THE COLLAPSE OF THE WAVE FUNCTION DESCRIBED AS A GRAVITATIONAL PHENOMENON

BY

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INTRODUCTION

It remains the greatest challenge in Physics to unify the Gravitational force and General Relativity with Quantum theory thereby going some way to describing the so-called Theory of Everything.

I must say at the outset of this paper that I am not convinced that this is necessarily the route to the Theory of Everything. I believe that the Theory can be far more satisfactorily approached by means of writing the values of all the physical constants in terms of each other as described in my paper 'The Large Scale Structure of the Universe.' In that paper, I was able to achieve that result by utilising the Einstein's Lambda factor to describe the expansion of the universe and subsequently to derive an accurate value for Hubble's constant.

Nevertheless it is important to attempt to explain the phenomenon of the State Vector Reduction or Collapse of the Wave Function in any attempt to derive the Theory and to describe the structure of the universe. Accordingly I intend to devote this paper to exploring the effect of Gravitation on the State Vector Reduction, that is to say to describe the effect of Gravitation on the transition of physical states from the microscopic quantum state to the classical macroscopic state.

In the preparation of this paper I have yet again, relied heavily on the works of Penrose and Moriyasu.

Let us begin by reviewing some pertinent facts about the quantum state by touching briefly on the work of John Bell. In 1964 Bell published his famous 'Inequality Theorem' which clearly showed that quantum theory defies common sense. A version of the theorem can be used to describe the Einstein, Podolsky, Rosen thought experiment (the E.P.R. experiment) as outlined by Andrew Whittaker in Physics World in 1998 as follows.

If we take a two wing quantum apparatus, the spin component of a quantum particle can be measured in one wing in direction *'a'* and in the other wing in direction *'b'*. The probability of both results being the same and both results being different can be described by defining *E(a,b)* as the difference between two probabilities i.e :-

E(a,b)≡(up,up; a,b) + P(down,down; a,b) - (up,down; a,b) - P(down,up; a,b).

If four experiments are carried out with directions *a* and *a'* in the first wing and directions *b* and *b'* in the second wing it can be shown that :-

$X(a,b,a',b') \equiv \{ E(a,b) + E(a'b) + E(a'b) - E(a'b') \} \leq 2$

This is the famous Bell's inequality which appears to show that both quantities *'a'* and *'b'* have 'exchanged information' at the outset of the experiment as to what the results (i.e. direction of spin) will be on examination of the individual spin states.

However, Bell's inequality is violated by quantum theory because, in quantum theory *E(a,b) = - cos (a-b).*

For example if $a=0^0$, $a'=90^0$, $b=45^0$, $b'=-45^0$ then;-

$X(a,b, a'b') = 2\sqrt{2}$

which is a clear violation of Bell's inequality.

In 1981 these results were conclusively proved through an experiment carried out by Alain Aspect and his colleagues which showed that entangled quantum particles do indeed behave exactly as predicted by quantum theory. That is to say, the spin state of one of the entangled states *instantaneously* fixes the spin state of the other regardless of the distance between the two events.

This experiment was designed, in part at least, to verify that there are absolutely no pre-set conditions which can produce quantum mechanical probabilities in the classical world. This remarkable fact totally rules out so-called local realistic models. In other words no 'message' can travel from the first measured particle to the second particle indicating the intended direction of measurement.

In addition to the direction of measurement, the two armed apparatus can be used to define the direction of the flow of time in an experiment decscribed by Roger Penrose. This experiment demonstrates conclusively that it is the act of observation which introduces time a-symmetry into the classical world from the time symmetric quantum world.

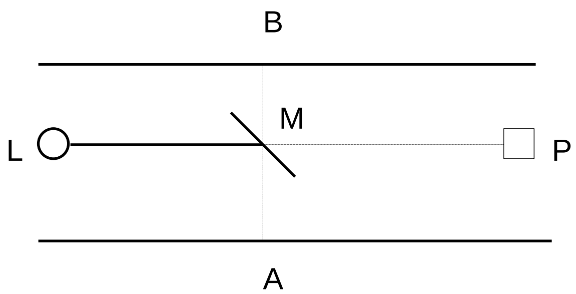

FIG.1

The experiment shown above illustrates the time irreversibility of a simple quantum experiment. Let us see why. Here we have a lamp L and a photocell P. Between L and P there is a half silvered mirror at an angle of 45 degrees to the line LP. A photon is emitted at L, the photon's wave function strikes the mirror and the wave function splits into two. There is an amplitude of $1/\sqrt{2}$ for the reflected part of the wave and an amplitude of *$1/\sqrt{2}$* for the transmitted part of the wave and the probability given by the square of the moduli of these amplitudes i.e. $(1/\sqrt{2})^2 = 1/2$ defines the alternatives. Therefore we can answer the question 'Given that L registers, what is the probability that P registers? and the answer we get is 'one half'. However, the time reverse of this question is 'Given that P registers, what is the probability that L registers' and the answer to this question is not one half---it is one! Thus in the case of our time reversed question, the quantum mechanical calculation gives completely the wrong answer. In other words the making of an observation is associated with an irreversible process and it is this irreversibility which can be said to produce three effects. These are (1) it provides us with the arrow of time, (2) it shows that it is not possible to make a macroscopic observation which is time reversed (i.e we are not able to view events running backwards in time) and most importantly, (3) the macroscopic world will only admit solutions which are time a-symmetric in the forward direction. More properly, the eigenstate which is detected when the wave function collapses can only be a state which is moving forward in time. This being the case, we must conclude that there exists a macroscopic world into which the wave function can collapse.

Of course, the foregoing is in complete contrast to quantum theory which is totally time symmetric. This is because the Wave Equation gives a completely deterministic solution to the wave function once the wave function is specified at any one time and this appears to establish that quantum theory is totally time symmetric, that is to say there is no preferred direction of time. Clearly this is not our experience of the world. The reason for this, is that the Wave Equation is largely mis-understood.

It is very often considered, even by many well established physicists that Quantum theory is a probabalistic theory. In fact this is not the case, and the reverse is true, the theory is mathematically precise and probability free and what is more, completly deterministic. It is however entirely reversible in time.

So why do some people consider the theory to be probabalistic in it's nature? It is because, when the wave function collapses, the decription of the system changes from the entangled quantum level state to a state where the system occupies one or another of the classical level alternatives open to it. However, and here is the difference, whatever state the system now adopts, it adopts a state which is forward moving in time and is now *non-time reversible.* Thus it is evident that at this point a causal relationship between space-time events has occurred. Now the only physical phenomenon which can influence the causal relationships between space-time events is Gravitation, but at the quantum level the gravitational force is not strong enough to have induced this effect. Clearly something is wrong and one would assume that the gravitational causal relationship must be incorrect. Fortunately it is not incorrect, but I shall return to this subject later.

The time symmetry of quantum mechanics refers only to that part of the wave equation where the wave function 'Ψ' is governed by the deterministic Schroedinger equation evolution and which is expressed in the form of probability amplitudes governed by complex numbers. For a quantum event to become manifest in the macroscopic world in which we all live, the complex numbers are replaced by the moduli of the complex amplitudes of the wave function which results in the admission of only one of the many available quantum states surviving into the macroscopic world. In other words, at this point the collapse of the wave function manifests itself and becomes a description of the world as we know it and it is here where the direction of time manifests itself and takes on the its forward direction.

Finally, there is one other well known quantum experiment that we should note before continuing with our search for an answer to the questions posed by the collapse of the wave function and that is the Double Slit experiment. This experiment clearly shows that a particle only comes into existence at the superposition of two wave functions and then only when those two wave functions are in phase. A particle does *not* register when both wave functions are out of phase with each other.

Therefore it follows that any detection of any quantum particle and the determination of its state can only take place when two wave functions are in phase with each other. Thus when we make a detection of say a spin up condition, that spin up wave function must be in phase with some other spin up wave function. Likewise its spin down partner must be in phase with some other spin down wave function in order to be detected. The wave function of these two states must be in phase with the wave function of the macroscopic universe or more particularly the observer's wave function must be in phase with the observed wave function.

The foregoing describes the three principal experiments which give rise to the time symmetric quantum universe and the time a-symmetric macroscopic universe of everyday experience. Clearly there is a dichotomy between the two world views and we are forced to ask some very fundamental and probing questions about both the nature of time and of the validity of the laws of Physics as they are generally accepted. Indeed we can make the observation that both world views cannot be correct, either time has a direction or it does not. In fact we can go further and say that if time does not have a direction then it cannot exist as a separate parameter in the laws of Physics for the simple reason that time reversed events cause such non-sensical results as, for example, a persons death before his coception. Clearly something is wrong and I believe we are forced to conclude that there exists an objective world separate from, and independent of, the quantum world and that there exists an objective reality outside of quantum theory.

If it is indeed the case that an objective deterministic universe exists and that this universe will only admit those quantum solutions which are a-symmetric in time, then we must set about creating a description of this universe and describing the method by which the collapsing wave function is admitted into it.

It seems to me that the indeterminacy of the quantum state has been resolved by the intervention of the macroscopic world. This is not the same as saying that the macroscopic world is not defined until a measurement is made but rather I am saying that it is the macroscopic world which defines the outcome of the observation. The outcome of the observation in Penrose's experiment is twofold. Firstly the quantum state is one which evolves into a state that is moving forward in time---the other solution of time reversibility is not allowed. Secondly the superposition of the spin state of the photon is resolved, and it is resolved by measuring the spin state at points A and P. That is to say that a measurement of spin up at point P would resolve itself into a measurement of spin down at point A.

Now if the mirror was an ordinary reflector (i.e. not a half silvered mirror) the photon would certainly register at A. It is the half silvered mirror which has split the wave function from probability 1 into two amplitudes of $1/\sqrt{2}$ each. In this sense then it is the mirror which becomes an operator and has the effect of squaring the moduli and the mirror is the point in space at which the wave function splits. Therefore at any point along the lines MP or MA a measurement can be made which will resolve the state of spin of either of the $1/2$ spin states. Now let us imagine that A and P are exactly equidistant from M and that the results are reflected back to a detector at M. In this way neither one of the spin states will have been established before the other (at least not as far as an observer at M would say). What will be the outcome of this experiment?

The answer is that we do not know for certain until the experiment is performed. The only certain answer is that one arm will be in a spin up state and one will be in a spin down state. Thus as far as an observer at M is concerned there is no spooky 'action at a distance'. Action at a distance only manifests itself when A tries to measure the spin state of B. The resolution of one spin state defines the other. Therefore we are led to the conclusion that the wave description as detected by an observer at M is not the same as the wave description detected by observers at L or P. In other words, a single wave function is not a complete description of quantum theory. Two wave functions are required, one for the originator of the system and one for the observer of the system.

Firstly we should note that action at a distance is not an instantaneous effect. The outcome of the second measurement is not instantaneous, it can only be be observed after the first observation has been made. There is therefore a time lapse between the two observations --- the one follows the other. Thus it follows that the total quantum state is the sum of three, not two observations. The spin state recorded by an observer at point M is :-

$|E\rangle = |\uparrow\rangle + |\downarrow\rangle = 1$

The point of this is that there is a preferred reference frame which is that of the observer at point M. Any observation at points P or A occurs after the decision about quantum up-ness or down-ness has been made.

There are three possible answers to this phenomenon. The first is that information travels instantaneously between A and B, i.e. at a speed faster than light. The second is that propagation backwards in time is involved where both reference frames are identical. Clearly both these concepts violate Relativity theory. The third is that Quantum theory is incorrect.

None of these concepts taken in isolation is satisfactory. Both Relativity theory and Quantum theory have been hugely successful and, as far as time reversal is concerned, the violation of causality is not a serious consideration.

So how do we attempt to solve the problem of quantum entanglement and the Collapse of the Wave function, especially if awkward people like myself are not prepared to accept that there is no solution to the problem? Let us try and let us begin by returning to the Bell theorem and examine exactly how it is that the indeterminacy of the quantum state arises.

Because quantum probabilities are given by the squared modulus of two complex numbers *'w'* and *'z'*, we do not get the sum of their squared moduli separately but simultaneously and the result of that sum is:- $|w+z|^2 = |w|^2 + |x|^2 + 2|w||z|\cos\theta$. The term $2|w||z|\cos\theta$ defines the probability of the quantum state at *z + w.* The value of *cos*θ can range between *-1* and *1,* thus when $\theta = 0^0$ then *cos* θ = *1* and the alternatives re-inforce one another so that the total probability is greater that the sum of the individual probabilities (constructive interference). When $\theta = 180^0$ then *cos* θ = *-1* and the total probability is less that the sum of the individual probabilitiesresulting in destructive interference. It is this phenomenon which lies behind the result of Bell's theorem.

I believe that these results are the product of the geometry of space-time. To illustrate this point more clearly, the spatial probability of an entangled quantum state is more clearly defined by the Argand diagram below. It should be noted that the structure of this experiment is exactly of the form of a real two armed experiment taking place in the laboratory reference frame. In other words, any experimental apparatus designed to test the outcome of a two armed experiment is the 'solid form' of an Argand diagram. That is to say the +Re axis of the apparatus resolves the alternative state in the -Re axis of the experiment.

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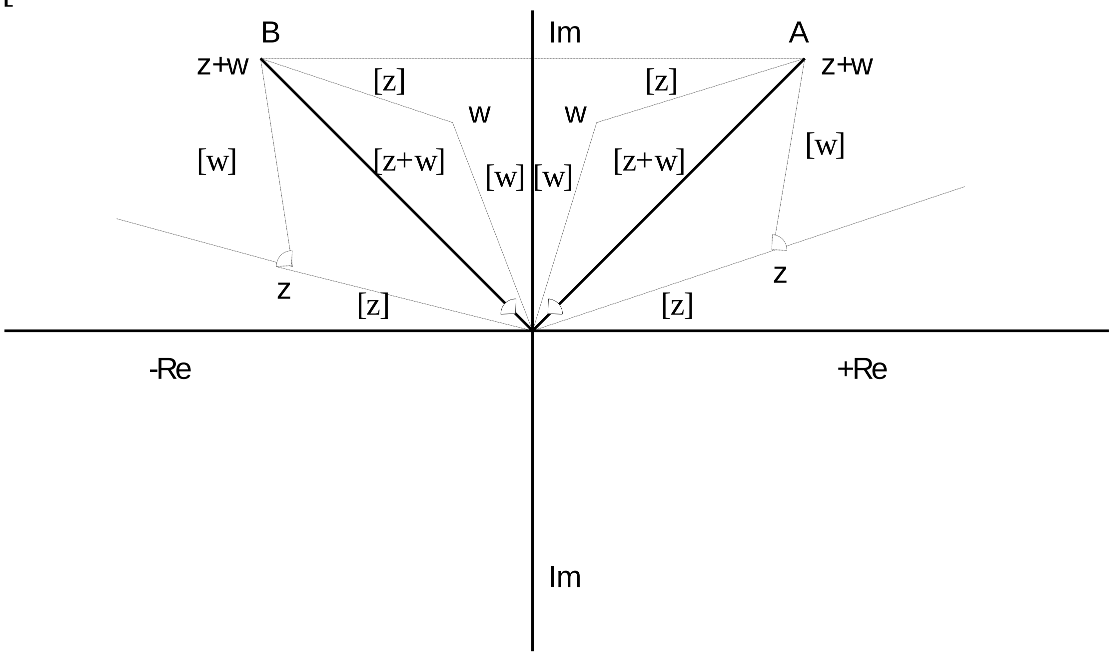

FIG.2

Generally, the quantum state defined at the point *'z'* on an Argand diagram is the squared distance $|z|^2$ from the origin 'O' and becomes an actual probability when magnified to the classical level, in other words the the quantum state at $z + w$ is the squared modulus of $z + w$ i.e. $|z + w|^2$. Going on from here it follows that the squared modulus in the negative (-Re) of the experiment is equal but opposite to the squared modulus in the positive arm (+Re), thus both possibilities are raised to realities by the intervention of the potential at 'O', the difference being that they are each of opposite parity. Thus it is the existence of the potential which resolves the quantum entanglement. Classically it is considered to be the act of observation which resolves the quantum state. But this is not a precise description, in fact it is the existence of a potential which decides the resolution of the state of entanglement.

It is most important that we understand that the quantum state defined at the points A and B in a two armed quantum experiment is the squared modulus of the sum of two complex numbers i.e $|z + w|^2$ and that the quantum state at A and B is defined by a distance in space-time OA or OB and that both states are real numbers but of opposite sign as demonstrated in FIG. 2 above. Furthermore it is the existence of the potential at O which has resolved the entangled state into it's component parts and it is the existence of a further potential at either A or B which provides information to the observer about which precise state, up or down that he is examining.

Thus it is the existence of potentials which resolve quantum probabilities into classical actualities.

Furthermore, in the diagram the line AB represent a distance in space-time between an observer at A say who defines a quantum state and the instantaneous resolution of the quantum state at B no matter how far distant B may be from A. Now if the observation at A was produced by the intervention of a potential at A, then it is reasonable to conclude that the observation at B has been produced by a potential of some kind at position B. But what kind of potential?

In his book 'Shadows of the Mind', Roger Penrose points out correctly, that the gravitational force between the electron and the proton in a hydrogen atom is smaller than the electric force between those particles by a factor of some $\frac{1}{2.85x10^{40}}$. In other words, gravity is not noticed by either particle at inter orbital distances and thus *can have no effect* and can be disregarded as having any influence on the state vector reduction. Clearly there is no point in continuing down this blind alley in order to explain the collapse of the wave function.

To sum up then, the collapse of the wave function is at once (1) a causal gravitational effect but the gravitational force involved is too weak to effect the cause by a factor of billions and (2) a non causal, non physical effect which travels faster than light. Both of these descriptions are outside the laws of physics as presently understood, so where do we look for an answer? We could try Tarot Cards or Tea Leaves, but we would probably do better to look for new laws of Physics applicable to both GravitationalTheory and Quantum Theory.

Earlier, I pointed out that the only physical phenomenon which can can influence the causal relationships between space-time events is Gravitation, I then went on to point out that this notion may be incorrect. In fact the theory is correct, what is incorrect is that physicists have been looking at the wrong gravitational field. They have been looking at universally attractive gravitation (gravitation is always assumed, wrongly, to be purely an attractive force) where the tensor Weyl $\rightarrow \infty$ whereas the the field to examine is that where Weyl = 0 and the tensor Ricci = ∞ , that is to say the repulsive gravitational field generated by the Cosmological Constant Lambda (Δ).

As described in my paper 'The Large Scale Structure of the Universe' the Lambda factor is the manifestation of the repulsive gravitational field responsible for the expansion of the universe and it provides a description of large scale structures,such as galaxies falling through a repulsive gravitational field.

How does this theory relate to the condition of quantum entanglement. The answer is surprisingly simple.

One of the most puzzling ideas of quantum theory is that a quantum measurement of a system made at one place can *instantaeously* define the quantum state of a system in another part of the universe which may be thousands of light years distant. One explanation put forward for disentanglement is that of time reversal in the case of the far distant particle. This is not quite correct. What is happening in the Lambda universe is that the far distant particle lies in a stonger gravitational field--by virtue of it's distance--than the particle 'A' which has been measured in the laboratory since, in a repulsive gravitational system, the strength if the gravitational field *increases* with distance from the measured particle 'B'.

Recall now that both the Cosmological principle and the Cosmological costant allow any point in space-time to be defined as the inertial reference frame at 'O'. Therefore events at 'b' occur more slowly than events at 'a' due to the slowing down of time in a fraviatational field and it is this phenomenon which accounts for the manifestation of the wave function at 'b'. To all appearances the event at'b' has taken place after the event at 'a'. The event has taken place more slowly because time slows down as1/g where 'g' is the gravitational field strength at any point in space distant from 'O'

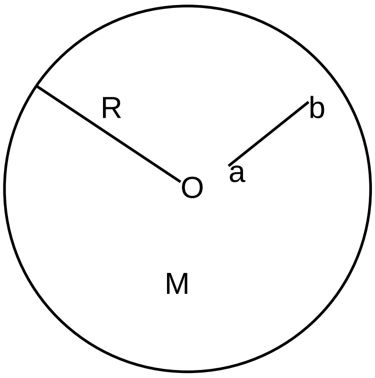

FIG. 3

Why is this? We can state that the gravitational field inside the mass M is :- $\bar{g} = \frac{MR}{4\pi G R_0^3} \hat{R}$. Fig 3 above illustrates schematically a spherically uniform volume mass.

Since the field is also radial we can find the potential difference by integrating 'g' along a radial path i.e:-

$$V_b - V_a = -\int_{r_a}^{r_b} \frac{Mr}{4\pi G R_0^3}\,\hat{r}\cdot dr\,\hat{r}$$

$$= -\frac{M}{4\pi G R_0^3}\int_{r_a}^{r_b} r\,dr$$

$$= \frac{M}{4\pi G R_0^3}\left[-\frac{r^2}{2}\right]_{r_a}^{r_b}$$

$$= \frac{M}{8\pi G R_0^3}\left(r_a^2 - r_b^2\right) \qquad EQU.(1).$$

To find the potential at any point inside the mass distribution we can say that the potential V_0 evaluated at any point on the surface of the sphere is given by :-

$$V_0 = \frac{M}{4\pi G R_0} \qquad EQU.(2).$$

By using Equ. (1) we can let r_b correspond to a point inside the sphere $(r_b = R,\ V_b = V(R))$ and let r_a correspond to a point on the surface of the sphere $(r_a = R_0,\ V_a = V_0)$ .This gives :-

$$V(R) - V(0) = \frac{M}{4\pi G R_0^3}\left(R_0^2 - R^2\right) \qquad (R \le R_0).$$

Substituting from Equ.2 into this expression and solving for *V(R)* we find :- $V(R) = \frac{M}{8\pi G R_0^3}\left(3R_0^3 - R^2\right) \qquad (R \le R_0)$

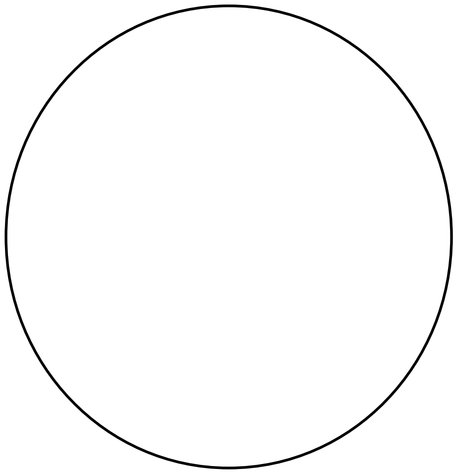

FIG. 4

Fig. 4 above illustrates schematically how the potential varies within the sphere. An equipotential surface is a surface on which the potential is constant or equal. The gravitational field lines point from higher to lower potentials . from Equ.2 we note that the potential is highest when *R* is smallest and decreases with increasing *R*. This means that a particle is moving from a higher to a lower potential.

Now the gravitational potential at a point in a gravitational field is defined as the potential energy per unit mass at the point.

designating the gravitational potential by *V* and the potential energy of amass *'m'* by E_p we have $V = \frac{E_p}{m}$ *or* $E_p = mV$. If a particle moves from one point r to another point *R* then the work done by the gravitational field is :- $W = E_p(r) - E_p(R) = m(V_r - V_R)$ so the difference in potential between point *r* and *R* is :- $V(r) - V(R) = \frac{W}{m}$ *or* $\Delta V = -\frac{W}{m}$.

In a gravitational field *W* = *mgr* therefore $W = \frac{1}{2}mv^2$ since $gr = \frac{v^2}{2}$. Noting that $w = \Delta E$ (because $W = E_r - E_r = m(V_r - V_R)$) we can state that $\frac{1}{2}mv^2 = V_r - V_R$.

In order to define the nature of the potential as a quantised gravitational field let us first review the aspect of the wave equation which defines the nature of quantisation and I will begin with the cocept of symmetry.

The existence of matter waves of opposite parity illustrates a condition of broken symmetry. The following describes how it is that broken symmetry of the wave function occurs.This approach may seem to be a little unconventional but it will lead us to the highly prized goals of the quantisation of gravity and to an explanation of the state vector reduction or the collapse of the wave function.

Perhaps the most defining characteristic of the collapse of the wave function is the broken symmetry of the in the time forward direction and I will now describe how it is that this broken symmetry occurs.

Schroedinger's wave equation can be written as :-

(3) $$-\frac{\hbar^2}{2m}\nabla^2\Psi - V\Psi = i\hbar\frac{\partial\Psi}{dt}$$

where in cartesian co-ordinates $\psi = \psi(x,y,z)$ = the wave function of the particle and :-

(4) $$\nabla^2\Psi = \frac{\partial^2\Psi}{\partial x^2} + \frac{\partial^2\Psi}{\partial y^2} + \frac{\partial^2\Psi}{\partial z^2}$$

and $V = v(x,y,z,t)$ = the potential energy of the particle and $i = \sqrt{-1}$.

If V is independant of time, we can separate space and time variables by setting $\psi = \psi(x,y,z)\ \tau(t)$.

Substituting into (3) and dividing by $\psi\tau$ we find :-

(5) $$-\frac{\hbar^2}{2m}\frac{\nabla^2\Psi}{\Psi} + V = \frac{i\hbar}{\tau}\frac{d\tau}{dt} \ .$$

From the R.H.S. of (5) we then obtain $\tau = Ce^{-i(E/\hbar)t}$ and the l.h.s. of (5) can be written as :-

(6) $$-\frac{\hbar}{2m}\nabla^2\Psi + V\Psi = E\Psi \ .$$

Now from inspection of Equations (4) and (5) we can see that the substitution $x \rightarrow -x$, $y \rightarrow -y$, $z \rightarrow -z$ (abbreviated by $\bar{r} \rightarrow -\bar{r}$ below) will not alter the solution of Schroedinger's equation if :-

(7) $V(-x, -y, -z) = V(x,y,z)$

The substitution $\bar{r} \rightarrow -\bar{r}$ is called the parity operation and a potential which has the property expressed in Equ.(7) is said to be conservative under the perity operation, or to conserve parity.

For a potential of the form in Equ.(7) the wave function ψ in Equ.(6) must have the property ;-

(8) $\Psi(-\bar{r}) = +\Psi(\bar{r})$

or

(9) $\Psi(-\bar{r}) = -\Psi(\bar{r})$.

The wave function (8) is said to possess even parity, the other wave function(9) is said to possess odd parity. Further if any system, however complicated, has a wave function of a given type it can never change over to the wave function of the other type so long as all the interactions in the system remain parity conserving. What has this to do with the manifest a-symmetry in the universe which we see in the direction of the arrow of time. We can explain this a-symmetry by returning to the particle in a box scenario.

The requirement that the wave function be continuous leads to the boundary conditions :- $\Psi(x) = 0$ at $x = 0$ and $x = L$. With $\Psi = 0$ the Schroedinger wave equation becomes $\frac{\partial^2\Psi}{\partial x^2} = k^2\Psi = 0$ where $k = \frac{\sqrt{2mE}}{\hbar}$.

The solution to this equation is $\Psi(x) = A \sin (kx + \varnothing)$. From the boundary condition $\psi = 0$ *at* $x = 0$ *it follows that* $\varnothing = kl$. From the condition that $\Psi = 0$ at $x = l$ we find $(kl) = 0$ which means that $kl = n\pi$ where n is an integer. Thus we have a wave function which satisfies the boundary conditions in the form of a standing wave i.e:-

$\Psi(x) = A\sin\left(\frac{n\pi x}{L}\right) n=1,2,3......$. Since $k = \frac{2\pi}{\lambda} = \frac{n\pi}{l}$ the wave length of the n th. standing wave is $\lambda = \frac{2L}{n}$. When this is equated to De Broglie's equation $\lambda = \frac{\hbar}{mv}$ we find that $v = \frac{n\hbar}{2ml}$. Since n takes on only integer values, the velocity is quantised. The particle's energy, which is purely kinetic, is $\frac{1}{2}mv^2$ and is thus also quantised :-

$E_n = \frac{n^2\hbar^2}{8mL^2} \quad n = 1, 2, 3........$. Thus the energy of any particle moving within fixed boundary conditions is, therefore quantised. The field itself can be descibed by imagining each potential field surface (or field line) to be quantised in terms of $\hbar$ and an integer where the integer 1 occurs at the surface of the strongest field. Thus we can say the the particle is moving from a position of high gravitational potential to a position of low gravitational potential.

The field surfaces (or the equipotential surfaces) are arranged in a manner which exhibits spatial periodicity. This periodicity has an effect on the particle moving through the field.

The periodicity is built into the potential for which we require that

$V(x = a) = V(x)$ since the kinetic term $-\frac{\hbar^2}{2m}\frac{d^2}{dx^2}$ is unaltered by the change $x \rightarrow x + a$ the whole Hamiltonian is invariant under displacements by *'a'*.

For the case of zero potential when the solution corresponding to a given energy $E = \frac{\hbar^2 k^2}{2m}$ is $\Psi(x) = e^{ikx}$ the displacement yields $\Psi(x+a) = e^{ik(x+a)} = e^{ika}\Psi(x)$, that is the original solution multiplied by a phase factor so that $|\Psi(x+a)|^2 = |\Psi(x)|^2$. The observables will therefore be the same at x as at $x + a$, thus we cannot tell whether we are at x or $x + a$. It sould be noted here that $\Psi(x)$ and $\Psi(x + a)$ differ only by a phase factor which need not necessarily be of the form e^{ika} .

We recall again the Cosmological principle which permits us to use the concept that any point in the universe can be used as the inertial reference frame of the system. With this in mind we now take the somewhat unconventional step of treating space as we would treat a particle in a closed cubical box. Now if the universe was indeed a closed cubical box the parity of the wave function i.e :- $\Psi = \left(\frac{2}{L}\right) \sin\frac{n_x \pi x}{L} \; \frac{\sin n_y \pi y}{L} \; \frac{\sin n_z \pi z}{L}$ is not a definate quantity (since $\Psi = 0$ outside the box we can see that $\Psi(x) \neq \psi(-x)$ for $0 \langle [x] \langle L$).

This occurs because the location of the box with respect to the origin causes V <u>not</u> to have the property as in (7) because the origin starts at the edge of the box. BUT if the origin is moved to the centre of the box as permitted by our universal model because the cosmological principle allows any point to be considered as the Observer's inertial reference frame, then *V* will have the property as in (7) and the wave function then has the form :-

$$\Psi = \left(\frac{2}{L}\right) \sin\left(\frac{n_x \pi x'}{L} + \frac{n_x \pi}{2}\right) \sin\left(\frac{n_y \pi y'}{L} + \frac{n_y \pi}{2}\right) \sin\left(\frac{n_z \pi z'}{L} + \frac{n_z \pi}{2}\right)$$

where *x',y',z'* are the coordinates measured with respect to the centre of the box $\left(x' = x - \frac{L}{2}\ etc.\right)$. For any odd value of n_x the first sine function becomes $\pm \cos\frac{n_x \pi x'}{L}$ which has even parity and for any even value of n_x the first sine function becomes $\pm \sin\frac{n_x \pi x'}{L}$. Hence the overall parity of the wave function is even or odd depending on whether or not $(n_x + n_y + n_z)$ is an odd or an even integer. (Here we note that $e^{is} = \cos s + i \sin s$ and $x = A \sin k_x x$ and $k_x = \frac{n_x \pi}{L}$ with n_x equal to an integer.)

This then is the description of a quantised gravitational field because it describes a matter wave moving from an area of high gravitational potential to an area of low gravitational potential.

More particularly the wave equation can be written in gravitational terms and here the potential *V(x)* can be said to represent the high potential at the point O in FIG.4, so we can write :-

$-\frac{\hbar^2}{2m}\frac{d^2\Psi}{dx^2} + \left(mV(x) - mgx\right)\Psi = E\Psi$ where *mV(x)* = energy due to the motion of the particle and *mgx = energy due to the gravitational field.*

sThus, as already stated, since time slows down in a gravitational field, an event at 'B' takes place later than an event at 'A'. Indeed time slows down as *1/g* where $g = \frac{M_0 R}{4\pi G R_0^3}$ $R \leq R_0$. Furthermore, since the gravitational field is quantised it follows that time itself is quantised in terms of $n\hbar$.

Looking at the role of the 'observers' at A and B, these observers, in effect, act as potentials in spacetime and have exactly the same effect as any potential such as the endpoint in a standing wave. Essentially what is happening is that the potential is generating a rotation in internal symmetry space. To generate this rotation we define the potential in the language of a rotation group. A three dimensional rotation *R(θ)* of a wave function is written as :-

$$R(\theta)\Psi = e^{-i\theta L}\Psi$$

where θ is the angle of rotation and L is the angular momentum operator. This rotation is comparable with the phase change of a wave function after a gauge transformation. The rotation has the same mathematical form as the phase factor of the wave function. But this does not mean that the potential itself is is the rotation operator like *R(*θ*)*. The most general form of the Yang Mills potential to which 'barrier potential' is exactly similar is a linear combination of the angular momentum operators:-

(10) $$A_\mu = \sum_i A_\mu^i(x) L_i$$

where the coefficients $A_\mu^i(x)$ depend on the space-time position. This relation indicates that the potential is not a rotation but is the generator of a rotation.

The relation in Equ.(10) displays the dual role is both a field in spacetime and an operator in the isotopic spin space. The potential then acts like a raising operator and can, for example, transform a down state into an up state because the phase of a wave function can be descibed as a new local variable. Instead of a change of scale a gauge transformation can be reinterpreted as a change in the phase of a wave function i.e:-

(11) $\Psi \rightarrow \Psi^{ie\lambda}$

and the familiar gauge transformation for the potential A_μ becomes :-

(12) $A_\mu \rightarrow A_\mu - \delta_\mu \lambda$

Thus the wave equation is left unchanged after the two transformations in Equs. (11) and (12) are applied. (Note: equations 10-17 inclusive are principally derived from material by k. Moryasu-'An Elementary primer for gauge theory'- World scientific publishing 1983)

In conclusion I have shown how the collapse of the wave function in a two armed quantum experiment is induced to take on the form of two states of opposite parity. This condition is the result of action on the wave function by a repulsive gravitational field defined by the Cosmological constant of thr lambda factor

END