equations in the appropriate limit. The $10,000.00 prize will be given to the individual (or divided among the group of individuals) who accomplishes this task and has the result accepted for publication in a suitable peer-reviewed journal. If no one succeeds in this task by April 1, 2025, the prize will be given to that individual or group which has made the most progress, as judged by me. The references below give a flavor of this approach. Updates will be posted on thetoffoliprize.org. Some of the conceptual ideas behind this project can be found at thequantumexplained.org.

References

1. Toffoli, T.: How cheap can mechanics' first principles be? In: W. Zurek, (ed.) Complexity, Entropy, and the Physics of Information. Redwood City, CA: Addison-Welsey Publishing Company, pp. 3-28. (1990).
2. Toffoli, T., How much of physics is just computation? Superlattices and Microstructures **23**, pp. 381-406 (1998).