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Entanglement: Exploring the Relationship Between Buddhism and Modern Science

Note to reader: The following discussion addresses some of the more fascinating aspects of modern physics. In choosing my major (physics) I was drawn to its fundamentalism as a base for all other sciences, and toward its ability to acutely explain the strange and complex world we inhabit. It is here that I must pause and note that many of the topics to follow are still hotly debated by those in the research and academia field, whose knowledge and expertise far exceed my own. As as undergraduate, I have merely scratched the surface of a deeply complex and wildly uncharted subject. That being said, I am not an expert on quantum mechanics or other aspects of modern physics. I am merely an inquisitive outsider, with an undergraduate introduction focused on the more mundane mathematical formalism associated with the subject. In fact, many of the subjects that I discuss were hidden in the 'appendix' section of my undergraduate Quantum Mechanics text, a strong demonstration of how little they are covered in the standard undergraduate curriculum.

During the introduction of his chapter on quantum mechanics in his book, *Tibetan Buddhism and Modern Physics: Toward a Union of Love an Knowledge*, Victor Mansfield writes that, "I never argue that quantum mechanics in any way proves the truths of Buddhism. Rather, I am considering a deep similarity in the respective approaches to indistinguishability, the establishment of it through exchange, and the consequences that flow from it" (Mansfield). I introduce this quote because my own thoughts are perfectly mirrored in Mansfield's words. In this discussion, I seek not to decisively 'prove' or draw concrete parallels between the two paradigms; rather, I serve my own intense interest in the nature of consciousness and reality by delving into a discussion of two worldviews that each uniquely seek to define, map, and quantify that which we perceive to be reality. In his manual on the Tibetan Book of the Dead as it pertains to the psychedelic experiment, infamous 20th century academic and social figure Timothy Leary points out that, "eastern philosic theories dating back from thousands of years readily adapt to the most recent discoveries of nuclear physics, biochemistry, genetics, and astronomy" (Leary). Indeed, I seek to show this throughout the next five sections, each highlighting a major topic of quantum mechanics (and cosmology), and the related Buddhist phenomena associated with it.

I. Copenhagen Interpretation

The wave function, commonly found by solving the Schrodinger equation associated with the wave (an ode to the 20th century physicist, Erwin Schrodinger, who first proposed the equation), is the basic pillar of quantum mechanics; it is a mathematical expression of spatial data of a wave (and thus also particle, see section II) and is expressed by the greek Ψ symbol.

What is key is that the wave function does not express a definitive set of coordinates or particular spatial location; rather, it presents a statistical interpretation of a particle's location; i.e., one can predict where a particle *might* be from it's wave function. This is quite a contrast compared to the classical view, which allows for clearly defined spatial coordinates for some particle in a system at any given time.

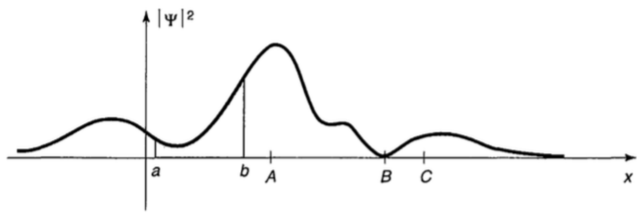

Figure 2(a): A graph representing a wave function: on the x-axis is position, and on the y-axis is probability amplitude. Thus in this situation, it is more probable that the particle will be found near position A (because of the large y-value, or probability) compared to position B.

The 'classical view' refers to the style of physics introduced by Isaac Newton hundreds of years before the modern physics era (the early 20th century). I mention it because it provides a stunning contrast between two styles of thinking: one, providing a concise, deterministic set of rules on how physical matter interacts. As an example, I could calculate to theoretically perfect accuracy the exact location an apple will fall from a tree given the law of gravitational motion and all the associated variables. The other level of thinking, the 'quantum style' radically differs, suggesting instead that even if you know all aspects about the particle, you can never predict the outcome of such an experiment with absolute certainty, you can only calculate a statistical probability of where the particle might end up. How can this be? Suppose that you conduct an experiment to determine the location of the particle, and find that it is at C[1]. There are two proposed explanations: The first one is referred to as the 'realist' position (of which Einstein was a proponent), argues that it was at C the whole time and it is simply the theory that is lacking- i.e. our current method of quantifying spatial information at tiny scales is simply inadequate. This statistical uncertainty, then, does not arise from nature but rather from us as observers with partial tools. The realist perspective suggests that in order to complete our 'toolbox', hidden variables are needed (see section V for more on this fascinating subject). The second explanation is called the 'orthodox' position, and suggests a more confusing reality, which is that "the particle wasn't really anywhere" (Griffiths). Puzzlingly, the act of measurement produces a result, and until the particle was measured, *its location was not determinate*. Surprisingly (to me), the latter

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[1] Argument inspired by one presented in David J. Griffiths *Introduction to Quantum Mechanics,* Chapter 1

position is the one that is held in popular regard by most modern physicists, and is what is known as the Copenhagen interpretation of matter[2].

This interpretation puts the observer in an interesting position; rather than a passive, non-interacting variable, he is in fact an active component in the system. Stated another way, the outcome of an event arises as part of an interrelated system of measurement, of which the observer is a member. Such a system of interdependency brings to mind the Buddhist idea of karmic imprints, the belief that one's conditions are the result of actions brought about by the self (Wallace). The reverberations of actions from a distant past life may be experienced at a later reincarnation due to the interdependence of mental and physical thoughts and actions on outcomes. In the Buddhist sutra text, *Majjhima Nikāya*, the Buddha describes the role of action as a mechanism for determining fate:

> *Student, beings are owners of their actions, heirs of their actions; they originate from their actions, are bound to their actions, have their actions as refuge. It is action that distinguishes beings as inferior and superior.*

As previously mentioned, and as can be seen from this excerpt, karma directly relates to and results from the actions of the individual. Of course, the Buddhist perspective puts emphasis on morality and defines good versus evil action, where the physical interaction between the observer and the system is impartial. Nevertheless, both Buddhism and physics suggests that our thoughts and actions as sentient beings play a deterministic role in the outcome of events, whether it be the karmic scoreboard or particle event detection.

II. Wave particle Duality, or Complementarity

Wave-particle duality, also called complementarity in some situations, refers to the quantum mechanical phenomenon whereby a quantum object cannot simultaneously be observed to have both wave and particle-like properties. Whether the former or the latter is observed depends on the nature of the experiment being conducted. Some experiments will demonstrate particle-like behavior, like collision/scattering with other particles, and others will demonstrate distinctly wave-like behavior, such as reflection/refraction. As is the case with many aspects of quantum mechanics, this contrasts the classically held belief that all objects have inherent, distinct properties.

A related phenomenon is Heisenberg's uncertainty principle, or the idea that one cannot not simultaneously determine with infinite accuracy both a particles position and momentum in space; that is, at a certain level, there is a irresolvable uncertainty in position and momentum. This idea can be explained by the wave-particle duality problem, because the wave nature of matter dictates that the position of a particle is purely probabilistic (see section II, Copenhagen Interpretation, for a more detailed discussion on this idea).

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[2] Note that there is a third theory, called the agnostic position, which, succinctly put, states that the only way to know where a particle is positioned is to do an experiment, and making predictions beforehand is essentially senseless.

The parallel between quantum complementarity and Asian religious thought is not a new one; indeed it is even suggested that Neils Bohr, an eminent 20th century physicist who flagshipped the idea, was himself familiar with Taoism, having chosen the t'ai chi symbol (the familiar ting-yang duality symbol) as the emblem for his coat of arms when he was knighted (buddhist christian complementarity). The Buddhist idea of the Middle Path is often cited as a conceptual parallel to complementarity. The Middle Path is an ideology popularized by the Madhyamika school, and advocates adhering to a 'middle road' and an avoidance of extremes. Madhyamika also teaches about the inherent emptiness of reality, or that all dharma is simultaneously existent and nonexistent (Lai).

The teachings of Nagarjuna (a contributor to Mahayana thought) overall mesh well with the idea of particle-wave duality in physics, which contradict the idea of absolute states of existence. Nagarjuna offers commentary on this paradox in the *Mulamadhyamikakarika* Sutras, noting, "we state that whatever is dependent arising, that is emptiness. That is dependent upon convention. That itself is the middle path" (Lai).

III. Entanglement and Wave Function Collapse

Here I discuss the titular phenomenon, quantum entanglement (or the non-locality of particles), as well as the implications due to the collapse of a particles wave function.

Entanglement describes to the idea of non locality and the inherent interconnectedness between two particles. Experimentally, entanglement (two particles remaining correlated as a system despite being separated by a great distance, exceeding the speed of light) has been verified to occur (Griffiths). The idea that a set of interrelated particles can remain 'in contact' despite being separated by a distance so large that the data cannot be exchanged between these particles at a fast enough speed is truly fascinating, as well as deeply perplexing. It also contrasts combatively against Einstein's theory of General Relativity, which famously determines that any influence can only move as fast as the speed of light (or slower) (Wallace). The idea of entanglement seems to suggest that there is some intrinsic interconnectedness between particles, objects, or systems, that as of yet evades our understanding.

The collapse of the wave function, although ominous sounding, is used to explain how the process of measurement effects the probabilistic nature of a wave function. The Copenhagen interpretation suggests that after a particle is measured in some experiment, its wave function 'collapses' from a range of probable quantities to a set quantity, or the measured value. Upon initial evaluation, it may appear foolish to suggest that a wave property 'collapses', but in fact it provides a palatable explanation of why we arrive at the experimental outcomes that we do.

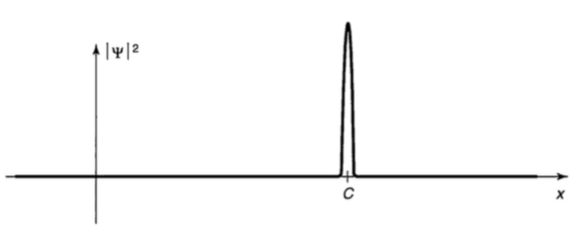

Figure 4(a): The wave function of the particle in Figure 2(a) after measurement. The particle is observed to have a defined position, C, and it's wave function 'collapses' from one of several probabilistic regions to one region with a sharply defined probability peak.

Again, one can compare this seemingly self-awareness of matter to ideas proposed by the Nagarjuna, whose prose describes a similar sense of interconnectedness:

Whatever is dependently arisen
Does not arise, does not cease,
Is not permanent, is not extinct,
Does not come, does not go
And is neither one thing nor different things

This idea is discussed in *The New Physics and Cosmology, Conversations with the Dalai Lama* (essentially a transcripted account of extensive conversation between eminent physicists and the Dalai Lama and notable monks on various subject about physics and modern theories about the physical world). In the subsection titled "Free Will in a Causal World", the Dalai Lama and astrophysicists discuss the Buddhist perspective on the topic. As previously discussed, karma acts as a self-determistic force, "he karma of all sentient beings that inhabit the universe plays a role in shaping the formation of the universe. Once the actual physical evolution begins, then there is a determined path". This shift from karmic possibilities to physical certainties described in the Buddhist perspective mirrors the collapse of the wave function phenomenon, where statistical probabilities also collapse into physical certainties.

IV. Multiverse and the Buddhist Cosmology

One perhaps whimsical parallel between the two paradigms is the idea of a multi-verse; that is, a large number, or perhaps infinitely many universes spanning space and time (Kaku). This multi-worlds cosmology is a central pillar of Buddhism; Tantric Buddhism, in particular, establishes a robust framework of universes inhabited by a whole host of sentient beings, from the lowest 'ranked' hell realms- which are plagued by suffering beings of low karmic birth- to the highly coveted Buddha fields (Mumford), the inhabitants of whom are privileged to regular contact with and teachings from enlightened beings (Samuel). The multiverse principle is demonstrated visually throughout the Tibetan Buddhist tradition by the careful creation and ceremonial use mandalas. Mandalas are a heavily symbolic and visually spectacular representation of the 'sacred geography' that defines the Buddhist worldview.

In physics, the multiverse concept is a somewhat fringe idea arising from String theory[3]. String theory is mathematical model that was proposed as a means of describing various perplexing phenomena, such as black holes, dark matter involvement in cosmic inflation, and early universe formation. It suggests that at a small enough scale, point particles can instead be thought of/ described as strings (which propagate and interact vibrationally in a manner similar to classical strings that are familiar to us). One mathematical consequence of String theory is the existence of extra dimensions beyond the four dimensional spacetime currently known to us. In *The New Physics and Cosmology, Conversations with the Dalai Lama* (chapter on the Origins of the Universe and Buddhist Cosmology) two eminent astrophysicists address this topic in conversation with the Dalai Lama. After probing by the Dalai Lama on the subject multiple

[3] A topic that is, unfortunately, not explored in the undergraduate curriculum due to scope, and thus not well known to the author.

universe, astrophysicist Arthur Zajonc notes that, “this is a very, very exciting topic; but we’ll have to come back in fifteen years to tell you the answer” (Zajonc). His comments accurately reflect the lack of understanding on this topic in the astrophysics and related communities. Therefore, with a lack of established theory about String theory and other multiverse, it is hard to truly comment on the similarity between Buddhism and universe cosmology.

It is interesting to note the similarities (and differences) between the Buddhist and physical sense of time. According to the Dalai Lama, Buddhism does not propose a ‘beginning point for the creation of time or of space’, rather, individual systems are seen to start or end, but the same viewpoint cannot be applied to the ‘universe’ as a whole (Zajonc). Of course physicists generally attempt to categorize the history of the universe with an exact and discrete timeline. Much energy has been spent calculating the age of the universe, up to enormous precision. Despite this, the physical theory behind the origin of the universe is still quite fuzzy. The Big Bang is widely believed to explain the genesis of the universe, however very little is known about the pre-origins, or ‘pre-Big Bang’ era. There is some speculation that new universes can arise from black holes or other means. If we follow this idea and view universes as arising continuously, then the Buddhist frame can be roughly applied; instead of our universe existing singularly, it is but one isolated system in a sea of many, and here the remarks by the Dalai Lama become more relevant.

V. Bell’s Theorem[4] and Conclusion

As mentioned in section II, Bell’s theorem debunks the realist stance of the indeterminacy of a particles position prior to measurement. This theory was postulated in 1964 by John Bell, and it was a truly shocking and revolutionary contribution to the indeterminacy discussion. Bell showed that if a particle had a precise position before the experiment was conducted, the outcome of the experiment would be effected.

Had Bell’s theorem instead been satisfied by experiment, it would have bridged the rift between quantum mechanical laws and classical intuition about objective reality (Nityananda). Instead, it indicates that either we are somehow limited as the observer, or that our present theoretical framework for describing quantum mechanical phenomena is fundamentally flawed. If the latter is true, a more adequate framework is needed.

It has been my experience that ‘metaphysical’ interpretations are regarded as taboo in the physics community. The quest for deep answers stops firmly at the empirical. This makes sense given the historical emergence of the separation of church and science (heralded largely by the Copernican scientific revolution in the 16th century), however will this tradition maintain a place in the scientific field as our understanding evolves? I posit that it will not; rather, scientists and thinkers may find that they have something to learn from certain world religions/worldviews that have been explored and refined by long lineages of inquisitive communities. Just as the physicists of the 20th century redefined our understanding of the physical universe with a shocking shift in perception, so too perhaps will the next ‘leap’ of understanding involve similar changes in perspective.

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[4] The mathematical argument behind Bell’s theorem is unsuitable for this context, so the equation itself is not presented in this discussion

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