Precognitive Quantum State: What Can We Know?

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For more than 15 years a little known debate has quietly raged within the world of quantum physics over the mere “existence” of information. This information is in the form of a Quantum state of a particle, prior to the actual measurement of that particle's state. It was in 1998 when theoretical physicist John Archibald Wheeler first introduced his infamous idea about the '*It-from-bit*' verses the '*bit-from-it'* concepts.

> *“every particle, every field of force, even the space-time continuum itself—derives its function, its meaning, its very existence entirely—even if in some contexts indirectly—from the apparatus-elicited answers to yes-or-no questions, binary choices, bits.“*
> --*John Archibald Wheeler*[1]

As Mr Wheeler saw things, one could know nothing about a particles' Quantum state until one interacts with it, and thereby could know anything about that system, including the fact that the particle was even there. The mere act of testing the state and acquiring the information about its state leads directly to the knowledge that a particle existed. Testing it directly leads to the cognition of the existence of that particle, and its associated state.

Conversely, if you know nothing about a given quantum system then can you say nothing about it, including making any predictions about that particles' past or future. Through testing one may gain enough information to assemble a partial history of the particle, but due to the *Heisenberg Uncertainty Principal*[2], even that little bit of knowledge gained will be quite limited. In measuring that state you will have just changed the particles future just by interacting with it, and so you will only know some portion of its past once measured. According to Wheeler, what you will have learned is little more than the answer to a very simple yes or no question. That yes or no answer can then be represented and recorded as a single 'bit' of binary information.

Even more bizarre is that without testing a particle's state there is no proof that the particle even exists, much less knowing that the particular particle had any state to be measured. Without knowledge of its *existence* first, the state of that particle essentially has no meaning, and can only be predicted using statistical mathematical methods. In other words any statistical prediction would be little more than just a mathematical guess, given an already incomplete set of information. A good educated guess perhaps, but still just a guess.

Because the existence and state are both bound so closely to the event of the measurement some scientists believe that it is actually the cognitive process itself that defines reality with respect to a quantum state. Some believe that without a person to “witness” that result then there is no defined value for that quantum state. The extreme example often sited would be the *Schrodinger's Cat* thought experiment[3], where a sealed box containing a single radioactive particle, a vial of poison, and a live cat all exist in a state of superposition together, with the cat being both alive and dead because the fate of the particle decay is in question. Simultaneously all would exist in an indeterminate state until the experimenter opens the box to witness the result. It is proposed that it is through the act of observation and cognition that superposition of the three in the box collapse into a single known state.

Some proponents not only question that a given particle *state* exists before testing it, but even the existence of the *particle itself*, prior to that measurement being taken. Extensively some scientists jokingly take the question of that particles “existence” to the extreme, and even question if the Moon exists when nobody is looking at it, given that the Moon is simply made of many particles each with its own quantum state. Even stranger still is that some scientists are simply not joking when they ask that very same question. This might make one wonder if this series of existence questions are better suited for a theologian, or perhaps even a clinical psychologist.

As to when this quantum state information actually comes into existence is contentiously debated. Those that follow the Copenhagen Interpretation[4] of Quantum Physics have a tendency to lean towards the *it-from-bit* philosophy where the act of testing itself “creates” the particle. On the opposite end of the scale is the *bit-from-it* philosophy where the particle not only exists but has a definitive state just waiting to be read by a physical measurement. These scientists are often called Quantum Realists, in that they believe that there is some physical underpinning that provides the answers, and we just need to discover what makes all these things work. Somewhere in the middle are those that believe that the particle exists, but that the state is indeterminate until an actual measurement is made. The statistical wave function collapses into a final determinate state at the actual time of measurement. This is what most scientist currently believe happens.

Summary of particle pre-cognitive state possibilities

	particle existence	**determinacy of state**
#1	non-existence	indeterminate
#2	existence	indeterminate
#3	existence	determinate

Finding truth

How can we know which of the above three is the actual truth? Well the problem is that no matter how many times you test it, you will never be able to know what the state was *before* you actually tested it. No amount of testing 'it' will ever answer that question. As an example, suppose we examine a particle in a state of superposition. We can only know that the particle is either in a *spin-up* or *spin-down* configuration upon testing it. A simple yes or no. But was it spin-up *before* it was tested? Spin-down? Neither? We can't know, as the act of testing it is thought to have caused that particle to take on a definitive state *only at the time of measurement*.

Scientists have spent a lot of time and resources trying to answer this question, but all attempts have failed to gain any new insight. Logically the it-from-bit philosophy(#1) is untestable because ironically one is not even allowed to ask the question about the existence if the particle itself, much less its current properties. If there is no particle how can their be a state? As experimental scientists or quantum realists this paradigm will simply have to be a fall-back position if neither of the other two paradigms can be proven. Since we have already noted that the other two paradigms (#2,#3) seem to be untestable as well, so exactly where does that leave us? Is this a true stalemate with quantum physics?

Not quite. We still have a few cards we have not played yet. If we are to think about following up on the state-exists (#3) or state indeterminate (#2) paradigms we still have hope. Logically we just need to differentiate between the two, and although we can't actually test for it, we may still be logically able to think through the problem.

Sometimes when you are stuck with finding a solution to a very hard problem it is beneficial to step back from from that problem and rephrase the original question in a manor in which some other supporting answer can be derived. Suppose instead of asking “is there state before we look at it”, we instead ask the following question:

> ***Is there any set of physical processes, arrangement, or conditions in which a Quantum Realist would find it 'acceptable' to not be able to answer the question of a particles' state attributes prior to a physical measurement?.***

If we can find a logical solution to that new question then that answer will cause us to lean substantially towards *the particle state is indeterminate*(#2) interpretation. The answer to this new question is fortunately not only demonstrably answerable, but also gives us a way forward in hope of experimentally answering the original question. Let us take a moment to walk down that path to enlightenment. To do that we must first start with a slight detour though a thought experiment founded in Special Relativity, to give us the proper tools to work with.

Thought Experiment: The Alien visitor

An alien comes for an emergency visit to Earth after developing problems with her spacecraft. A set of earth scientists volunteer to help get her ship back up and running by engineering new replacement parts to the alien's purposefully cryptic specifications, and the alien is therefor grateful to be able to return home. Intergalactic law prohibits the alien from teaching foreigners about intergalactic flight or interstellar communication technology, but she is able to get around that regulation to show her thanks by permitting the scientists to do one limited relativistic experiment, without her guidance, using the repaired ship as an instrument. The scientist all confer and decide that one scientist will ride in the ship and perform some relativistic measurements at the speed of light, and the rest of the team, while sitting on an earth orbiting space station, will do similar measurements for the passing ship. The alien agrees.

Part 1. A set of common objects are dispersed at measured intervals along a linear path throughout Space, and these are to be measured for Lorentz length contraction[4] while the ship is traveling past them at the speed of light. The spacecraft is positioned at one end of the field of objects and will fly past each object one by one, and the scientist on board will measure each objects length. The final length of each object (L' below) according to Relativity should be equal to zero when traveling at the speed of light (e.g. where V=C).

$$L' = L\sqrt{1-\frac{V^2}{C^2}}$$

The Lorentz Formula for Length Contraction

L = original length of the object
V = the velocity of the ship while passing
C= the speed of light
L' = the contracted length of the object

At the start of the test the craft quickly accelerated to the speed of light and first passed a simple desk ruler suspended in space. Due to length contraction on the ruler, just as is predicted by the length contraction formula, it's length is zero. Next, the meter stick, zero again. So far so good. Next up, two space buoy's spaced at 10 kilometers apart, but tethered by a thin string. Zero again. Finally, one buoy orbiting earth and one orbiting Alpha Centauri (4.37 light years away). Your guess as to the length/distance of 'the space' in between the two? Of course, zero. At the speed of light all distances are Zero length. Had there been a string involved in the last test, we would be discussing the length of that string, but without it, the term “distance” is just another name for the length of string that would have been there. The string itself is not required for the measurement to take place, only the two endpoints to measure from. Mathematically, whether it's 10 kilometers or

4.37 light years, when that distance is multiplied by zero, the result is always zero.

Part 2. The remainder of the scientists were waiting on the earth orbiting station to measure the passing spacecraft on its way to Alpha Centauri. Because you can not “see” an object traveling at you while its traveling at the speed of light due to the extreme blue-shift of the light, the alien lent the scientists a special "clairvoyance clock". This is a special clock which, due to patented alien technology, will always display the current time according to the ships on-board computers no matter what circumstances are encountered or even the distance of separation. At exactly 12:01.00, according to the special clock, the scientists are to look to the side and measure the ships length as it passes. Unfortunately, as you will see, the scientist needed to contend with the affects of time-dilation[5] ($\Delta T'$, the duration of the relativistic clock cycle) during their test to make use of that clock.

$$\Delta T' = \frac{\Delta T}{\sqrt{1 - \frac{V^2}{C^2}}}$$

The Lorentz Formula for Time Dilation

ΔT = clock cycle period on the observers reference frame
V = the velocity of the ship ($V=C$)
C = the speed of light
$\Delta T'$ = clock cycle period in the moving reference frame

At the start of the test, as the ship accelerated towards Earth, and the clairvoyance clock began to slow down, 11:59.58, 11:59.59999, 11:59.59999999. After many hours of the earth stations scientists own time the clairvoyance clock eventually stopped precisely at 12:01.00. With the clock slowing down progressively, the scientists were having great difficulty in deciding when the exact moment of measurement should occur. When the clock finally stopped they attempted to measure a passing ship but there was nothing visible to measure. The ship was of course zero length, and was edge on, so there was no surprise of having nothing to see, much less to measure.

Several hours later it was noticed that the clock was still showing 12:01.00, and it was still that way several days after the ship had passed. Keep in mind that the ship is known to be *physically traveling at the speed of light*. Yes, the ship is traveling an arbitrary distance, all the way to Alpha Centauri, and yet is accruing *no time* on the ships own clock! Not even a fraction of a nanosecond. This clock continues 'not to tick' for 4.7 of our years until the ship eventually slows down at Alpha Centauri to return back to Earth.

What have we learned?

When traveling at the speed of light not only do objects contract due to Lorentz contraction, but also the space-time itself along the axis of travel. At the speed of light there was zero distance for the ship to travel between Earth and Alpha Centauri. Because of the length contraction at the speed of light, within the ships reference frame, the ship was simultaneously occupying every possible position between Earth and Alpha Centauri at the very *instant* when it passed the Earth/Alpha-Centauri measurement test. It was at that instant when the ship's position is blurred across all possible positions between those two points, simultaneously, thus the ships position should be deemed as being indeterminate. In fact the more time dilation there is between the two reference frames the more indeterminate that the ships position should be to the earth stations scientists.

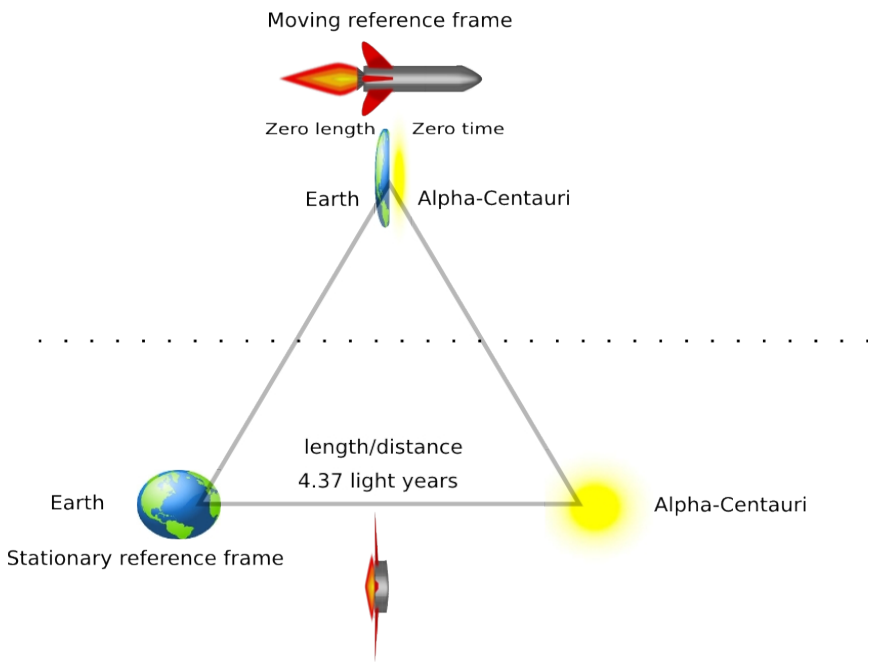

Illustration 1: Differing viewpoints of the same event

But, because the Earth bound scientists would have otherwise seen, or at least calculated, the ship as traveling between the two celestial bodies over a period of 4.7 years, we now have two very different views of the exact same event with respect to both space and time. Both viewpoints are equally correct, so when discussing the actual position and path of the ship, or anything moving at the speed of light for that matter, <u>both viewpoints must be assumed to be correct</u>. Neither viewpoint is correct just by itself.

Both the *distance to travel* and the *time of travel* approach zero as one accelerates to the speed of light in the moving reference frame. The space-time in between essentially compresses down to a singularity within the reference frame of any moving body, yet there is no tell tale sign of this transformation to any outside observer or measuring apparatus. To an outside observer the distance and time required to travel that distance is completely unchanged, but *logically* it must be considered that in the history of the crafts own reference frame, it occupied all positions during its relativistic traversal.

Wave Particle Duality

We do know from experiments that there is a wave/particle duality in which particles can act as waves. The De Broglie hypothesis[7,8], which was first stated in a 1924 thesis paper authored by Louis de Broglie, showed that there is a mathematical relationship between both particles and waves. In 1926 this property was mathematically extended by Erwin Schrodinger in his famous Wave Equation[9] and was later confirmed experimentally in 1927.

Back to our Superposition Example

We have now made an observation such that when something is traveling at the speed of light its position will necessarily be indeterminate in position with respect to an outside observer (aka, the experimenter).

If DeBroglie was correct in his prediction about particles behaving as waves, then by extension he should also be right about the particle state as well. After all, a particle state is nothing more than an attribute of the particle itself, and therefore should be directly dependent on the physical nature of the particle. If the particle behaves as a wave then so must the information stored within that particle.

If the information within our own sample particle found in the Superposition state is composed of a physical wave like motion at its very core, then that information of spin-up or spin-down could very well take on this same indeterminate position property as is required to satisfy our conditions in our existence-indeterminate state (#2) above. Due to the affects of time dilation the outside observer, or his experimental apparatus would always find the particles state to be somewhat random and indeterminate, and thus would see exactly what we see experimentally.

So, with getting back to our original question as to whether there is any specific state prior to the actual measurement, we should now be leaning heavily towards the answer 'NO'. There is no determinate state of the particle as seen by any experimenter, no matter how it is tested, prior to that measurement. As much as we would like to think that everything in our world is completely deterministic, there appears to be some things that should not be, though we are still left with the problem of proving that this is the case. But with this wave-particle duality explanation in place it is quite possible that "reality" can and must mirror exactly what we see experimentally on the physical level. That leaves us with a still important question; what is the nature of this internal wave like motion?

On the other hand, it is still possible, but unlikely, that the state of the particle could be completely independent from the physical particle, or the particle actually does just pop into existence prior to measurement, and thus still allow for the nonexistence-indeterminate paradigm (#1) above. Proof of these possibilities would likely be impossible. It would require us to show that either there is a complete independence between the physical particle and its information content, or for us needing to prove a negative (a particular particle does not exist), which is logically not possible.

One possible way forward to prove the existence-indeterminate state paradigm (#2) might be to perform a test in which the actual measurement is performed within the same moving relativistic reference frame, such that two interacting particles are already synchronized as far as their time-dilated moving clock is concerned. By drawing conclusions about some soft measurement of a minor wave-like property disturbance of the matter waves, and perhaps a final emitted photon generated from that interaction, we may gain new knowledge about the internal state that exists before that interaction. The key here is that both the particle and sensor particle must be in the same reference frame before interaction, which may be difficult or even impossible to achieve. Given the ingenuity of the scientific community it is likely that someone will devise such an experiment and learn something completely unexpected that will no doubt surprise us all.

References:

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Precognitive Quantum State Supporting Arguments

It may be important to dispel a few anticipated objections to the papers thought experiment and specific conjectures. Below are a few arguments that might be expected, and their counter arguments. If there are more arguments that I did not address please email me at Steve.Coleman@jhuapl.edu and I will do my best to address those as issues well.

Thanks!

Argument: Spaceships have mass and therefore they can not travel at the speed of light.

Counter argument: This is a *Thought Experiment*, to be used as a tool for understanding '*the process'* of dilation in the relativistic reference frame. The space ship is merely an analogy for the reader to objectively visualize the process being discussed in real world terms that they can comprehend. Who can visualize a real photon, given that the average person (or even scientist) doesn't really know what they are on a physical level. Ultimately the paper talks about electromagnetic waves, which actually *do* travel at the speed of light, so there is no substantive issue here.

Argument: Einstein said that objects contract, not space-time.

Counter argument: Please note that 'distance' is just the name for *the length* of some intervening space between two objects and is thus is subject to the same length contraction conditions when measured at relativistic speeds. The use of the string with the first two space buoys was illustrative of this, but is unnecessary in order to measure the same amount of length contraction for the same length object. Adding the string changes nothing other than changing the endpoints from which you measure.

Argument: The ship slows down as its clock slows down.

Counter argument: You are now arguing for a modern day Zeno's Paradox, which we all know is completely false. Only instead of halving the distance you are halving/reducing/dilating the 'time' in which one can travel, which then translates into the distance being traveled. Achilles will always overtake the tortoise in real life, especially when he is traveling at the speed of light.

Obviously the ship does not slow down as the ship is speeding up. That makes no sense and would be a true paradox of logic. If photons slowed down as their clock slowed down then no emitted photons would ever be received, but rather would be stalled in mid flight as they are just leaving the source. Photons in a vacuum do travel with a stopped clock, which is exactly why the speed of light is the natural speed limit that it is. You can't do better than zero time (in the photons reference frame), so you can't go any faster without first going backwards in time. Note that in all experiments the time of travel is of course measured by the outside observers proper-time clock, not the photons time dilated clock. There in lye the true dichotomy in the speed of light.

The reason that *length contraction* even happens is because you travel further with each new clock cycle, as time starts to dilate. The ships pilot will be completely unaware of any change in length of his clock cycle with respect to any other clock, so to the pilot they would see this length contraction as just added acceleration. The ship won't actually be accelerating beyond C, but it will certainly appear to do so for the pilot.

2 June 2013 “Zeno's Paradox” Wikipedia
https://en.wikipedia.org/wiki/Zeno%27s_paradoxes#Achilles_and_the_tortoise [2013, June 25]

Argument: The ship does not exist for the Earth based observers since they can no longer see it, therefore #1 should be chosen, not #2.

Counter argument: You are merely outside the light cone temporarily due to the extreme blue-shift of the light from the ship. Once the ship is up to speed and headed directly towards you, for that time duration on your clock before they arrive, you can not be affected by the ship as it approaches you because they are traveling with the light emitted from them. The opposite direction of you affecting the ship might still be possible, as the ship is going to see your photons as extreme blueshift.

The ship will arrive to Earth at some point and your light cones will again fully intersect. Just because you are not able exchange photons bidirectionally does not mean that the ship does not exist. Does the *other side* of the Universe exist? Definitely yes, its just that we can not know anything about it because we can not exchange photons.