Leibniz, Heisenberg, & Einstein

A likely account of quantum mechanics.

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Introduction…

One of the most intriguing aspects of Leibniz's <u>Philosophical Essays</u> is the manner in which he bridges experimental physics with his conception of the metaphysical world. As an enlightened thinker in both realms we must take this merger seriously. Leibniz develops and utilizes the concept of kinetic energy in his of account metaphysics and to make sense of the confused experiments of his contemporaries. For Leibniz, kinetic energy, or as he variously calls it action, power, and force, is more than a physical concept to explain motion. It is a fundamental metaphysical reality that God created as a key component of his original universal harmony.

Leibniz's explanation of kinetic energy is accepted by physicists today; indeed, modern physics descends from it. One must wonder then, if Leibniz were here today, how would he incorporate modern physics into his metaphysical view. Would he take it all in stride? Would he have to modify his metaphysics? Reject quantum mechanics? Have a nervous breakdown?

Perhaps the fact that modern physics is typically considered enigmatic when compared to classical Newtonian physics and not to Leibniz's metaphysics will lead us to reconcile the two without difficulty. On the other hand, perhaps the strange conclusions of Bohr, Born, Einstein, and Heisenberg will seriously undermine Leibniz. In his absence, we will consider this issue by examining Heisenberg's Uncertainty Principle and a Leibnizian account of Einstein, Podolsky, and Rosen's "spooky" action at a distance.

Part I, Background…

The uncertainty principle is, on its face, easy to state and easy to understand. It is when we delve deeper that we face serious philosophical questions about both the laws governing the world and our role in viewing it. Let us begin with a detailed description of the uncertainty relation that we will refer to throughout and then consider Leibniz's likely response to its phenomena and the philosophical implications. Heisenberg demonstrated that certain pairs of physical parameters can not be known simultaneously with more than a given fixed accuracy. For example, the position of a baseball can not be simultaneously known with its momentum. If we say that the ball is exactly at the center of home plate, we can not know how fast it is going. On the other hand, imagine 1978 relief pitcher for the New York Yankees, Goose Gossage, coming in to save the game. (I'm a bit out of touch with more recent heroes.) If Goose sends the ball hurling towards home at exactly ninety miles per hour, we can't say where it is with any certainty whatsoever. The ball might still be in his hand, at home plate, or spoiling Billy's ice cream sandwich at the concession stand.

Interestingly, if we are willing to compromise on our desire to know *exactly* the momentum of the pitch we can gain better knowledge of its position. Heisenberg requires only that the product of the uncertainty in position (delta x) and the uncertainty in momentum (delta *p*) be at least a certain amount[1]:

delta x * delta *p* >= constant

It is important to note that this relationship is not a statement about our measuring instruments. One might think that if we had better instruments that this problem would go away. Indeed, for everyday living, the limitations imposed by Heisenberg do not come into play. Knowing that the pitch crossed *about* the center of home plate at *about* 91.86 miles per hour is good enough to keep the network ratings high. Heisenberg tells us, however, that there is a theoretical limit on simultaneous accuracy of certain pairs that can not be improved upon even with the best measuring devices of the rocket scientists in Los Alamos.

Let us look more closely at how our instruments become intertwined with the uncertainty principle because doing so may provide us a window into Leibniz's windowless monads. In the famous double slit experiment we are interested in understanding the curious patterns that electrons create on a distant screen. If we close the right slit and shoot electrons, one at a time, through the left slit we will develop, over the course of the experiment, a bell-shaped curve on the screen with the peak lined up with the left slit. Then, if we cover the left slit, open the right, and repeat the experiment we will get a

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[1] Page15, The Physical Principles Of The Quantum Theory, Werner Heisenberg, Translated by Carl Eckart and F.C. Hoyt, Dover Publications, 1949

similar bell-shaped curve but shifted so that its peak is in line with the right slit. This is perfectly reasonable and consistent with an electron as a particle.

Since we surmise now that electrons are particles we might as well open both slits and let the electron go through either one slit or the other (the particles can't split up and go through both). In this case, the pattern we obtain is very bizarre. The pattern is that of a diffraction pattern. That is, the electrons create a pattern consistent with wave theory. Somehow each electron "knows" that it has a choice between two slits and "goes through both" acting like a wave, causing interference, and making a diffraction pattern.

"Well," we say, the electron can only go through one slit at a time and to prove it, we will keep an eye on the electrons by shining light on each of the slits. When the electron passes through a given slit we see a reflection at the slit and we will know through which slit it has passed. As predicted, this experiment works well and we are able to track each electron's "choice." Surprisingly, with our light on, the diffraction pattern disappears and we return to the same two bell-shaped curves that we had when the electron was acting like a particle. Somehow each electron knows that we are watching and it acts differently; it goes back to acting like a particle.

This statement is really Heisenberg's uncertainty principle manifest: When we shine light on the electrons we impart some of the momentum of the light (photons have momentum) to the electron itself. This causes the electrons to land differently on the distant screen and thus change the pattern. Our next alternative is to lower the energy of the photons so that they disrupt the electrons less. This is a viable option. Unfortunately, as the energy of the photon decreases its wavelength increases. Yet we need low wavelength light to discern which slit the electron goes through. As soon as we lower the energy enough so that we do not disrupt the pattern we loose the necessary resolution to determine the position of the electron. Once again we don't know which slit the electron goes through and we are forced to conclude it goes through both. The electron acts as a wave. When we watch (or close one slit) the electron acts like a particle. When we don't watch (or open both slits) the electron acts like a wave.

Part II, Leibniz meets Heisenberg…

Now, finally, let us wonder what Leibniz would conclude about this bizarre state of affairs. For the moment we will concentrate on the phenomena. Leibniz would likely be relieved by the fact that electrons and numerous other sub-atomic particles have been discovered. In fact, he would relish current popular opinion that holds that "they're discovering smaller particles all the time." Leibniz wasn't an atomist and didn't accept the existence of any fundamental indivisible body. He stated that *"There is no atom, indeed, there is no body so small that it is not actually subdivided.*"[2] For Leibniz, if there were an indivisible body it wouldn't be capable of representing the entire universe. Monads on the other hand are capable of networking with the entire fabric of the universe

[2] Page 33, Philosophical Essays, G.W. Leibniz, Translated by Roger Ariew and Daniel Garber, Hackett Publishing Company, 1989

because each simple monad *"is surrounded by a mass composed of an infinity of other monads."* [3] It is through its group of surrounding monads that the individual soul receives representations of the entire universe. Modern particle physics would, in Leibniz's view, keep all those (damn) atomists quiet.

Heisenberg's interest in the position and momentum of a particle also would not be problematic for Leibniz. Leibniz views both position and momentum as modifications of extension that do not carry any metaphysical import. In the essay, <u>On the Nature of Body and the Laws of Motion</u>[4], he demonstrates that it is impossible for quantity of motion (momentum) to account for the results of collisions. He shows the absurdity of the Cartesians' conclusion that a small body could collide with a large body at rest and carry it away at the speed of the original small body. In another case he shows that by only analyzing quantity of motion one could design an apparatus to raise the center of gravity of a group of bodies without outside influence.[5] One could also develop a perpetual motion machine[6]. In each case the implication is that there is a metaphysical effect that needs consideration. For Leibniz the answer lies in what he calls power, force and action. We call it kinetic energy.

[3] Page 207
[4] Page 245
[5] Page 109
[6] Page 108

Unlike Descartes, Leibniz finds the modifications of extension purely phenomenal - no more metaphysical than size, heat, taste, texture, and color. They lead nowhere - a dead end. So while Leibniz would not object to Heisenberg's interest in position and momentum he would surely point out that Heisenberg was not investigating metaphysical concepts.

At the same time we must wonder what Leibniz would conclude about the fact that position and momentum can not be simultaneously measured with precision beyond that imposed by the uncertainty relation. What does this say about the monad whose body is the electron? How does this monad then relate to the rest of the network of monads? At first, the uncertainty of position *or* momentum would likely please Leibniz. Monads ought to have a confused relation to the world. The farther one monad is, metaphysically, from another the more confused is the view. Confusion is part and parcel of the being of the monad. Only God has an unconfused knowledge of the network of monads.

Leibniz argues that we choose to pay attention to certain perceptions more than others. That is, we have appetitions. With this in mind, the fact that we choose to focus on an electron is consistent with our free will. He might find it odd that the focus of our experiment yields *such* confused results but that, in itself, is not a contradiction. What, however, would he conclude when faced with the fact that confusion of the momentum is inextricably bound to the confusion of the position?

Leibniz could not simply dismiss these two confusions as examples of the many confusions that our bodies (or scientific instruments) present to us. No, the confusion of momentum and the confusion of position are *mathematically linked*. When the confusion of position diminishes the confusion of momentum increases. This would certainly be an issue with which Leibniz would have to contend and we will discuss one plausible response after mentioning a few others. First, we must acknowledge that Leibniz might not admit the question at all because of its reliance on a notion of time and space to which he does not subscribe. Heisenberg does not use the absolute space of Newton but does assume a given frame of reference (typically the frame of the laboratory). On these grounds Leibniz might dismiss the premise of the question. It is possible, however, that he would accept the question after explaining that the Heisenberg's notion of time and space in the laboratory is just a perception that the monad uses in its thinking. It is not metaphysically real but, like extension, is nonetheless useful to the monad. (We will address Leibniz view of space and time when he meets Einstein below.)

Presuming the question is admitted, what are some of Leibniz's possible responses to the uncertainty relation? He might explain that this mathematical link is just another trivial form of confusion not worthy of consideration. Or, perhaps, that the link is a part of God's overall plan which is way beyond our comprehension. In the Discourse on Metaphysics, Leibniz explains:

> "Thus, what passes for extraordinary is extraordinary only with some particular order established among creatures; for everything is in conformity with respect to the universal

> order…. But, when a rule is extremely complex, what is in conformity with it passes for irregular."[7]

Both these explanations are reasonable although not compelling. If we look now at the implication of the uncertainty principle we arrive at an analysis that would surely resonant with Leibniz. If the uncertainty principle didn't exist then we could measure both position and momentum to unlimited precision. This means then that we could know exactly where *all* particles are as well as their trajectories. Once we have this knowledge we can also predict with absolute certainty where they will be at any time in the future and exactly where there were at every moment of the past. Suddenly, our confused world becomes much less confused. This doesn't give us access to the monads themselves but our representation of all aspects of extension becomes perfect. Leibniz would argue that a fully accurate knowledge of the motion of all bodies for all time is not part of God's plan and thus the uncertainty principle, which prevents this knowledge, is reasonable.

As an introduction to the uncertainty principle, we discussed the double slit experiment. In it we not only saw wave/particle duality but also that the uncertainty principle is bound up in the duality itself. We must ask then, how would Leibniz react to wave/particle duality? And, given that reaction, what is at stake for the uncertainty principle?

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Leibniz could respond to wave/particle duality as a form of confusion or as an inexplicable part of God's plan but again these types of explanations are unsatisfying. One aspect of duality would certainly not trouble Leibniz. The fact that on Mondays and Wednesdays we conduct experiments that make the electron act like a wave and on Tuesdays and Thursdays like a particle would be easily handled. God created, he would say, the harmony in advance and knew which experiments we would freely choose. Long ago he spun out the correct harmony for each day of the week. (He also knew that the scientists in Los Alamos would get Fridays off.) So, the timing of the experiments fits nicely with original harmony. But, why would God choose to have different representations according to how we set up the experiment (one slit open or two, shining light or not)? Imagine the complications. He would have to have four complete sets of representations: Two for the electron as represented to its monad (one set for wave and one set for particle) and two sets for the experiments to be represented to the scientist. In addition, the scientist would have a set of apperceptions for each case. Of course, God could do all this – but why? It seems that Leibniz would be at a loss to explain wave/particle duality.

Above, we saw that the uncertainty principle was manifest in wave/particle duality. It appears that this would initially present a problem for Leibniz because he likes the uncertainty principle but can't explain duality. Yet they are bound together. It appears that Leibniz would have trouble reconciling his reconciliation with modern physics – sometimes he would like to accept the uncertainty principle and other times he wouldn't.

Fortunately, Leibniz would have a way around this problem. We must understand that while the uncertainty principle can be see manifest in experiments it does not rely on experiments. In fact, this is a common misconception. The average junior scientist believes that the uncertainty principle is a statement about measurement - that it prevents us from conducting an experiment without influencing the results. While it is true that our measurements will influence an experiment, the principle exists independent of experiment. It is, for example, used to prove that electrons can't exist within a nucleus even *without ever doing an experiment*. With this in mind, there is no contradiction and Leibniz could accept uncertainty but not duality.

Part III, Philosophical Implications…

In part II, we looked at some of the phenomena of the uncertainty principle. Now we must ask what the philosophical implications of the uncertainty principle are and how Leibniz might respond. Before doing so we must reach further clarity on the status of the electron before we measure it. One would quite reasonably assume that the electron has both momentum and position before we measure it. However, this is not correct. The particle does not have a given position and momentum before our measurement. Rather, the particle has a wavefunction that describes the probability that if and when we make a measurement we will find a certain position or a certain momentum. Since the wavefunction describes a probability, we obtain any number of probable results. Any measurement collapses the wavefunction and "forces" a reading on our instruments.

This has two profound philosophical implications and we are now ready to investigate how Leibniz might regard them. First, the fact that the wavefunction describes a probability causes us to re-examine our view of the world. We believe in causality. When I apply the brakes to my car it slows down and comes to a stop. When I hit a baseball it flies off into foul territory (baseball isn't my game). What then, does modern physics imply, when it tells me that when I apply the brakes there is a certain probability that I will not slow down or when I hit the exact same baseball the exact same way that next time it may be a home run. We have always believed that the world is deterministic, i.e. causal. Now we see it isn't. We ask: "Mr. Leibniz, how do you respond to the fact that the world is not causal?"

Leibniz would agree wholeheartedly that the world is not causal. After all, his metaphysics is dependent on the fact that the monads don't influence one another. They are correlated to one another; but the entire set of predicates of each is known in advance by God. (God exists outside of time so the term "in advance" is a misnomer.) So, Leibniz might respond: "Of course, the world is non-causal. The better question is why has God created the harmony of the world so that it appears causal on the macroscopic level and has now allowed you to discover non-causality through quantum mechanics?" The apparent causality of the world is done for mans' benefit by God. Of all the worlds that God could have chosen, he realized, using his own internal reason, that it was best that the world appear orderly to man. That man has, by his own free will, chosen to conduct experiments demonstrating non-causality is neither a contradiction nor an indication that God has made a world less perfect than it could be.

The second important philosophical implication refers us back to the double slit experiment. There we saw that it is through interaction with measuring devices that the wavefunction collapses into measurable results. These devices need not be scientific. For example, when a photon hits an eye its wavefunction collapses and the eye notes the energy. When an electron of a sugar molecule reacts with an enzyme on the tongue its wavefunction collapses and the tongue notes the taste. What are the implications of a particle not having a value until it interacts? The particle seems to have one being before the measurement and one after.

This philosophical issue has been troubling for many 20th century physicists. That the being of a body is bound up in our measurement of it raises many questions. What happens if we don't look at the measurement? Does the being belong only to the particle or to the system of the particle and the instrument? Perhaps it belongs to the particle, instrument, and laboratory all together. In fact, the whole notion that the wavefunction collapses has led some to believe that there are multiple parallel universes. They believe that when the wavefunction collapses each universe obtains one of the probable results of the measurement.

Leibniz, on the other hand, would be delighted with the collapse of the wavefunction. He would point out that every monad "*expresses, however confusedly, everything that happens in the universe, whether past, present, or future…*"[8] Every predicate of the monad is contained within it. At certain times, predetermined by God, these predicates rise to the level of representations of external events. Leibniz would argue that the collapse of the wavefunction is equivalent to a predicate rising to the level of a representation. That is, before we make a measurement we have no representation although the predicate is lying in wait within our monad. When we make the measurement, the wavefunction collapses, and the representation arises from the predicate.

Part IV, Leibniz & Einstein…

In a 1935 paper, entitled <u>Can Quantum-Mechanical Description of Physical Reality be Considered Complete</u>, Einstein, Podolsky, and Rosen argued that the formulation of Quantum Mechanics is incomplete. Their objection was based on the following Gedanken experiment. Imagine two particles that interact in such a way that they effect one another's momentum. If the total momentum before the interaction was zero then, by the law of the conservation of momentum, the total momentum afterwards must also be zero. If, for example, we could determine that particle one has a momentum afterward of positive 5 then particle two automatically has a momentum of negative 5. It is important

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to realize that although the particles may appear to split up and go their own ways, they share a common history by virtue of the fact that they once interacted and their momentums must still add to zero. We say that the particles exhibit quantum entanglement. That is, the particles do not have independent wavefunctions but, rather, share a single joint wavefunction. A reasonable analogy would be a couple that has separated but has joint responsibility for the children forever. A similar description can be made for the position of each particle after the interaction - as soon as we know one particle's position we know the other's.

Now, let's conduct the experiment. We let the particles interact and then we wait quite a long time so that they can get very far apart. In fact, we wait so long that even light couldn't travel the distance between them in several minutes. According to Heisenberg's uncertainty principle we can choose to make a precise measurement of position (sacrificing momentum) or momentum (sacrificing position). We choose to make a precise measurement of momentum on particle one. Therefore, we automatically know the precise value of particle two's momentum (because they must add to zero). We could have, however, made a precise measurement of the position of particle one and then would have automatically known the precise position of particle two. It is important to realize that the measurements are made on particle one and in no way effect particle two. In fact, particle two is already on the other side of the universe. Einstein pointed out that this situation is a direct violation of the uncertainty principle because it implies that both the momentum and the position of particle two exist simultaneously with precision. He concludes, therefore, that the formulation of quantum mechanics is incomplete:

> "While we have thus shown that the wave function does not provide a complete description of the physical reality, we left open the question of whether or not such a description exists. We believe, however, that such a theory is possible."[9]

Implicit in Einstein's description is the fact that particle one can not effect particle two because it is so far away. Any effect by particle one on particle two would rely on a cause or at least a signal that travels faster than the speed of light which is prohibited by the theory of relativity. Thus the formulation of quantum mechanics includes "spooky action at a distance."

We know today that any measurement on particle one will, in fact, influence particle two despite its distance. Specifically, the joint wavefunction collapses everywhere instantaneously. Nonetheless, the theory of relativity is still upheld because no information is transmitted faster than the speed of light. Since the joint wavefunction collapses for both particles, we are not able to ascertain the second particle's position and momentum simultaneously and therefore Heisenberg's uncertainty principle is not violated. Nonetheless, it is quite bizarre that the joint wavefunction collapses everywhere without any regard for the speed of light.

To understand Leibniz's likely response we have to first elucidate his conception of time and space. In the Newtonian world, time and space are absolute. They exist outside of objects and serve as a backdrop for all events. We say that the train arrived in time, in two minutes the cars will collide, and that time is wasting. In each case, we believe that time carries on its duty, that is time passes, completely independent of all the events that are happening in time.

We, following Newton, believe that time exists absolutely. Similarly, we conduct our lives believing in the absolute nature of space. My book is over there. That is my space. Let's exchange places. Once in a while we think of the validity of different reference frames. We might, for example, realize that when one walks to the lavatory in an airplane that one is actually moving hundreds of miles per hour with respect to the earth. Nonetheless, we still believe that the frames of reference themselves exist in a true absolute space – the space where the planets reside.

Leibniz dismissed absolute time and space and his objection was based on the principle of indiscernibles. For Leibniz,

> "...there cannot be two individual things that differ in number alone... There is no vacuum. For the different parts of empty space would then be perfectly similar and mutually congruent and could not be distinguished from one another. And so they would differ in number alone, which is absurd."[10]

A similar argument holds for time. In both realms, an indiscernible implies something that would exist for no sufficient reason which is contrary to the best possible world God created. What then is Leibniz's formulation of time and space? For Leibniz, what we call time and space are ideas in our minds. They have a certain appeal and are useful but

[9] Page 780, Physical Review, 1935

are not externally real. Both come about as the result of our understanding of relations. If book A is in a place, and books B and C exchange places, we develop the (unfounded) notion that the places themselves exist in absolute space. We not only have an entire network of relations but we impose characteristics on the relations. Place A is further than place B. Place A is inside of place C. Place A overlaps with place B. All these characteristics reinforce our belief that places exist in a real absolute space. In a similar fashion we come to believe that instants exist in a real time. We make the mistake of concluding that because relationships exist they must exist in something external and substantive. Leibniz argues that space and time are simply the playing out of the pre-established harmony.

We can now see how Leibniz would respond to the conundrum posed by Einstein, Podolsky, and Rosen. Since he would accept Heisenberg uncertainty principle he would be pleased to find that recent experiments have shown that it is not violated. How would Leibniz respond to the fact that the collapse of the joint wavefunction exceeds the speed of light? Einstein didn't live to see the proof of this startling result nor to see the experiments confirming it. Would Leibniz also consider it "spooky?" Given his conception of time and space as illusions, Leibniz would have little difficulty with "action at a distance" nor relativity for that matter. For Leibniz there is a (non-spatially) large network of monads, which is God's creation of the universe. Those monads that are minds, as opposed to beasts or coffee cups, have representations that they interpret as

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[10] Leibniz, Pages 31 & 32

spatial and temporal. That is, in their view of the network they imagine different monads in different places and different times. However, this does not depict any metaphysical reality. So, if the joint wavefunction, of two particles (that a mind believes exist very far apart) collapses and effect one another faster than the speed of light there would be no metaphysical import. Leibniz would argue that the mind is questioning phenomena that are, well, only phenomenal. God, he would argue, has nothing at stake in the speed of the collapse of the joint wavefunction. Time and space do not exist in an external absolute sense. So the mind can impose any rules it deems necessary, using its free will on its illusions of time and space. God made the world appear orderly for man. Leibniz would say that perhaps man is distressed by the speed of collapse of the joint wavefunction but, in due time, man will come to accept it and once again the world will look orderly. In the meantime there is no contradiction with the network of monads – God's universe.

Before moving to a recent hot topic in physics, let us gather our results. After seven innings:

	Leibniz Yankees	Quantum Mechanics
Discovery of new particles	No problem	No problem
Interest in position and momentum	No problem	No problem
Uncertainty principle	No problem	Problematic
Wave/Particle Duality	Big problem	Problematic
Causality	No problem	Problematic
Collapse of the wavefunction	No problem	Problematic
Action at a distance	No problem	Problematic

Teleportation…

In recent decades, scientists have accepted action at a distance and have utilized it for practical purposes. The nascent fields of quantum cryptography, quantum computing, and quantum teleportation all rely on the collapse of the wavefunction. Quantum teleportation is the duplication of the wavefunction of one particle at a far distant second particle. That is, particle A is in certain state – it has a wavefunction. Scientists can now teleport this wavefunction to particle B so that particle B is identical to particle A in every respect. What would Leibniz think about this exciting development?

It appears that teleportation would be problematic for Leibniz. Teleportation is not a substantive statement about space and time so he couldn't dismiss it as illusory. Rather, it is a statement of perfect duplication. How would Leibniz react to this Star-Trekian advance? Luckily, since particle A's wavefunction is destroyed in the process of teleportation, Leibniz's law of indiscernibles is not violated.

We must wonder more about the nature of a representation and the wavefunction. Representation is the way that phenomena of external monads are re-presented to a monad. An infinite group of monads surrounds the individual monad and due to its infinite nature it is able to re-present all the phenomena of the universe to the monad at its center. Each part of the surrounding group is responsible for representing, to greater and lesser degrees, each external phenomenon.

What then does teleportation of a wavefunction imply? It feels like a wavefunction is not purely phenomenal. It would be too presumptuous to say that the wavefunction is the monad but it appears to have a closer connection to a monad than does extension for example. Extension simply gets represented to the monad. The wavefunction has an intimate relationship with the central monad. Perhaps the wavefunction is the conduit for all acts of representation. That is, the wavefunction carries the representation to the central monad. It is the communication between the surrounding group to the center. We saw above, that when man forces the collapse of the wavefunction a predicate rises to the level of perception. Now we are suggesting that representation requires a medium for communication to the central monad and that medium is the wavefunction.

Or, perhaps, the wavefunction *is* the representation itself. When the surrounding group of monads re-presents the external phenomenon of interest to the central monad it does so by encoding all the (confused) possibilities into a probabilistic wavefunction. When the wavefunction collapses, one representation arrives, if you will, at the monad.

With these as possibilities, teleportation would still be enigmatic for Leibniz. After all, we are saying that either the conduit of representation or the representation itself gets teleported from one arc of the circle of monads (the arc representing particle A) to another (the arc representing particle B). This situation is reminiscent of the problem of transubstantiation. Professor if this note is still here then your student plagiarized my paper from pnca.edu slash tilda mlawton In his letters to Des Bosses, Leibniz was compelled to account for transubstantiation and did so by identifying a unifying substance that changes during the Eucharist. Although the monads themselves are necessary for the unifying substance they and the phenomena that are represented to them do not change. That is, the little boy in the church still tastes bread and wine but, Leibniz would argue, is consuming the true metaphysical body and blood of Christ. It was necessary for Leibniz to account for transubstantiation, but while teleportation might be supported in a similar fashion, the motivation certainly would not be as strong and thus it would remain enigmatic.

It is clear that central to any reconciliation between 17th century Leibniz and 20th century quantum mechanics, especially wave/particle duality and teleportation will require serious reflection on the metaphysical status of the wavefunction, its collapse, and its role in binding the observer to the observed. To attempt to address these questions in Leibniz's absence has been a challenge and at times unsettling and intimidating. Perhaps some years down the road we will be able to purchase some ticketless time travel and teleport the expert himself into the conversation.