Completing the Information Interpretation of Quantum Mechanics

Thomas Alexander Meyer

Quantum mechanics is a solidly founded mathematical theory, but it has yet to be explained in first conceptual principles. The most obvious aberration to explanation that quantum mechanics has is interference and coherence. We simply do not understand why the preparation of a quantum mechanical system must not allow knowledge of path in order to display interference effects. We present the first principles of the information interpretation which provide a proper conceptual foundation of quantum mechanics and also lead to an explanation of interference and coherence.

The Information Interpretation

In the history of the information interpretation of quantum mechanics there are many authors[1,2,3] whom argued that quantum mechanical systems are information, but these presentations of the interpretation have not been able to fully explain the demands of coherence and interference. We argue here that the other interpretations have lacked a "second principle" that could properly clarify the issue. Specifically, they have lacked a principle that much like the principle of relativity theory is founded on a reasoning of *consistency of all perspectives*.

The earliest of interpretations would all have presented the same underlying argument, that quantum mechanical systems are information, and some formalize this in the manner of *truth value to proposition*. The most noted information interpretation to use this formality is the interpretation of Zeilinger in reference 2. In this paper he clarifies that not only are quantum mechanical systems information, but they are formalized or described as information in the form of truth value to proposition. Specifically, the propositions spoken of are ones which state the outcomes of measurements of quantum mechanical systems, so the system is the truth value of a set of propositions which state possible measurement outcomes. The philosophical motivation for this perspective is the role of the physicist, if the role of the physicist is to collect measurements then it is the role of the physicist to collect information about the system. In this perspective it is natural to conclude that the system itself is information. However, when interpreting the underlying philosophy of quantum mechanics, to interpret quantum mechanics, there is no such role to be played by the physicist which would dictate how we understand this mechanics. This type of philosophy that includes the role of the physicist is *cut from the cloth of the Vienna circle* so to speak. One must not confuse the philosophy of science with the philosophy of quantum mechanics, as the philosophy of quantum mechanics must answer many more questions than that of how science operates. Quantum mechanics is the theory that all of the sciences must be reducible to, and in so it must answer all questions of life and philosophy that could possibly be asked of it.

We present the first principle of quantum mechanics in a form that is similar to others:

A quantum mechanical system is an amount of information, in the strictest existential sense.

Some might be wondering then, so what is our philosophical motivation for making this claim? Our motivation is simple, we wish to have correspondence between the state description of quantum mechanics and the system which this description describes.

So with this in mind we first ask why it is that the effects of interference and coherence demand of a preparation that it be without path information. Why, we ask, is path information relevant? Because the state description of quantum mechanics is fundamental to coherence and interference, the state description of quantum mechanics *is* what a quantum mechanical system *is*. And this is also how we formalize our interpretation. If we were to ask "exactly how much information is a quantum mechanical system" our answer would be "however much information its description sais it is." To put it more clearly, a quantum mechanical system is the amount of information that is the truth value to the propositions which state its state description. A particle has four degrees of freedom and each may represent one component of the state description in the representation of choice, so together we would require four propositions to state the state description of a particle. Therefore a particle is four bits of information in the form of analytic truth value. (This of course does not take into account additional pseudo-degrees of freedom like charge.)

We might add one point here, that the description of quantum mechanics is only properly satisfied by a statistically relevant set of measurements of particles. An individual system is randomly influenced. So we only consider a quantum mechanical system to be a statistically relevant set of particles. You could say that the system is 4N bits of information rather than just four.

This puts us along side of other information interpretations of quantum mechanics which have stated a similar principle, so how does our interpretation differ and how do we explain coherence and interference? First, one might point to the fact that in quantum mechanics there is a theory of decoherence, even though one's experiment might involve particles it is no guarantee of coherence in one's preparation. The preparation must be decoherence free in order to exhibit such effects as interference. So what is the border line or boundary between coherence and decoherence? We answer this with the statement of our second principle, a principle which is of a conceptual type which draws inspiration from the relativity postulate which states a *consistency of perspectives*, that the laws of physics be identical in all reference frames. Of course, the relativity postulate is about the mechanics of space and time, which is natural to a postulate of classical mechanical phenomena. We are dealing exclusively with quantum mechanical phenomena that are the irreducible systems of measurement events. So we state our principle as follows:

*For a **coherent** quantum mechanical system with a state description at an exact time, it must be the case that **all** measurements at that time or any time later which may in principle be performed that imply information pertaining to the description of the system must be consistent with the state description.*

This principle assumes two important points. First, that the description may be a superposition which would imply that the description must be a coherent superposition, and the principle defines this difference of coherence. Second, the full extent of the quantum mechanical system being considered may be vast, it may be a single particle or many entangled particles. The principle states that for a *coherent* system there may be no measurement of the system which would infer knowledge of the system that is inconsistent with the state description of that system. This defines coherence for us in the context of the preparation of the system, if a system is to be coherent (if the desired superposition is to be the true description) then the preparation of the system must be such that there can be no possible measurement of the system which would infer knowledge that is inconsistent with the state description. This perfectly explains to us why an interference effect demands of the preparation that there be no knowledge of path of the interfering system, because such knowledge of path would only be available by virtue of a measurement which if possible would be inconsistent with the state description, the desired superposition.

With this principle we can now clearly see the boundary between coherence and decoherence, inferential information is the boundary. Why? Because information is what the system is.

References

1) I don't know the earlier work myself, but the first versions of the information interpretation are due to von Weizsäcker. Subsequently you have J. A. Wheeler who wrote an essay called *It From Bit* which was published in the book *At Home in the Universe*. There is also the "digital logic" interpretation of quantum mechanics which is also on information foundations.

2) Anton Zeilinger, *A Foundational Principle for Quantum Mechanics*, *Found. of Phys*., **29,** 631 (1999).

3) Caslav Brukner and Anton Zeilinger, *Information and fundamental elements of the structure of quantum theory* in *Time*, *Quantum*, *Information*, edited by L.. Castell and O. Ischebeck (Springer, 2003), This is also available as arXiv:quant-ph/0212084v1 (2002).