WHAT IS A WAVE FUNCTION?

by Christina Munns

ABSTRACT

This paper addresses the historical inconsistencies that arise from the lack of definition of the wave function by Edwin Schrödinger in his wave equations, along with the associated misperception of the exact description of the superposition state and whether or not this state is random or deterministic in character.

A redefinition of the wave function is proposed as being the hidden variables existing within the quantum superposition state. This definition is in coherence with actual quantum research. The hidden variables existing within the superposition state are defined. The inconsistencies of the concept of the wave-particle duality are also explained and reasons given why the wave and particle states are discrete.

INTRODUCTION

The intention of this work is to explain how the historical misperceptions about the phenomenon of a wave function; how they have arisen and to also provide a new definition of a wave function based on current research of the quantum state.

CURRENT DEFINITION

The current definition of a wave function is a mathematical description of a quantum system giving the probability amplitude (i.e. the square of which provides the probability density of finding a particle at a particular location at a particular time). The Greek letter *psi* ψ is used as the symbol to represent the wave function in Schrödinger's wave equation. In this way every particle can be represented as a ψ (momentum and time).[1]

Initially, the concept of a wave function arose from the Schrödinger wave equation, which describes how a quantum state of a <u>physical</u> system changes with time. It is a predictive equation that demonstrates the evolution of the wave state over time in the quantum state, and since, from Schrödinger's perspective, the wave and the particle state exist in a coupled or dual state, then the wave state can ostensibly predict the approximate location of a particle state at a particular time. However, Edwin Schrödinger never actually defined what the wave function was in his wave equation. The task of assigning a clear definition of a wave function was taken up by Max Born in 1926 that created "Born's rule" from the Schrödinger wave equation. This law states that the probability density of finding a particular particle at a particular location at a specific time can be established by squaring the wave function, which is the same as squaring the probability amplitude - ψ^2. Thus in Born's rule, the wave function is defined as the probability amplitude. So historically, quantum physicists have taken the definition of the wave function as being equated with the probability amplitude on board, which is where it stands today.

Historical Misperception

One of the most salient remarks to make in the chequered history of quantum physics is that the Schrödinger wave equation defines the state of a physical system – i.e. a quantum state that is comprised of both a wave AND a particle state. However, it is important to appreciate the fact that the state in which both a wave and a particle exist is in the collapsed state on the quantum scale, not the superposition state. It is a very subtly nuanced point to make, but nonetheless a very important one, in order to correctly understand the exact dynamics of a quantum system, that both waves and particles (which are discrete states) actually only exist in the collapsed state and not in the superposition state.

Below is a diagram that shows the current perception of a wave function:

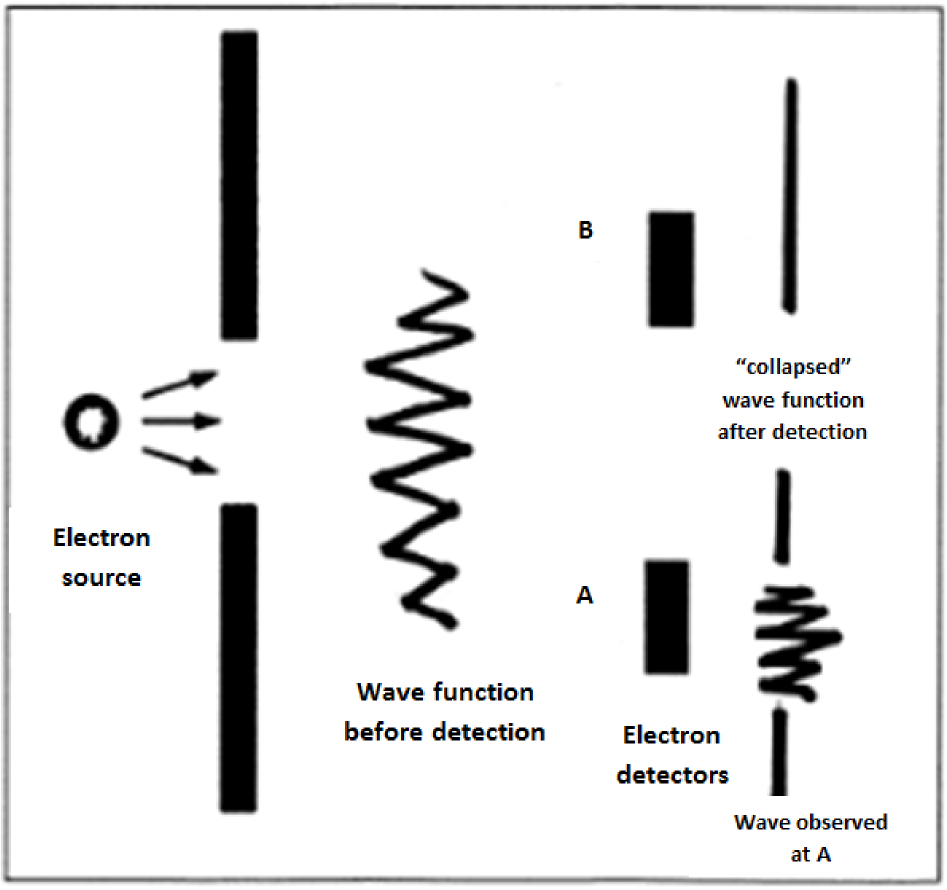

Figure 1 - Current perception of wave function

It can be noted in the above diagram that the wave function before detection takes the form of a wave – i.e. that the wave exists in the superposition state AND in the collapsed state. I strongly disagree with this interpretation and wish to provide a diagram of a wave function that more accurately describes the rôle of the wave function - i.e. the superposition state that exists before observation:

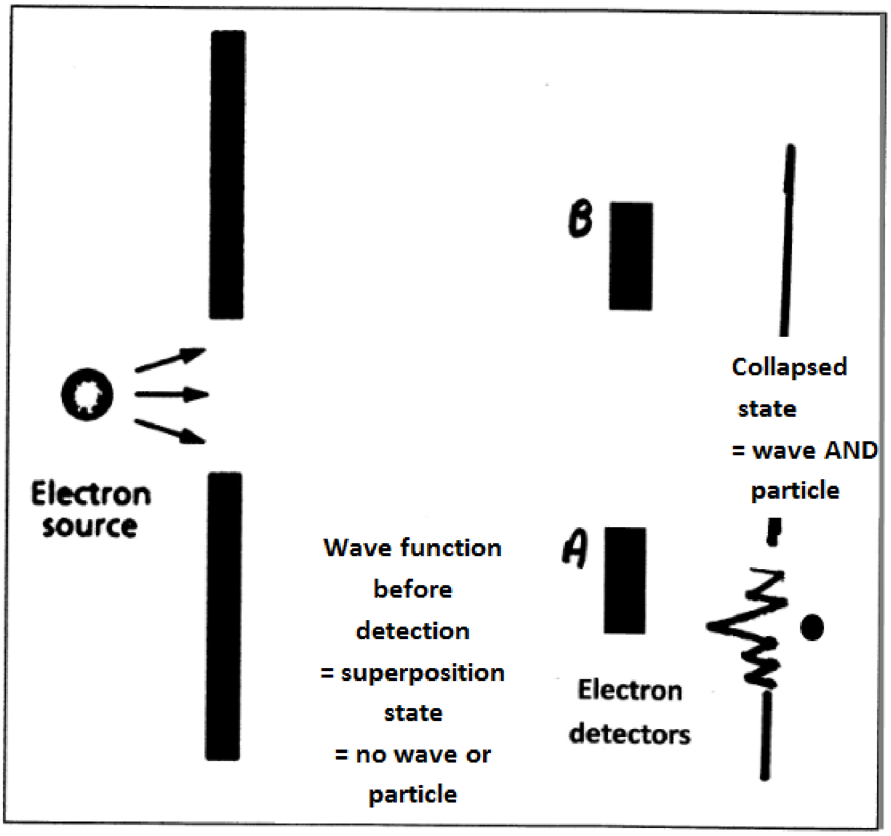

Figure 2 - Actual wave function – no wave or particle state

It can be noted that in Figure 2 there is nothing perceptible in the state before detection – i.e. the superposition state contains nothing visible; no form whatsoever. It contains no wave state and no particle state. It is my strong view that this diagram of the superposition state more accurately describes the state prior to observation. This state is non-local in character and contains no wave or particle state. It is both silent and without motion. In other words, the state before detection does not exist on either the imaginary (wave state) or real (particle state) planes. There is no motion or form in the superposition (pre-observed) state. It is this historical misperception which needs to be corrected. Edwin Schrödinger's intention was to describe the wave state over time, which is not the same process as describing the superposition state (i.e. pre-observed state), since time does not exist in the quantum superposition state. The Schrödinger wave equation describes the evolution of the wave state over time but it does not describe the superposition state. There are three important misperceptions I wish to correct in this paper about the Schrödinger wave equation. These are:

1. That it describes the superposition state = wave function before observation
2. That the superposition state contains both waves and particles
3. That it suggests that a particle can be in two locations simultaneously
4. That the quantum particle state is simultaneously a wave state.

The superposition state is NOT the state that the Schrödinger wave equation describes. It is an equation of motion, not an equation of abstraction or state of rest.

The superposition state is not the probability amplitude, since the probability amplitude describes a wave state which cannot exist in the pre-observed state, since the wave state represents the kinetic energy of a quantum system, whilst in the pre-observed state there is no kinetic energy, no actual motion taking place. The superposition state is an informational state that exists on the abstract plane. It contains the information sets that will form both the wave and particle states upon collapse. These two informational sets each contain information subsets. The informational sets are intrinsic angular momentum or spin quantum number (m_s) and total angular momentum or magnetic quantum number (m_l). Upon observation, the superposition state collapses to the states of the wave (taking the form of angular velocity – ω = principal quantum number from the state of total angular momentum - m_l) and particle (taking the state of orbital angular momentum or azimuthal quantum number from the state of intrinsic angular momentum - m_s).

Below is a diagram showing both the angular momenta and quantum number states of a quantum system both in the superposition state and the collapsed state:

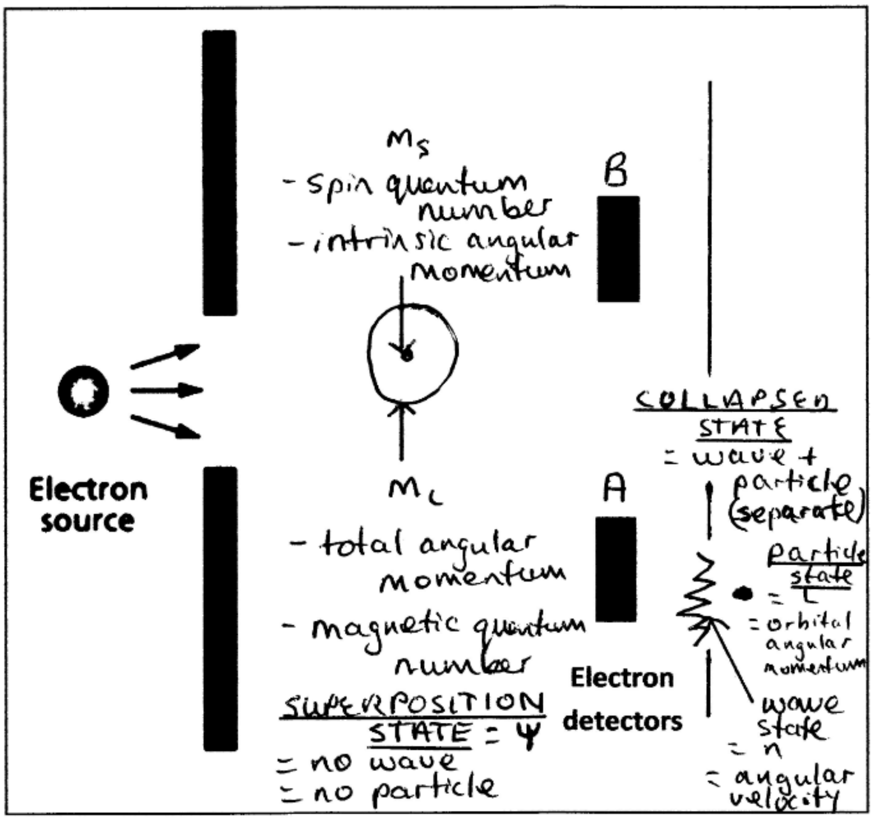

Figure 3 - Annotated superposition and collapsed states of a quantum system

Thus, it can be understood that the real wave function state represents the state before detection – i.e. before quantum collapse. Currently, there is a confused cross-wires explanation of the wave function that defines it as being associated with both the probability amplitude of the Schrödinger wave equation as well as the superposition state and not purely representing the superposition state that it needs to be, without any association with the actual wave. Schrödinger never defined what a wave function truly was and its definition has become confused with the incorrect concept of a probability amplitude, which itself has arisen from an erroneous view of the wave-particle duality! (see section below). Further complicating matters, Max Born's rule does not describe the wave function, but describes the probability density born out of the Schrödinger wave equation's probability amplitude. It is important to comprehend that the wave function <u>is not</u> the probability amplitude, since the issue of the existence of a probability amplitude itself is erroneous, as particles cannot exist in two discrete states of space simultaneously as the Fermi-Dirac statistics attest. They can only exist in one field state at a time.

The current understanding of the superposition state is that it is a state in which both a wave and a particle state can exist. This is incorrect. Neither a wave nor a particle can exist in the unobserved state. Only the informational blueprint, template or hidden variables of the wave state and particle state can exist. The wave function is an informational state that contains hidden variables that operate as different trajectories that can be chosen, depending on the environment that is external to the quantum field.

We must never forget the fact that Edwin Schrödinger never actually defined the wave function. So, for Max Born to boldly declare his Born's rule based on the Schrödinger equation, which itself provides no definition of a wave function, is based on shaky ground indeed! In my view, it is preferable to totally omit the term "wave function" from both the Schrödinger equation and the Born rule and replace it with the term "probability amplitude" for an accurate description within his concept of a quantum state. However, given the fact that Schrödinger believed that a particle can exist in the superposition state, which in turn gives rise to the whole plethora or problems associated with the subject of probability, this makes his entire wave equation questionable in real terms, despite its mathematical elegance.

Here is a summary of the information relating to the relationship of the wave function to the Schrödinger equation as it pertains to this paper:

<u>Time independent Schrödinger equation</u> = standing wave states
<u>Time dependent Schrödinger equation – (non-relativistic)</u> = longitudinal wave state
<u>Time dependent Schrödinger equation – (general)</u> = transverse wave state

<u>Wave function</u> ≠ probability amplitude
= superposition state

<u>Superposition state</u> = information of hidden variables of m_s:m_l = wave function = ψ
= m_s = spin quantum number = intrinsic angular momentum = U(1-0)
= m_l = magnetic quantum number = total angular momentum = U(1-1)
= unobserved/undetected state
= Schrödinger wave equation does not apply
= no wave or particle state = information at rest and in potential

<u>Collapsed state</u> = wave and particle states (discrete states)
= Schrödinger wave equation applies
= observed/detected state
= wave state = n = principal quantum number = angular velocity (ω) = SU(3)
= particle state = l = azimuthal quantum number = orbital angular velocity = SU(2)

CORRECT DEFINITION

Now that the historical misperceptions have been illustrated, I will explain how the wave function needs to be defined in order to accurately reflect the actual dynamics of the quantum state.

New Definition:

A <u>*wave function*</u> *is an informational dual space of the unobserved quantum superposition state which, upon observation, and subsequent collapse of the quantum superposition state, gives rise to the discrete states of the wave and particle. This information of the wave function is in the form of intrinsic angular momentum and total angular momentum, each of which contain four parameters within themselves that together represent the sum of eight hidden variables. This informational state of the wave function is a deterministic state that represents the phenomenon of the quantum superposition state.*

I do not believe that the wave function is the probability amplitude. I think it would be a good idea to change the symbol of the probability amplitude – ψ to ⇝ in order to accurately reflect the difference between the wave function (deterministic superposition state = ψ) and the Schrödinger wave function (probability wave state = ⇝).

The wave function describes the information of the superposition state that contains the hidden variables of spin and total angular momentum or m_s and m_l. These two parameters each have their own variables hidden within them. These hidden variables can be considered to be different possible states in the unobserved superposition state that the wave and particle can take upon collapse. I will explain:

The state of spin (m_s) has four possible states which are: spin up; spin down; right hand chirality and left hand chirality. Thus each of these states of spin represents a different spin state that the particle can be in upon collapse. These four states of spin can be illustrated as follows:

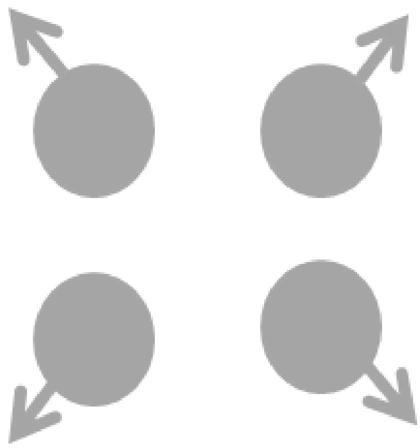

Figure 4 - Four possible spin states

The superposition state can be perceived as consisting of two diagonal axes of $-k/k$ and $j/-j$ at right angles to each other as the diagram below demonstrates:

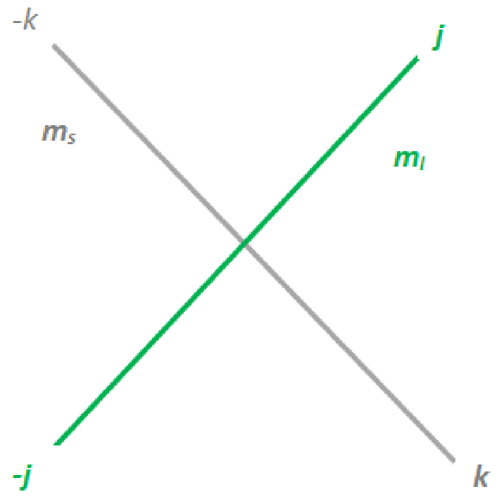

Figure 5 – Dual axes of superposition state = wave function

It can be seen in the above diagram that the state of intrinsic angular momentum or m_s exists on the $-k/k$ axis and the state of total angular momentum or m_l exists on the $j/-j$ axis.

We can plot these four types of spin on our two axes that exist within the superposition state as follows:

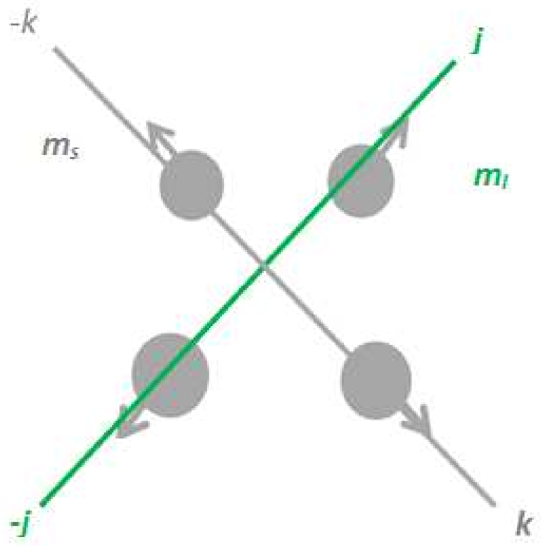

Figure 6 - Four spin states in quantum superposition = hidden variables

These are the hidden variables of the spin quantum number which I believe can be seen in the image of the hologram of a single photon performed by Polish physicists[2] in the dark areas of the image shown below. I propose that the four regions of darkness that exist on the dual axes in Figure 6 above, represent the quantum vacuum state or quantum space that exists in the fifth dimension, since the quantum state is itself the fifth dimension.[3]

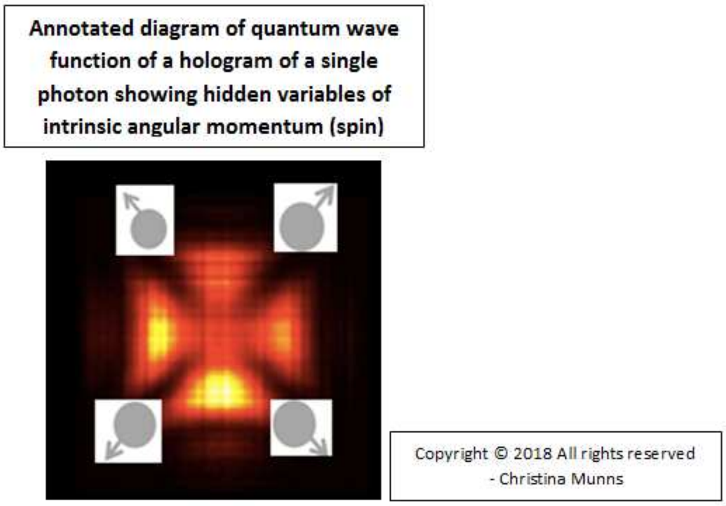

Figure 7 - Four possible spin states of photon superposition

Similarly, the state of total angular momentum or m_l or magnetic quantum number also contains its own set of hidden variables. Since the formula for total angular momentum is J = S + L (+ω)[1]. Then it can be understood that each of these operators represents a variable within the phenomenon of total angular momentum. These four hidden variables can be plotted in the superposition state on the *j*/-*j* axis as follows:

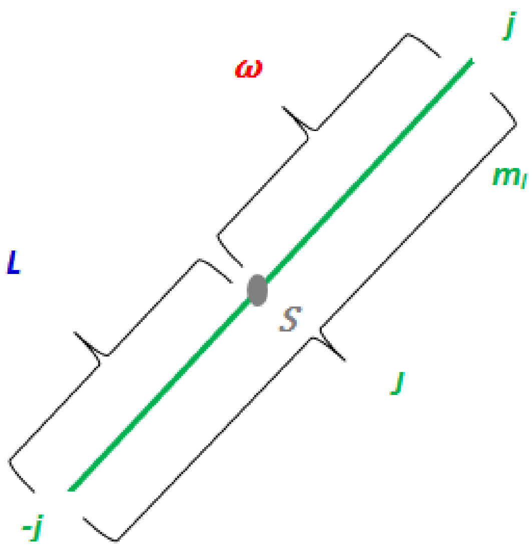

Figure 8 – Four states of total angular momentum in quantum superposition = hidden variables

These are the hidden variables of the state of total angular momentum or or m_l or magnetic quantum number that can also be perceived in the image of the hologram of a single photon in the same experiment by Polish physicists as follows:

[1] It is implicit in this formula of J = S + L that the state of angular velocity or ω exists as a pseudo vector, since there cannot be any state of orbital angular momentum without an associated state of angular velocity.

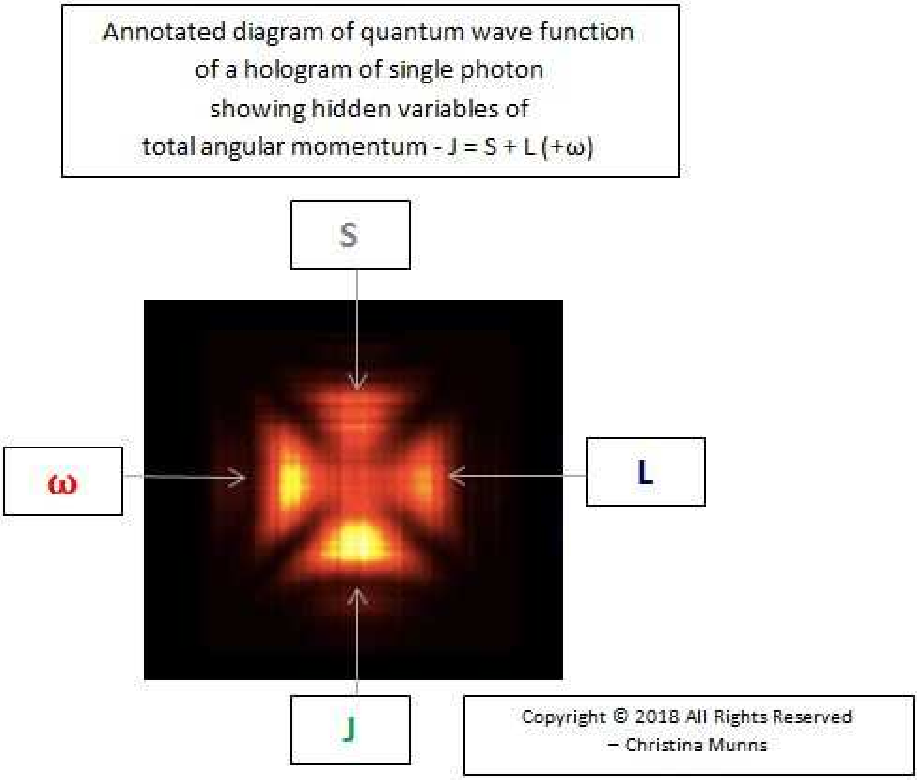

Figure 9 – Four possible total angular momentum states in the photon superposition

I propose that the red areas represent the state of total angular momentum and the yellow ones within the red areas express the energy level of that aspect of total angular momentum. I propose that the area at the base of the image, with the largest yellow zone shows the energy level of the state of angular velocity or *n* or ω and the top area having a zero yellow colour exhibits the state of spin which is a state with zero angular momentum, hence the lack of yellow colouration. Thus, it can be appreciated that both the states of spin and total angular momentum (or spin and magnetic quantum numbers) each contain four different parameters within themselves, which makes a total of eight hidden variables within the quantum superposition state.

I believe we must return to the pre-Schrödinger phase of the evolution of quantum physics and revive Einstein's concept of hidden variables that exist within the superposition state that represent the wave function itself. It is these eight hidden variables within the quantum superposition state that cause the wave to actually function as it does, (hence the name "wave function"). I believe that these eight hidden variables are directly related to the gluon octet of quantum chromodynamics. These eight hidden variables represent the "master plan" or informational sets that contain the data to create both a wave and a particle state upon observation. The state of spin and its magnetic monopole state in the superposition state gives rise to the magnetic dipole of the particle state upon observation. Similarly, the state of total angular momentum in the superposition state gives rise to the wave state or state of angular velocity upon observation. Here is a diagram showing this cross-product process:

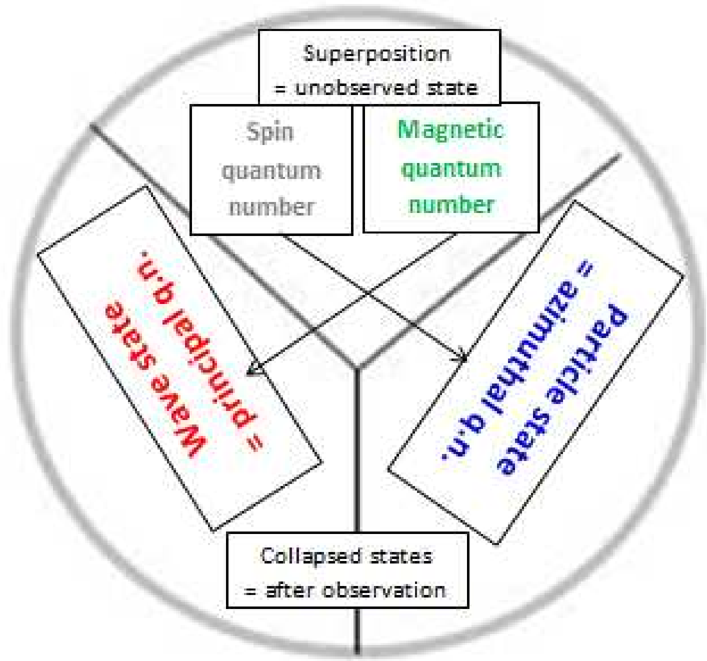

Figure 10 - The superposition state translates to wave and particle states

WAVE AND PARTICLE STATES

The Schrödinger wave equations describe wave states. They do not describe the particle state. This is the reason why they do not predict the reality of a single particle at a particular location in space and moment of time, because they are wave equations not particle equations. The definition of a wave in classical mechanics is: "*a disturbance in a medium that transports energy, but not matter*".[4] The definition of a wave in the classical state no different to the quantum state. Waves do not carry particles. They carry energy. They describe energy transportation. This is the function of the wave state – to transport energy.

It is important to appreciate the fact that when a particle moves, it creates a wave, but in itself the particle is not a wave, but is a discrete state from the wave state. The particle is not the wave, but its motion creates a wave. Just as a ship is not a wave, but the motion of the ship through water creates waves. It is the MOTION of the particle that creates the wave, not the particle actually containing the wave. It is true that particles are associated with waves, but they are not waves themselves, they are particles. Waves and particles are separate phenomena and exist in different special unitary symmetry groups. The motion of particles creates waves and waves create particle states in certain conditions. This is a similar dynamic to the reciprocal relationship between the states of the electric field and magnetic field in classical mechanics, as Maxwell's equations attest.

In real terms, the essence of the problem about the difference between the theory and reality of the subject of the probability wave, is that at the local level there is only one particle state not two. However, the mathematics of the Schrödinger equations gives us multiple choices in the probability wave theory but this theory is not borne out at the local level, since here there is only one particle, not two.

There is no doubt that the Schrödinger equations do indeed predict the evolution of the wave state under different conditions. The wave equations do predict the wave state with great mathematical elegance. However, it is important to appreciate the fact that the question of whether or not the particle states exists <u>within</u> the actual wave itself is a very salient point. I believe it is an unreal expectation that the particle state exists within the wave state, and this is one of the issues I am addressing in this paper. The Schrödinger equations do not predict the reality of the particle state. The particle and the wave states act independently of each other and since the particle state cannot exist in the superposition state, then the question of the probability wave does not arise. Hence, whilst the Schrödinger equations predict waves mathematically, they do not predict them in real terms, since the particle does not exist either in the superposition state nor <u>within</u> the actual wave itself. That is to say, it is not part of the structure of the wave state and it exists in a separate non-abelian symmetry group to the wave state.

GEOMETRY OF SUPERPOSITION & COLLAPSE

The superposition state is devoid of a wave state and also devoid of a particle state. It is an informational state that only ever exists on the abstract plane. Geometrically, we can consider the superposition state to be a circle. In this circle, the state of spin is its centre and the state of total angular momentum is its circumference. In this circle, that is the unobserved superposition state, the circle is complete. It has perfect U(1) symmetry and is unbroken. However, upon observation the circle is divided in half – i.e. it becomes split, such that there are two semi-circles. I propose that it is these two semi-circle states of the circumference of the circle that represent the wave state. Here is a diagram explaining the geometry of the emergence of the wave and particle state from the unobserved symmetry of a complete circle that is the superposition state:

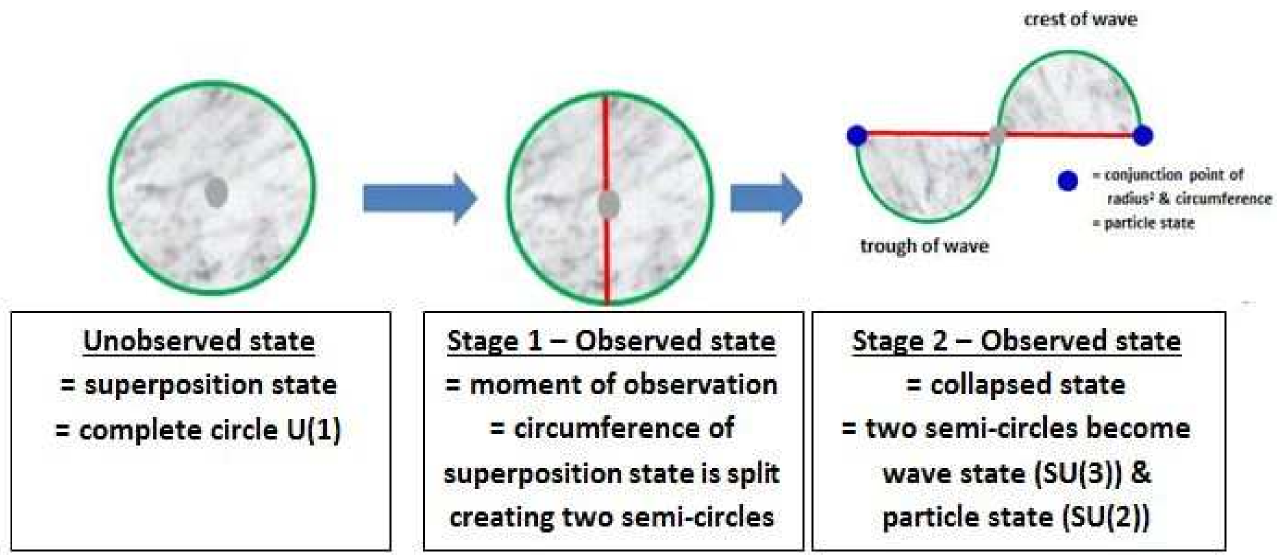

Figure 11 - Geometry of the emergence of the wave and particle state

SCHRÖDINGER'S CAT

There is a fundamental flaw in the Schrödinger equation which is being corrected in this paper and that is the fact that the superposition state cannot contain any particle state at all. This is the reason why the hotly debated issue of whether or not Schrödinger's cat is alive or dead is in fact a totally irrelevant question, since there can be no cat (i.e. no particle state) in existence in the superposition state to start with, because the superposition state operates on the abstract plane and thus cannot contain any particle state. It is only when the box is opened, (i.e. upon observation) does the state of the cat arise. Before the box is opened, there is only the information of the hidden variables of a cat (e.g. long fur/short fur; grey/black/white colour etc.). Before the box is opened, the cat does not actually exist, only the information of a cat and its possible variations in type exist. This is the reason why my response to the question of Schrödinger's cat is that "*it is neither dead nor alive, it doesn't even exist".*

The particle state belongs to the unitary symmetry group of SU(2), which is the unitary symmetry group of asymmetry. It is precisely the fact that the superposition state is in the unobserved state that renders its coherence and perfect symmetry of a circle – of the unitary symmetry group of U(1), which is represented by the circle group. If there were to be a particle in the unobserved superposition state then its intrinsic asymmetry of SU(2) would break the unitary symmetry of the circle of the unobserved state and there would be no superposition state.

CONCLUSION

Thus I propose that the real definition of a wave function (ψ) is indeed the quantum superposition state or unobserved state which contains the eight hidden variables of the states of intrinsic angular momentum and total angular momentum (or m_s and m_l). These states are also known as the spin quantum number and magnetic quantum number. This definition provides us with the much needed differentiation between the superposition and collapsed states and also removes any confusing implication of a particle state being present within the wave state (which it simply cannot since the wave and particle states are intrinsically discrete).

By transforming the definition of a wave function to explain that it resides only in the superposition state and contains no actual wave state or state of motion, we can thus leave the vexed issue of probability amplitude totally out of the equation (pun intended!). In fact we can totally divorce the association of the word wave function with the Schrödinger wave equation and let the ψ symbolise the probability amplitude within the context of the Schrödinger wave equation, since the reality of the phenomenon of probability amplitude does not actually exist.[2] In this way the concept of a wave function becomes a description of the superposition state with its eight hidden variables of spin and total angular momentum and is not associated at all with Schrödinger's wave equations.

[2] The subject of the existence or non-existence of the probability amplitude is a hotly debated issue. My interpretation of quantum theory is that the probability amplitude is not a valid quantum phenomenon, since every fermion must exist in its own quantum state and cannot co-exist with another quantum state, as the Fermi-Dirac statistics indicate. This nullifies the question of probability itself. Since the particle state cannot exist in the quantum superposition state, then there is no likelihood of a probabilistic position, since the particle state can only ever exist in the collapsed state, where there is no doubt as to its position and thus there is no need for the topic of probability to ever be raised.

The historical misperceptions about the wave function brought about by Edwin Schrödinger, Max Born and Paul Dirac have unfortunately been carried through to the present day interpretation of quantum mechanics with the current Copenhagen interpretation believing that the phenomenon of probability exists. It was Edwin Schrödinger's viewpoint that the wave and particle states in a quantum system somehow co-existed in the same space, despite the constraints of the laws of physics which explain that a wave state is an energy transport phenomenon and does not and cannot transport matter, and that the particle state is independent of the wave state. For example, when waves move through water, the water molecules do not travel <u>in</u> the wave but the wave moves <u>through</u> the water molecules. Another example is when a billiard ball is pushed into a line of billiard balls, all the balls stay stationary except the last ball which moves. The same dynamic applies at the quantum scale.

No doubt this paper will cause much consternation amongst the followers of the Copenhagen interpretation of quantum physics, since it implies an annulment of the perspective of probability in the quantum state which is one of its fundamental precepts. Nonetheless, these words must be written and historical misperceptions need to be corrected, in order that the real nature of the quantum superposition state is correctly defined. The aim of science is to understand how things operate in reality, so it is not advisable to invent a state such as the probability amplitude that does not actually exist in real terms. Edwin Schrödinger, Paul Dirac and Max Born based most of their work on the existence of a probability amplitude and did not believe in the reality of the hidden variables theory which this text elucidates. Each of these physicists believed in the existence of a particle state <u>before</u> observation (hence the vexed question of whether or not Schrödinger's cat is dead or alive) and did not comprehend the fact that the superposition state is purely informational and therefore contains neither a wave nor a particle state. This false assumption has led to a series of further complicated misperceptions including the many worlds theory and multiple universes. The web of misunderstanding created by the belief in a probability wave has itself led to more and more complicated understandings of the quantum state. Nature is simple. Quantum mechanics is also. It is simple in its dynamics and form. Quantum physics must return to its simplistic roots in order to advance.

For those physicists who are brave enough to swim upstream against the strong undertow of the Copenhagen interpretation to reach the pure, clear waters of the reality of hidden variables, will find a far more fertile soil in which to further their research into the subtleties of the quantum state. For it has been admitted by eminent physicists[5] that the Schrödinger equation does not predict the reality of a single particle state existing at a local level, but rather its mathematical elegance predicts a state where two particles exist in different locations simultaneously, which has never actually been observed and will never be observed, since it is a false notion that two particles can exist in two discrete spaces simultaneously.

It is my solemn and heartfelt wish that this paper will be given serious consideration and review in scientific academic and research circles. The unanswered question of the true definition of a wave function and the lack of clarity regarding the existence of either the probability amplitude or hidden variable states needs to be settled once and for all, in order that previous inconsistencies can be ironed out and the necessary corrections made. These corrections include the realistic definition of the wave function as being the information of the quantum superposition state of the states of spin and total angular momentum. These two states hold within themselves the hidden variables pertaining to the formation of the wave and particle states that occurs upon observation and subsequent collapse of the superposition state. It is the information of these hidden variables that determine the type and properties of the kinetic wave and inertial particle states. As Albert Einstein so famously said "God does not play dice". This paper finally gives credence to this statement and explains why the perspective of indeterminism within the quantum state is incorrect. This deterministic theory of hidden variables of both m_s and m_l of the superposition state (a.k.a. wave function) presented herein, permits the creation of the wave and particle states in a way that mirrors the quantum state observed in actual quantum research. The fact that for over eighty years – no probability wave has ever been discovered gives further leverage to the reality of quantum determinism discussed herein. This dilemma of whether hidden variables or a probability amplitude exist in the superposition state, is at the heart of the schism of thought in quantum physics. In order to move quantum research forward, we need to gain a unified perspective of what exactly the superposition state is comprised in order to move forward

The material universe operates under the auspices of the three unitary symmetry groups of the Standard Model of physics. These three unitary matrices underpin all dynamics and particle states. There is an implicate order to the cosmos[6]. The cosmos does indeed contain randomness, chaos and entropy but these states themselves emerge from a highly ordered state of coherent symmetry. Just as information theory arises from the states of nought and one, so too does quantum field theory emerge from the states of m_s and m_l. It is from this informational dual space of the quantum superposition in the unobserved state, that the discrete states of the wave and particle emerge upon observation. Order precedes disorder and determinism is embedded in the superposition state which is the wave function itself.

I rest my case.
Christina Munns
10/05/2018 11:08 PM

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[1] http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/wvfun.html
[2] Chrapkiewicz, Radosław; Jachura, Michał; Banaszek, Konrad; Wasilewsk, Wojciech – Paper: "*Hologram of a Single Photon*", Faculty of Physics, University of Warsaw - https://arxiv.org/pdf/1509.02890.pdf
[3] Munns, Christina, *Principia Unitas – Vol. II – The Quantum Mechanism* – ISBN 978-0-9807766-8-3
[4] http://www.physicsclassroom.com/class/waves/Lesson-1/What-is-a-Wave
[5] Greene, Brian, World Science Festival video - *Quantum Reality: Space, Time, and Entanglement* https://www.youtube.com/watch?v=BFrBr8oUVXU
[6] Bohm, David, *Wholeness and the Implicate Order*, Routledge Classics, 1980, ISBN 978-0415289795