The Measurement Problem in Quantum Mechanics

By Sam Vaknin

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Arguably the most intractable philosophical question attached to Quantum Mechanics (QM) is that of Measurement. The accepted (a.k.a. Copenhagen) Interpretation of QM says that the very act of sentient measurement determines the outcome of the measurement in the quantum (microcosmic) realm. The wave function (which describes the co-existing, superpositioned, states of the system) "collapses" following an act of measurement.

It seems that just by knowing the results of a measurement we determine its outcome, determine the state of the system and, by implication, the state of the Universe as a whole. This notion is so counter-intuitive that it fostered a raging debate which has been on going for more than 7 decades now.

But, can we turn the question (and, inevitably, the answer) on its head? Is it the measurement that brings about the collapse – or, maybe, we are capable of measuring only collapsed results? Maybe our very ability to measure, to design measurement methods and instrumentation, to conceptualize and formalize the act of measurement and so on – are thus limited and "designed" as to yield only the "collapsible" solutions of the wave function which are macrocosmically stable and "objective" (known as the "pointer states")?

Most measurements are indirect - they tally the effects of the system on a minute segment of its environment. Wojciech Zurek and others proved (that even partial and roundabout measurements are sufficient to induce einselection (or environment-induced superselection). In other words, even the most rudimentary act of measurement is likely to probe pointer states.

Superpositions are notoriously unstable. Even in the quantum realm they last an infinitesimal moment of time. Our measurement apparatus is not sufficiently sensitive to capture superpositions. By contrast, collapsed (or pointer) states are relatively stable and lasting and, thus, can be observed and measured. This is why we measure only collapsed states.

But in which sense (excluding their longevity) are collapsed states measurable, what makes them so? Collapse events are not necessarily the most highly probable – some of them are associated with low probabilities, yet they still they occur and are measured.

By definition, the more probable states tend to occur and be measured more often (the wave function collapses more frequently into high probability states). But this does not exclude the less probable states of the quantum system from materializing upon measurement.

Pointer states are carefully "selected" for some purpose, within a certain pattern and in a certain sequence. What could that purpose be? Probably, the extension and enhancement of order in the Universe. That this is so can be easily substantiated by the fact that it is so. Order increases all the time.

The anthropocentric (and anthropic) view of the Copenhagen Interpretation (conscious, intelligent observers determine the outcomes of measurements in the quantum realm) associates humans with negentropy (the decrease of entropy and the increase of order).

This is not to say that entropy cannot increase locally (and order decreased or low energy states attained). But it is to say that low energy states and local entropy increases are perturbations and that overall order in the Universe tends to increase even as local pockets of disorder are created. The overall increase of order in the Universe should be introduced, therefore, as a constraint into any QM formalism.

Yet, surely we cannot attribute an inevitable and invariable increase in order to each and every measurement (collapse). To say that a given collapse event contributed to an increase in order (as an extensive parameter) in the Universe – we must assume the existence of some "Grand Design" within which this statement would make sense.

Such a Grand Design (a mechanism) must be able to gauge the level of orderliness at any given moment (for instance, before and after the collapse). It must have "at its disposal" sensors of increasing or decreasing local and nonlocal order. Human observers are such order-sensitive instruments.

Still, even assuming that quantum states are naturally selected for their robustness and stability (in other words, for their orderliness), how does the quantum system "know" about the Grand Design and about its place within it? How does it "know" to select the pointer states time an again? How does the quantum realm give rise to the world as we know it - objective, stable, certain, robust, predictable, and intuitive?

If the quantum system has no a-priori "awareness" of how it fits into an ever more ordered Universe – how is the information transferred from the Universe to the entangled quantum system and measurement system at the moment of measurement?

Such information must be communicated superluminally (at a speed greater than the speed of light). Quantum "decisions" are instantaneous and simultaneous – while the information about the quantum system's environment emanates from near and far.

But, what are the transmission and reception mechanisms and channels? Which is the receiver, where is the transmitter, what is the form of the information, what is its carrier (we will probably have to postulate yet another particle to account for this last one...)?

Another, no less crucial, question relates to the apparent arbitrariness of the selection process. All the "parts" of a superposition constitute potential collapse events and, therefore, can, in principle, be measured. Why is only one event measured in any given measurement? How is it "selected" to be the collapse event? Why does it retain a privileged status versus the measurement apparatus or act?

It seems that preferred states have to do with the inexorable process of the increase in the overall amount of order in the Universe. If other states were to have been selected, order would have diminished. The proof is again in the pudding: order does increase all the time – therefore, measurable collapse events and pointer states tend to increase order. There is a process of negative, order-orientated, selection: collapse events and states which tend to increase entropy are filtered out and statistically "avoided". They are measured less.

There seems to be a guiding principle (that of the statistical increase of order in the Universe). This guiding principle cannot be communicated to quantum systems with each and every measurement because such communication would have to be superluminal. The only logical conclusion is that all the information relevant to the decrease of entropy and to the increase of order in the Universe is stored in each and every part of the Universe, no matter how minuscule and how fundamental.

It is safe to assume that, very much like in living organisms, all the relevant information regarding the preferred (order-favoring) quantum states is stored in a kind of Physical DNA (PDNA). The unfolding of this PDNA takes place in the physical world, during interactions between physical systems (one of which is the measurement apparatus).

The Biological DNA contains all the information about the living organism and is replicated trillions of times over, stored in the basic units of the organism, the cell. What reason is there to assume that nature deviated from this (very pragmatic) principle in other realms of existence? Why not repeat this winning design in quarks?

The Biological variant of DNA requires a biochemical context (environment) to translate itself into an organism – an environment made up of amino acids, etc. The PDNA probably also requires some type of context: the physical world as revealed through the act of measurement.

The information stored in the physical particle is structural because order has to do with structure. Very much like a fractal (or a hologram), every particle reflects the whole Universe accurately and the same laws of nature apply to both. Consider the startling similarities between the formalisms and the laws that pertain to subatomic particles and black holes.

Moreover, the distinction between functional (operational) and structural information is superfluous and artificial. There is a magnitude bias here: being creatures of the macrocosm, form and function look to us distinct. But if we accept that "function" is merely what we call an increase in order then the distinction is cancelled because the only way to measure the increase in order is structurally. We measure functioning (=the increase in order) using structural methods (the alignment or arrangement of instruments).

Still, the information contained in each particle should encompass, at least, the relevant (close, non-negligible and non-cancelable) parts of the Universe. This is a tremendous amount of data. How is it stored in tiny corpuscles?

Either utilizing methods and processes which we are far even from guessing – or else the relevant information is infinitesimally (almost vanishingly) small.

The extent of necessary information contained in each and every physical particle could be somehow linked to (even equal to) the number of possible quantum states, to the superposition itself, or to the collapse event. It may well be that the whole Universe can be adequately encompassed in an unbelievably minute, negligibly tiny, amount of data which is incorporated in those quantum supercomputers that today, for lack of better understanding, we call "particles".

Technical Note

Our Universe can be mathematically described as a "matched" or PLL filter whose properties let through the collapsed outcomes of wave functions (when measured) - or the "signal". The rest of the superposition (or the other "Universes" in a Multiverse) can be represented as "noise". Our Universe, therefore, enhances the signal-to-noise ratio through acts of measurement (a generalization of the anthropic principle).

References

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What is the Quantum Connection? Description by Charlotte Anthony

Quantum Connections
Quantum Connections is the ezine of A Quantum Reach, where we are putting the heart in health care, one person at a time. We believe it's time to gain control over OUR personal health and OUR health care system. Wherever you are in the system (a patient, a caregiver or completely healthy), A Quantum Reach shows you real-life techniques to integrate intuition and intention, partner with your doctors and effectively communicate your health needs. We do this through books, e-books, articles, reports and the renowned Vital Transformations seminar series. For more information, visit www.a-quantum-reach.com

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