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Quantum time measurements
Q-Turn abstract

We propose a time-of-arrival operator in quantum mechanics by conditioning on a quantum clock. This allows us to bypass some of the problems of previous proposals, and to obtain a Hermitian time of arrival operator whose probability distribution arises from the Born rule and which has a clear physical interpretation. The same procedure can be employed to measure the “time at which some event happens” for arbitrary events (and not just specifically for the arrival time of a particle).

In textbook quantum mechanics time measurements cannot be described in the same way as all other observable quantities: time appears as a parameter and not as an observable. In other words, one cannot assign a self-adjoint operator to time that would place it on the same footing as all other quantum observables, and it was not clear (up to now) how general time measurements must be described.

Of course, the literature on the subject is enormous, but no one previously managed to provide a general description, like we do here, that applies to arbitrary measurements of time. All previous literature focused on very specific time measurements, such as the time at which a particle arrives at a certain position (i.e. the “time of arrival”).

The main trick that we used to overcome the difficulties of previous proposals is that we gave a fully-quantum description of what it actually means to measure the time: one has to use a quantum system as a clock. A time measurement then consists in recording the correlations between that clock and the rest. This means that we can use the textbook formalism for quantum measurements also for time, under the condition that we consider an extended system that includes also the clock. Once this is realized, the rest is quite simple and one can easily construct a time operator by using the Bayes rule of conditional probabilities and other conventional techniques. Our main result is that we provide a prescription for writing down the probability distribution for a general time measurement.

This is mostly based on a research done in collaboration with Krzysztof Sacha and published in *Lorenzo Maccone and Krzysztof Sacha, Phys. Rev. Lett. 124, 110402 – Published 16 March 2020.*

Sincerely,
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