

## SCIENTIFIC GROUNDS FOR PRECOGNITION

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Abstract: I will show that there exist within modern Quantum Mechanics and modern String Theory some valid grounds for a scientific study of Precognition known as Parapsychology.

Precognition is [psychic](#) knowledge of something in advance of its occurrence. It comes under those subjects generally discussed in the field of **parapsychology**, where scientific methodology is applied to the subject of ESP in general. However, many have often raised the question of just how Scientific is such a subject when it includes action (one's thoughts) being influenced by another action or event at a distance. I believe part of this question can be answered via the field subject of Quantum Mechanics.

### QM & ACTION AT A DISTANCE

Let's take a specific example of a hidden variables theory(1). We'll start with the simplest possible case, in which we only allow Alice and Bob to measure the spins along the z-axis. Then, instead of describing the state of the system by the quantum mechanical wave function above, we will simply assume that there is a random mixture of two types of particle pairs:

50% of the pairs will be described by  $(+1)_A$  and  $(-1)_B$

50% of the pairs will be described by  $(-1)_A$  and  $(+1)_B$

Hopefully the notation here is obvious. The idea is simple. Rather than describing the particles with an "entangled" wave function that "collapses" at the moment of measurement, we'll just assume that there is a 50-50 mixture of two different (but fully well-defined) types of pairs. In half the pairs, Alice's particle has spin "+1" and Bob's particle has spin "-1," and vice versa for the other half. No problem, right? This simple theory obviously reproduces all of the quantum mechanical predictions, namely (a) that each experimenter should see a random 50-50 sequence of "+1"s and "-1"s as the spins are measured, and (b) that there should be a perfect anti-correlation between the results. Moreover, the theory does so without any of the dubious concepts of QM.

Remember, though, that nothing forces Alice and Bob to measure only along the z-axis. Let's now permit them to choose (independently, and randomly) between two different possible measurement axes. We could choose, say, the z-direction and the x-direction, but instead let's be completely general and call our two arbitrary directions  $\hat{n}_1$  and  $\hat{n}_2$ .

(So, to be clear, Alice and Bob each choose one of  $\hat{n}_1$  or  $\hat{n}_2$  as the direction to measure along. That is, what we before called  $\hat{n}_A$  will be either  $\hat{n}_1$  or  $\hat{n}_2$ , and  $\hat{n}_B$  will likewise be either  $\hat{n}_1$  or  $\hat{n}_2$ .)

Let's just do what we did before and assume that, at their common moment of birth, each particle is created with certain pre-existing spin properties -- answers, if you will, to the questions that the experimenters may choose to ask down the line. Here, since we haven't specified the relative orientation between  $\hat{n}_1$  and  $\hat{n}_2$ , we'd better leave as arbitrary the "populations" (call them "F" for fraction) of each of the cases:

F1 of the pairs will be described by  $(+1,+1)_A$  and  $(-1,-1)_B$

F2 of the pairs will be described by  $(+1,-1)_A$  and  $(-1,+1)_B$  (4)

F3 of the pairs will be described by  $(-1,+1)_A$  and  $(+1,-1)_B$

F4 of the pairs will be described by  $(-1,-1)_A$  and  $(+1,+1)_B$

The notation here is similar to that used above, except that now for each particle (A and B) we have to specify its properties for both of the measurements that Alice and Bob might decide to make, namely the spin components along  $\hat{n}_1$  and  $\hat{n}_2$ . Note that we aren't saying that Alice or Bob could measure both at the same time. (This would be a gross violation of quantum mechanics.) All we are saying is that, in principle, the information determining the result of a measurement of either spin component exists already in the local properties of that particle alone.

Now, we just have to ask whether it's possible to choose the populations in such a way that we reproduce the quantum mechanical predictions. Indeed, this is pretty easy to do. In writing only these four types of pairs, we've already guaranteed that if Alice and Bob measure along the same axis, the results will automatically be completely anti-correlated. For the other cases, where they measure along different axes, we see that we can reproduce the correct QM result if we take:

$$F1 = \frac{1}{2} \cos^2(\theta/2)$$

$$F2 = \frac{1}{2} \sin^2(\theta/2)$$

$$F3 = \frac{1}{2} \sin^2(\theta/2)$$

$$F4 = \frac{1}{2} \cos^2(\theta/2)$$

where  $\theta$  is the angle between  $\hat{n}_1$  and  $\hat{n}_2$ . The four cases have a probability that sums to unity, which is good, and each term is positive definite. If it's not clear why these have been chosen this way, simply go back to the previous table. For example, the case labeled "F2" results in Alice measuring "+1" on her particle (along  $\hat{n}_1$ ) and Bob measuring "+1" on his particle (along  $\hat{n}_2$ ). According to QM, this result (Alice and Bob each measuring "+1" along  $\hat{n}_1$  and  $\hat{n}_2$  respectively) is supposed to happen with a frequency given by Eq. (2), so we simply copy that result as the population fraction F2. The other cases follow in the same way. Again, this allows us to trivially reproduce the quantum mechanical prediction in a completely local, deterministic, common-sense manner.

This may seem arbitrary at this point, because we aren't actually specifying any *mechanism* by which these population fractions are generated. But that is precisely the point. The idea is that if we were to seriously advocate this kind of theory, we would posit some mechanism to explain these probabilities. For example, they might depend on some further hidden parameters involving the original decaying particle, or perhaps some influence coming from the detectors which stimulates or otherwise affects the decay, or even some process by which the particle properties evolve based on local effects as they fly apart.

Anyway, so far the analysis is general, and we see that it's clearly possible to invent *some* mechanism which would explain the above populations, and thereby reproduce the quantum mechanical predictions in a completely local, deterministic, common-sense picture.

However, when we allow Alice and Bob to choose from among *three* possible directions along which to measure the spin. We can go through the same kind of argument as before, and define populations for each of the (now) eight necessary cases:

F1 of the pairs will be described by  $(+1,+1,+1)_A$  and  $(-1,-1,-1)_B$

F2 of the pairs will be described by  $(+1,+1,-1)_A$  and  $(-1,-1,+1)_B$

F3 of the pairs will be described by  $(+1,-1,+1)_A$  and  $(-1,+1,-1)_B$

F4 of the pairs will be described by  $(-1,+1,+1)_A$  and  $(+1,-1,-1)_B$

F5 of the pairs will be described by  $(+1,-1,-1)_A$  and  $(-1,+1,+1)_B$

F6 of the pairs will be described by  $(-1,+1,-1)_A$  and  $(+1,-1,+1)_B$

F7 of the pairs will be described by  $(-1,-1,+1)_A$  and  $(+1,+1,-1)_B$

F8 of the pairs will be described by  $(-1,-1,-1)_A$  and  $(+1,+1,+1)_B$

where the three numbers in parentheses refer to the spin components along  $\hat{n}_1$ ,  $\hat{n}_2$ , and  $\hat{n}_3$  respectively. As before, we have built in the required property that the spins are anti-correlated for any case in which Alice and Bob measure along the same axis. And again as before we will be interested in testing whether or not it is possible to reproduce the quantum mechanical result by judiciously choosing the F's. We make a step in this direction by noticing that we can write the probability of any specific result as a sum of two of the F's. For example,

$$P(+1, \hat{n}_1; +1, \hat{n}_2) = F3 + F5$$

since it is precisely in cases F3 and F5 (and no others) that particle A has spin "+1" along  $\hat{n}_1$  and particle B has spin "+1" along  $\hat{n}_2$ . All other possibilities (e.g.,  $P(-1, \hat{n}_3; +1, \hat{n}_2)$  etc.) can be written in a similar way, by simply reading off the table which cases give the desired result.

Now we are ready to write down a condition that must hold true, but which will be shown to be in conflict with the quantum mechanical prediction. That is, we will show that it is impossible to pick the F's in such a way that we reproduce the results predicted by QM. Since each of the F's is a probability (and therefore positive definite), we must have inequalities like the following:

$$F3 + F5 \leq F3 + F5 + F2 + F7 = (F2 + F5) + (F3 + F7)$$

But we also recognize this as a statement about the relative probabilities, namely:

$$P(+1, \hat{n}_1; +1, \hat{n}_2) \leq P(+1, \hat{n}_1; +1, \hat{n}_3) + P(+1, \hat{n}_2; +1, \hat{n}_3)$$

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This is our first example of a so-called Bell inequality. It follows simply from the assumption that each particle has well-defined pre-existing properties corresponding to all of the directions along which its spin might eventually be measured -- and, as mentioned before, the further assumption that the act of measurement on one particle has no effect on the second particle. It also follows directly from the restraints imposed by Special Relativity on the lightcone that only C limited exchanges of information can take place. Yet, Bell's inequality clearly shows us there must exist forms of communication that transcend the normal C restraint. It is also simple to show that for at least certain choices of the angles, the predictions of QM *violate* the Bell inequality. For example, choose  $\hat{n}_1$ ,  $\hat{n}_2$  and  $\hat{n}_3$  to be co-planar, with  $\hat{n}_3$  bisecting the angle formed by  $\hat{n}_1$  and  $\hat{n}_2$ . Specifically, choose the angle between  $\hat{n}_1$  and  $\hat{n}_2$  to be 90 degrees (so that the angle between  $\hat{n}_1$  and  $\hat{n}_3$  or  $\hat{n}_2$  and  $\hat{n}_3$  is 45 degrees). Then, using the quantum mechanical result and plugging into Bell's inequality, we have:

$$\frac{1}{2} \sin^2(90/2) \leq \frac{1}{2} \sin^2(45/2) + \frac{1}{2} \sin^2(45/2)$$

or

$$0.25 \leq 0.146$$

which is obviously false. This shows that if we use the quantum mechanical result, we violate the Bell inequality. So it seems that the observation of Bell-inequality-violating correlations between entangled particles *must be taken as evidence for some kind of super-fast "non-local" interaction*. That implies that so-called action at a distance, whither via space or time is possible. So at least the cornerstone concept behind Precognition and **parapsychology** is sound and can be studied by scientific methods using scientific experiments and modern theory.

## HOW THE FUTURE COULD CONTACT OUR MINDS

The simplest solution is of course 26D flat space-time with constant values of all the fields. For this case we have a 2D free theory, which can be easily quantized by

$$\partial^\mu \partial_\mu X^M = 0$$

solving the wave equation , the fields  $X^M$  can be written as:

$$X^M(\sigma, \tau) = X_R^M(\tau - \sigma) + X_L^M(\tau + \sigma)$$

as usual,  $X_R^M$  and  $X_L^M$  represent right- and left-moving modes of the string respectively, with the mode expansion

$$X_R^M(\tau - \sigma) = x_R^M + p_R^M(\tau - \sigma) + \frac{i}{2} \sum_{n \neq 0} \frac{1}{n} \alpha_n^M e^{-2in(\tau - \sigma)}$$

$$X_L^M(\tau + \sigma) = x_L^M + p_L^M(\tau + \sigma) + \frac{i}{2} \sum_{n \neq 0} \frac{1}{n} \tilde{\alpha}_n^M e^{-2in(\tau + \sigma)}$$

Since this is a free theory, quantization assigns canonical commutation relations to the Fourier coefficients  $\alpha_m^N, \tilde{\alpha}_m^N$ , like oscillators of the harmonic oscillator. The Hamiltonian then gives rise to the mass formula:

$$M^2 = N_R + N_L - 2.$$

Where  $N_{R,L}$  refer to the harmonic oscillator occupation numbers for left and right movers and the level matching condition requires  $N_L = N_R$  for consistency. Note that the 'vacuum' state ( $N_L = N_R = 0$ ) is a tachyon due to negative mass. But the level

matching condition requiring  $N_L = N_R$  can also be achieved if  $N_L$  say is positive and  $N_R$  is negative, yet still equal which is similar to the case of my own models proposed Advanced/Retarded wave mix. So we could in theory get a mixed condition where level matching does not exist and yet the sum remains positive and non-tachyon. (Example  $1+1-2=0$  and  $3-1-2=0$  still achieves the same end result. The same goes for any positive solution of mass. The next state requires one left-moving and one right-moving

oscillator ( $N_L = N_R = 1$ ), since both oscillators carry a target space index, the state

corresponds to an arbitrary two-index tensor  $\alpha_{-1}^M \tilde{\alpha}_{-1}^N |0\rangle$  of which the symmetric part is

the metric  $G_{MN}$ , the antisymmetric part is  $B_{MN}$  and the trace is the dilaton  $\Phi$ . That we can see are massless and are always present. Either way, the tachyon can be easily cured by canceling out, which is what our vacuum state seems to naturally do. This suggests that if we could cancel out the Retarded wave from the past we could manifest tachyon state-vectors for any particle or object composed of particles.

Particles with space-like momentum are called tachyons. Their presence is usually considered as undesirable feature for a theory, due to associated hyper-light motion, leading to violation of causality principle. However, in some theories (such as Standard Model of electro-weak interactions) the tachyon is one of main ingredients, responsible for the effect of spontaneous symmetry breaking. Briefly speaking, this effect consists in involving of tachyon into interaction with other particles, after which it disappears, and some of initially massless particles acquire (real positive) mass.

The Goldstone model is a simple model with spontaneous symmetry breaking. Starting with a classical theory, take a Lagrangian density

$$L = \partial^\mu \varphi^* \partial_\mu \varphi - V(\varphi), \quad (2.7)$$

where  $\varphi$  is a complex field

$$\varphi = \frac{\sqrt{2}}{2} [\varphi_1 + i\varphi_2], \quad (2.8)$$

and  $V(\varphi)$  the potential energy

$$V(\varphi) = \mu^2 |\varphi|^2 + \lambda |\varphi|^4. \quad (2.9)$$

The constants  $\mu^2$ ,  $\lambda$  are real with  $\lambda$  positive to make the total field energy bounded from below. The Lagrangian is invariant under the global U(1) transformation describing rotations in the complex plane. It should be noted that  $\varphi$  is a function of the space-time coordinate  $x$  which is suppressed to simplify the notation.

Requiring that the vacuum, the lowest energy state, is invariant under Lorentz transformations and translations implies that  $\varphi(x)$  is a constant in this vacuum state. Two different possibilities exist for the vacuum state depending on the parameter  $\mu^2$ .

If  $\mu^2$  is positive the situation is quite normal with the minimum potential energy when  $\varphi = 0$ . If instead  $\mu^2$  is negative, the minimum energy no longer corresponds to a unique value of  $\varphi$  but is instead degenerate with the minimum as a ring in the complex plane

$$\varphi_{V_{min}} = \sqrt{\frac{-\mu^2}{2\lambda}} e^{i\theta}, \quad 0 \leq \theta < 2\pi.$$

As the Lagrangian is invariant under rotations in the complex plane of  $\varphi$  each direction is equally good and setting  $\theta = 0$  such that

$$\varphi_{V_{min}} = \sqrt{\frac{-\mu^2}{2\lambda}} \equiv \frac{v}{\sqrt{2}}$$

can be done without loss of generalization. A theory where the vacuum has less symmetry than the Lagrangian is called a theory with spontaneous symmetry breaking.

The deviation from the chosen minimum can be described by the two real fields  $\sigma$  and  $\eta$  defined through

$$\varphi = \frac{\sqrt{2}}{2} [v + \sigma + i\eta].$$

The Lagrangian rewritten in terms of  $\sigma$  and  $\eta$  is

$$L = \frac{1}{2} \partial^\mu \sigma \partial_\mu \sigma - \lambda v^2 \sigma^2 + \frac{1}{2} \partial^\mu \eta \partial_\mu \eta - \lambda v \sigma [\sigma^2 + \eta^2] - \frac{1}{4} \lambda [\sigma^2 + \eta^2]^2 + c$$

with  $c$  a constant of interest only for general relativity. Taking the higher order terms as interaction terms the free Lagrangian reads

$$L = \frac{1}{2} \partial^\mu \sigma \partial_\mu \sigma - \lambda v^2 \sigma^2 + \frac{1}{2} \partial^\mu \eta \partial_\mu \eta$$

It is seen that  $\sigma$  and  $\eta$  in fact are two real Klein-Gordon fields. By quantising these fields the Lagrangian describes two different spin 0 particle fields. The  $\sigma$  bosons will have mass

$$m_\sigma = v \sqrt{2\lambda}$$

arising from the  $\sigma^2$  term while the  $\eta$  bosons will be massless. The masslessness of the  $\eta$  bosons is a direct consequence of the minimum being degenerate. The remaining terms from can be treated as interactions among the  $\sigma$  and  $\eta$  particles through perturbation theory.

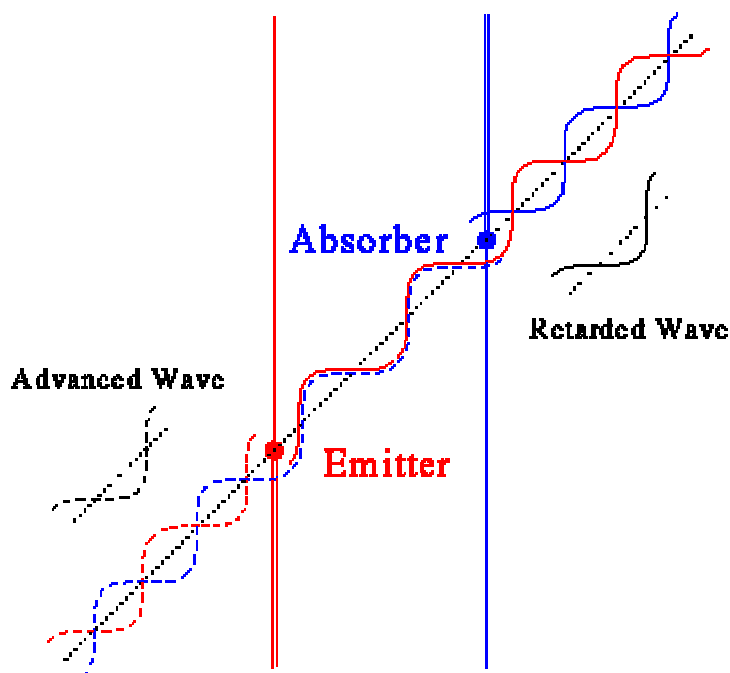
From the above situation it can be seen how the spontaneous symmetry breaking of the U(1) symmetry caused by the degenerate energy minimum of the Lagrangian creates a perturbative theory with a massive scalar boson. So in essence the Tachyon has already found a valid position in our models of physics.

I identify this with the **Wheeler-Feynman Absorber Theory(2)**. Yet, the model I use in my own work is similar to that employed by N. Arkani-Hamed, and S. Dimopoulos **(3)** Advanced waves have characteristic eigenvalues of negative energy and frequency, and they propagate in the negative time direction as both are illustrated below.





A plane-wave transaction between emitter and absorber through the exchange of advanced and retarded waves. Waves from emitter are indicated by red lines and waves from absorber by blue lines. Retarded waves are shown as solid, and advanced waves are shown as dashed. Relative phase of waves is indicated schematically by sinusoids inscribed on lightlike world lines. Double timelike world lines for emitter and absorber indicate higher energy state. Wave amplitudes have the value  $\Psi + \Psi^* = 2\text{Re}(\Psi)$  at emitter and absorber loci and are therefore real.



The result is our normal particle state in a normal Lorentz Invariant Vacuum state. The junction where the emitter and absorber meet as illustrated above we call the present or now. Each cycle outside of this now event becomes its own now event during the course of its evolution, even though from a present perspective the outside cycles are past or future events. But the result is our mind since it basically works on the exchange of electro-chemical processes involving particles could become a receptor of what under QM we term Advanced waves coming from future events. So the subject of Precognition does find some solid support in modern Quantum Mechanics and M-Theory. But it must be remembered that this is theory. As such it is subject to the same restraints as any theory and must be supported by observation and experiment, as well as math.

## References

- 1.) The presentation of this section is taken verbatim from Sakurai's book "Modern Quantum Mechanics", J. J. Sakurai. *Modern Quantum Mechanics*. Addison-Wesley, Reading, 1985. 10
- 2.) Wheeler, J. A., and R. P. Feynman, 1945, *Reviews of Modern Physics* 17, 157, Wheeler, J. A., and R. P. Feynman, 1949, *Reviews of Modern Physics* 21, 425.
- 3.) Arkani-Hamed, N., Dimopoulos, S., Kaloper, N. & Dvali, G. *J. High Energy Phys.* <http://jhep.sissa.it/archive/papers/jhep122000010/jhep122000010.pdf> (2000)