



“Why the Quantum? It from Bit? A Participatory Universe?: Three Far-reaching, Visionary Questions from John Archibald Wheeler and How They Inspired a Quantum Experimentalist”

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Quantum World is full of paradoxes, of which the most well-known is Schrodinger's cat. There have been a number of attempts in the history of quantum physics to somehow bypass the conceptual problems of quantum physics, witness for example Albert Einstein's position. Not the least because all these attempts have turned out not to be very fruitful, the only productive approach is to accept quantum phenomena and ask what the message of the quantum really is. John Archibald Wheeler has formulated this in his far-reaching questions.

It turns out that very naturally the referent of quantum physics is not reality per se but, as Niels Bohr said, it is "what can be said about the world", or in modern words, it is information. Thus, if information is the most fundamental notion in quantum physics, a very natural understanding of phenomena like quantum decoherence or quantum teleportation emerges. And quantum entanglement is then nothing else than the property of subsystems of a composed quantum systems to carry information jointly, independent of space and time; and the randomness of individual quantum events is a consequence of the finiteness of information.

The quantum is then a reflection of the fact that all we can do is make statements about the world, expressed in a discrete number of bits. The universe is participatory at least in the sense that the experimentalist by choosing the measurement apparatus, defines out of a set of mutually complementary observables which possible property of a system can manifest itself as reality and the randomness of individual events stems from the finiteness of information.

A number of experiments will be reviewed underlining these views. This will include an entangled-photon delayed choice experiment where the decision whether a photon that has passed a double slit did this as a particle or a wave is delayed not only until a time after its passage through the double slit assembly but even after it has already been registered. Thus, while the observed facts, i.e. the events registered by the detectors, are not changed, our physical picture changes depending on our choice what to measure.

Another experiment discussed is the observation of the quantum interference of fullerenes which are so hot that they are not at all decoupled from the environment. The reason why interference is still observed is due to the fact that the photons emitted by the fullerenes do not carry path information into the environment. The criterion for observation of interference is simply whether or not path

information is available anywhere in the universe, independent of whether or not an observer cares to read that information out.

Finally an experiment on the teleportation of an entangled photon demonstrates that the decision whether or not two photons are entangled or not again can be made at a time long after these photons have already been observed. More precisely, the quantum state we assign two photons for a time period before they have been registered depends on our future choice whether or not we then implement the Bell state measurement these two photons are entangled with. This experiment lends support to the idea that the quantum state is just a representation of our knowledge and that this knowledge changes when an observation is made. Thus the reduction of the wave packet is just a reflection of the fact that the representation of our information has to change whenever the information itself changes as a consequence of an observation.

In conclusion it may very well be said that information is the irreducible kernel from which everything else flows. Then the question why nature appears quantized is simply a consequence of the fact that information itself is quantized by necessity. It might even be fair to observe that the concept that information is fundamental is very old knowledge of humanity, witness for example the beginning of gospel according to John: "In the beginning was the Word".

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