What is erased in the quantum erasure?

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In this paper we re-examine a series of gedanken welcher Weg (WW) experiments introduced by Scully, Englert and Walther that contain the essential ideas underlying the quantum eraser. For this purpose we use the Bohm model which gives a sharp picture of the behaviour of the atoms involved in these experiments. This model supports the thesis that interference disappears in such WW experiments, even though the centre of mass wave function remains coherent throughout the experiment. It also shows exactly what it means to say "that the interference can be restored by manipulating the WW detectors *long after* the atoms have passed." It does not support Wheeler's notion that "the past is undefined and undefinable without the observation [in the present]"

KEY WORDS: Quantum erasure, Welcher Weg experiments, Bohm trajectories.

1 INTRODUCTION

We have recently returned to examine the criticism that Bohm-type trajectories have such 'bizarre' properties that they must be dismissed as physically unreasonable and should be regarded as 'surreal'(1). In Callaghan and Hiley(2) and Hiley(3) we show that, if we use the Bohm interpretation (BI) as defined in Bohm and Hiley(4,5), we do not reproduce the strange behaviour predicted by Aharonov and Vaidman(6) , Englert, Scully, Süssman and Walther(7) and Scully(1). In fact the Bohm trajectories do *not* actually exhibit the unreasonable behaviour predicted by the above authors, but produce exactly the same behaviour as those obtained by Scully(1) using standard quantum mechanics (SQM) as they must.

In view of these results we have decided to re-examine what new light the BI could throw on the phenomenon discussed under the heading of the

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'quantum erasure'. We will confine our discussion to the particular case of the two-slit interference experiment introduced by Scully, Englert and Walther, (SEW)[8] (See figure 1 for the experimental set up. This figure is taken from their paper.) The reason for restricting our discussion to this particular experiment is that it uses atoms whose time development is described by the Schrödinger equation. It is from this equation that the particle Bohm model used in this paper is derived[1]

The device shown in Figure 1 allows for the possibility of later erasing information as to which slit each atom passed through. In such an experiment the essential question raised by SEW is whether erasing this welcher Weg (WW) information will restore the interference after the atoms have passed through the slit system and indeed what this 'restoration' actually means.

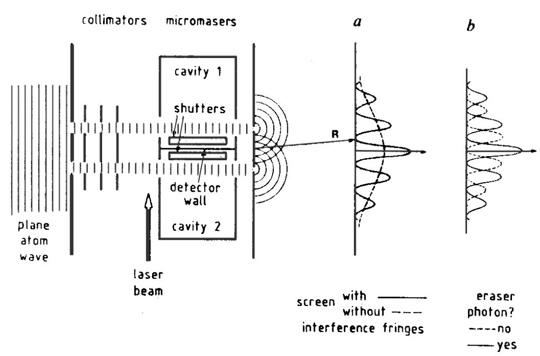

Figure 1: The 'which way' [WW] experiment of Scully, Englert and Walther [SEW]. The uniform distribution, as opposed to fringes, appearing when the shutters are in place is shown in (a). The fringes (antifringes) appearing when the cavity detector fires (does not fire) are shown in (b)

The original impetus for studying such experiments appear to stem from Wheeler's analysis of the delayed choice experiment. Wheeler[11] argues that these experiments leave us no option but to embrace the notion that 'the past is undefined and undefinable without the observation [in the present]'. The

[1]While many quantum erasure experiments are done using photons, we will not discuss these here because they require quantum field theory. Even in the Bohm model[5,9] it is not possible to construct photon trajectories. For a detailed discussion of this point see Holland[10]

word ‘undefinable’ seems to suggest that a very radical position has been adopted, too radical for some. However the proposal becomes plausible only if we insist there is no knowable reality underpinning the quantum formalism. We will show in this paper that the BI does not support this notion. It provides a consistent model which insists that what has passed is past and cannot be altered by some measurement that is performed in the future. We will show here that the BI provides a consistent and physically reasonable account of these WW experiments without the need to propose any radical new notions. An important consequence of all this is that the BI does not support the notion of a ‘quantum eraser’ if it is meant by this that the past dynamics is changed when we can no longer have access to the original WW information. In fact we will show that past dynamics cannot be erased by any future action.

In this paper we will assume by now that the particle Bohm model [BI] is well known. Those unfamiliar with this model are referred to the books of Bohm and Hiley(5) and Holland(12) where references to more detailed discussions can be found. We will simply adopt its framework and examine how it treats the WW experiments introduced in the excellent paper of SEW(8).

To bring out these details we want to concentrate solely on the two-slit experiments that are clearly laid out in their paper. This experiment (see figure 1) consists of a beam of atoms, all in the same excited state, incident on a pair of slits. Two maser cavities are placed in front of the two-slit system so that it is possible to determine through which slit each atom passes. This is achieved by assuming that when an excited atom enters a cavity it gives up its internal energy to the cavity with 100% efficiency without changing the phase of the centre of mass wave function of the atom. Furthermore we assume the photodetector within the cavity is also 100% efficient. This ideal situation is assumed so that we can bring out the principles involved in the experiment in as simple a way as possible. The reasonableness of these assumptions have been excellently discussed in SEW so we will not dwell further on these issues here.

Thus, as each atom passes through the cavity, it gives up all its internal energy to the cavity and then continues onto the screen. As this process does not disturb the centre of mass momentum, the emerging beam remains coherent. In spite of this no fringes appear. This is explained in SQM by the orthogonality of the cavity states involved (see equation (1)). The vanishing of the interference is sometimes explained by arguing that future measurement on the cavities will identify through which slit each atom passed and this knowledge will violate the uncertainty principle.

The question that SEW raise is as follows. Suppose one does not measure the energy of a cavity to find out which way an atom went but rather simply joined the two cavities by removing the shutters shown in figure 1. This allows the cavity fields to combine removing any possibility of finding out which way any particular atom went. Will this process allow the interference fringes to reappear? In other words will erasing the 'which way' information allow interference to reappear?

To ensure that such an erasure has taken place, a detector is placed in the cavity behind the pair of shutters. When the shutters are removed the detector will be called into action (See figure 1 for details). The interaction Hamiltonian describing the field/detector interaction couples the detector only to the symmetric combination of the fields. It does not couple to the antisymmetric combination. The presence of the cavity detector thus ensures the WW information is destroyed. Let us therefore compare the interference pattern before and after the shutters are removed.

In terms of the Copenhagen interpretation, we can say nothing about what goes on until a measurement is actually made. Thus there appears to be a different outcome depending on which measurement we choose to take no matter when we chose to do the measurement, hence the notion of delayed choice. If one subscribes to the Wheeler analysis then since the past is only revealed in the present action, the present experiment suggests that we have somehow miraculously created interference 'long after the atoms have passed' as SEW put it.

No such ambiguity shows up if we use the BI. If the atoms have reached the screen and been detected at the screen then clearly delayed measurement of the content of the cavity will have no effect. However, what happens to the subsequent behaviour of the atoms if the screen is removed and the atoms are not detected? We will show that, if the atoms have passed through the slits, the subsequent removal of the shutters allowing the cavity detector to function produces no effect on the atoms that have passed through the slit system. The influence of the two-slit/cavity set-up is over, it is complete. What any subsequent cavity measurement establishes is what *would have been* the situation had the measurement been carried out before the particles enter the two slits, that is, the cavity measurement is instantaneous and not delayed. What the so-called eraser does is to identify positions on the screen where atoms would have arrived had the cavity detector fired instantaneously. Of course this is the conclusion one would also arrive at in SQM provided we examined carefully the time evolution of the total wave function using the Schrödinger equation. The advantage of the BI is that this behaviour can be made much more transparent. We will now go through the mathematical details more fully to substantiate our claims.

2 WELCHER WEG EXPERIMENT BEFORE MAKING A MEASUREMENT OF THE CONTENT OF THE CAVITY

Consider a coherent beam of atoms in an internal energy state $|a\rangle$ incident on the cavity-slit system. On passing through one of the cavities, the atom gives up its internal energy leaving it in the internal energy state $|b\rangle$. If the centre of mass wave function is $\psi(\boldsymbol{r})$, then the total wave function at the screen will be

$$\Psi(\boldsymbol{r}) = \frac{1}{\sqrt{2}}\left[\psi_1(\boldsymbol{r})|1_1 0_2\rangle + \psi_2(\boldsymbol{r})|0_1 1_2\rangle\right]|b\rangle \tag{1}$$

Since the cavity radiation states $|1_1 0_2\rangle$ and $|0_1 1_2\rangle$ are orthogonal, the probability $|\Psi|^2$ contains no interference terms and, as we have already pointed out, no fringes are predicted.

In terms of the BI we write the wave function as

$$\Psi(\boldsymbol{r},\Phi) = \frac{1}{\sqrt{2}}\left[\psi_1(\boldsymbol{r})\Phi(\phi_1(\boldsymbol{r}'),\eta_0(\boldsymbol{r}')) + \psi_2(\boldsymbol{r})\Phi(\phi_0(\boldsymbol{r}'),\eta_1(\boldsymbol{r}'))\right] \tag{2}$$

Here $\Phi(\phi_i(\boldsymbol{r}'),\eta_j(\boldsymbol{r}'))$ is the wave functional of the cavity fields $\phi_i(\boldsymbol{r}')$, and $\eta_j(\boldsymbol{r}')$. ϕ_i is the field in the top cavity while η_j is the field in the bottom cavity in figure 1. The suffixes i and j (= 0,1) refer to the number of photons excited in each cavity. The easiest way to exhibit the interference terms is to examine the quantum potential. In the case we are considering, the quantum potential takes the form

$$Q = -\frac{1}{2}\int d^3\boldsymbol{r}'\left[\frac{1}{m}\frac{\nabla_r^2 R}{R} + \frac{\frac{\delta^2 R}{(\delta\Phi)^2}}{R}\right] \tag{3}$$

where we re-write $\Psi(\boldsymbol{r},\Phi)$ as $R(\boldsymbol{r},\Phi)\exp[iS(\boldsymbol{r},\Phi)]$. Here $\delta/\delta\phi$ in the functional derivative and we have put $\hbar$=1.

We then find

$$\begin{aligned}|R(\boldsymbol{r},\Phi)|^2 &= \left[R_1(\boldsymbol{r})R(\Phi(\phi_1(\boldsymbol{r}'),\eta_0(\boldsymbol{r}')))\right]^2 + \left[R_2(\boldsymbol{r})R(\Phi(\phi_0(\boldsymbol{r}'),\eta_1(\boldsymbol{r}')))\right]^2 \\ &+ 2R_1(\boldsymbol{r})R_2(\boldsymbol{r})R(\Phi(\phi_1(\boldsymbol{r}'),\eta_0(\boldsymbol{r}')))R(\Phi(\phi_0(\boldsymbol{r}'),\eta_1(\boldsymbol{r}')))\cos\Delta S.\end{aligned}$$

Now the contribution of the cavity fields (second factor of each term in the sum) to the quantum potential (3) is negligible outside the cavities so that the main contribution comes from the first term. In fact a detailed calculation of the quantum potential is not necessary, all we need to do is carefully examine the interference term.

At first sight the last term in the expression for $|R(\boldsymbol{r},\Phi)|^2$ suggests that interference is present. However we will now show that in this case it always vanishes, contributing nothing to the quantum potential. To see this remember that the quantum potential must be evaluated over the *actual* position of the atom and all of the variables describing the properties of the cavities concerned. Thus, if the atom actually goes through the top cavity then the probability of finding the bottom cavity in an excited state $\eta_1(\boldsymbol{r})$ (i.e. containing a photon) is zero. Therefore $R(\phi_0(\boldsymbol{r}'),\eta_1(\boldsymbol{r}'))$ must be zero, so the interference term must vanish. In fact we are only left with one term

$$|R(\boldsymbol{r},\Phi)|^2 = \left[R_1(\boldsymbol{r})R(\Phi(\phi_1(\boldsymbol{r}'),\eta_0(\boldsymbol{r}')))\right]^2$$

Again if the atom actually went through the lower cavity then the probability of finding a photon in the upper cavity will be zero. In this case $R(\Phi(\phi_1(\boldsymbol{r}'),\eta_0(\boldsymbol{r}')))$ will be zero. Again we are left with one term

$$|R(\boldsymbol{r},\Phi)|^2 = \left[R_2(\boldsymbol{r})R(\Phi(\phi_0(\boldsymbol{r}'),\eta_1(\boldsymbol{r}')))\right]^2$$

and the interference will therefore once again vanish. Thus there will be no interference term in the quantum potential for whichever way the atom actually goes and therefore no fringes will appear. This is in complete agreement with the predictions of SQM as it must be since BI simply uses the standard quantum formalism.

The distribution on the screen will be the sum of two independent single slit distributions. We can confirm this result by calculating individual trajectories using the so-called guidance condition $\boldsymbol{p} = \nabla S(\boldsymbol{r},\Phi)$. The corresponding trajectories are sketched in figure 2.

Notice in this diagram that individual trajectories cross the horizontal axis of symmetry. That this must be so can be seen from the following argument. Let us consider one atom incident on the slit system and suppose it enters at the lower edge of the top slit. It will travel on one of the lower trajectories emanating from the top slit. Since there is no contribution from the bottom slit, it will travel along the trajectory crossing the axis of symmetry before arriving at the screen. Similarly, consider another later atom incident on the upper edge of the bottom slit. It will follow the trajectory that crosses the axis of symmetry from below.

If a bunch of atoms approach the slits together then we can think in terms of currents as does Erez and Scully(13). This means that we will get

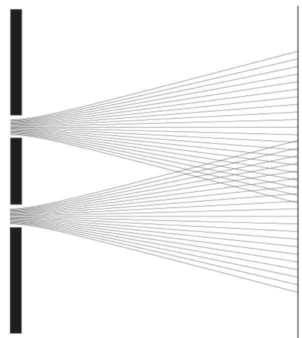

Figure 2: Sketch of trajectories expected if the effects of the two slits behave independently

a current from the top slit crossing the axis of symmetry and there will also be a current from the bottom slit crossing the axis of symmetry in the opposite direction. Of course these currents are symmetric about this axis so that the algebraic sum of the vertical component of the currents is zero as argued by Erez and Scully, but their conclusion that no atoms cross the axis of symmetry is clearly incorrect.

3 WHAT HAPPENS WHEN A MEASUREMENT IS MADE ON THE CAVITIES THAT DESTROYS THE WELCHER WEG INFORMATION?

Now we must investigate what happens when we remove the shutters between the two cavities and allow the detector in the cavities to function. The first point to remember is that the detector in the cavities is described by an interaction Hamilton that only couples with symmetric combinations of the two fields. This means that only the symmetric combination will cause the detector to fire, while the antisymmetric combination will leave the detector unaffected. This process will destroy the WW information. What we must do now is to analyse how we can apply the quantum formalism to this situation.

In SQM it is first necessary to find an expression for the wave function that will allow the field to couple with the detector. To this effect we introduce the symmetric, $|+\rangle$, and antisymmetric, $|-\rangle$, states of the radiation fields in the cavity so that

$$|\pm\rangle = \frac{1}{\sqrt{2}}\left[|1_1 0_2\rangle \pm |0_1 1_2\rangle\right] \tag{4}$$

At the same time we introduce the symmetric, ψ_+, and antisymmetric ψ_- atomic states defined by

$$\psi_\pm(\boldsymbol{r}) = \frac{1}{\sqrt{2}}\left[\psi_1(\boldsymbol{r}) \pm \psi_2(\boldsymbol{r})\right] \tag{5}$$

Then it is easy to show that the wave function of the combined system (1) can be written as

$$\Psi(\boldsymbol{r}, \Phi) = \frac{1}{\sqrt{2}}\left[\psi_+(\boldsymbol{r})|+\rangle + \psi_-(\boldsymbol{r})|-\rangle\right]|b\rangle|d\rangle \tag{6}$$

where $|d\rangle$ is the 'unfired' state of the detector in the cavities. If we now introduce the interaction Hamiltonian coupling the cavity field to the cavity detector, the final wave function becomes

$$\Psi(\boldsymbol{r}, \Phi) = \frac{1}{\sqrt{2}}\left[\psi_+(\boldsymbol{r})|0_1 0_2\rangle|f\rangle + \psi_-(\boldsymbol{r})|-\rangle|d\rangle\right]|b\rangle \tag{7}$$

where $|f\rangle$ is the 'fired' state of the cavity detector. Again because of the orthogonality of $|f\rangle$ and $|d\rangle$ no interference fringes will be seen.

In order to get clear on what is involved in a delayed removal of the shutters, let us first see how SQM and BI deal with the case when the shutters are removed *before* the atoms pass through the cavity. We will later discuss what happens if the removal of the shutters is delayed.

Since in this case the detector either fired or did not, both SQM and BI claim that the wave function splits into a mixture of two sub-ensembles. SQM uses the collapse of the wave function to establish this. The BI uses an argument similar to the one used in section 2.

Let us first use SQM to analyse these two sub-ensembles. First consider the case where the cavity detector fires. Here the wave function for this sub-ensemble is

$$\Psi(\boldsymbol{r}, \Phi) = \psi_+(\boldsymbol{r})|0_1 0_2\rangle|f\rangle|b\rangle \tag{8}$$

If we expand the term $\psi_+(\boldsymbol{r})$, we see that interference terms are present which is confirmed by writing down the probability of an atom arriving at the screen

$$P_f(\boldsymbol{r}) = \frac{1}{2}\left[|\psi_1(\boldsymbol{r})|^2 + |\psi_2(\boldsymbol{r})|^2 + Re[\psi_1^*(\boldsymbol{r})\psi_2(\boldsymbol{r})]\right] \tag{9}$$

This sub-ensemble clearly shows the presence of an interference effect.

If the cavity detector does not fire, then the wave function for this sub-ensemble is

$$\Psi(\boldsymbol{r}, \Phi) = \psi_-(\boldsymbol{r})|-\rangle|d\rangle|b\rangle \tag{10}$$

Again interference arises as can be seen by expanding the term $\psi_-(\boldsymbol{r})$. In this case the probability is

$$P_d(\boldsymbol{r}) = \frac{1}{2}\left[|\psi_1(\boldsymbol{r})|^2 + |\psi_2(\boldsymbol{r})|^2 - Re[\psi_1^*(\boldsymbol{r})\psi_2(\boldsymbol{r})]\right] \tag{11}$$

Here it is the minus sign that produces what SEW[8] call the 'antifringes' (See figure 1). This difference in sign simply means that the points of maximal arrivals on one interference pattern will correspond to the points of minimum arrivals on the other. When taken together it appears as if there is no interference present at all.

The BI also offers a very straight forward explanation of these two sub-ensembles. In the previous section we used the quantum potential to show why there were no interference terms present, but here we will simply use the guidance condition, $\boldsymbol{p} = \nabla S$ directly. This is more convenient in this case because we are only interested in the trajectories and these are calculated directly from the guidance condition simply by integration.

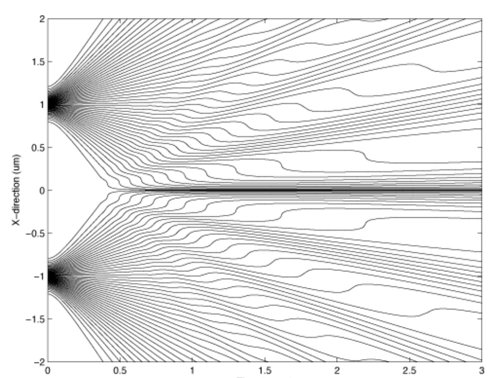

Figure 3: Fringes produced when WW information is lost and detector fires.

In the case where the cavity detector fires, we clearly must use wave function (8). However since we are only interested in the general structure of the trajectories, we need only consider part of the wave function $\psi_+(\boldsymbol{r}) = R_+(\boldsymbol{r})\exp[iS_+(\boldsymbol{r})]$. We can then put this in the guidance condition which in this case reads

$$\boldsymbol{p} = \nabla_{\boldsymbol{r}} S_+ \tag{12}$$

Here S_+ is given in terms of ψ_1 and ψ_2 by the equation

$$\tan S_+ = \frac{R_1 \sin S_1 + R_2 \sin S_2}{R_1 \cos S_1 + R_2 \cos S_2} \tag{13}$$

Integrating equation (12) numerically we find the trajectories shown in figure 3.

In the case where the cavity detector does not fire, we need only consider the wave function $\psi_-(\boldsymbol{r}) = R_-(\boldsymbol{r}) \exp[iS_-(\boldsymbol{r})]$ and again use the guidance condition

$$\boldsymbol{p} = \nabla_{\boldsymbol{r}} S_- \tag{14}$$

where

$$\tan S_- = \frac{R_1 \sin S_1 - R_2 \sin S_2}{R_1 \cos S_1 - R_2 \cos S_2} \tag{15}$$

Because of the negative sign appearing in this expression the trajectories bunch to form ‘antifringes’. These trajectories are shown in figure 4. So once again we see that the BI merely reinforces the conclusions derived from SQM.

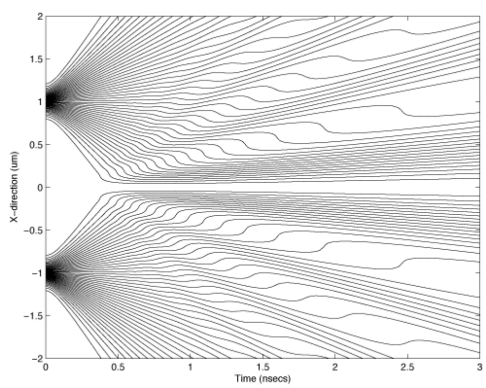

Figure 4: Antifringes produced when WW information is lost and cavity detector does not fire.

4 DISCUSSION OF RESULTS

In sections 2 and 3 we have discussed two extreme situations. The first case, case A, involved keeping the cavity shutters in place throughout the experiment and the other, case B, involved keeping the shutters open all the time. In these two cases we see that we obtain very different sets of trajectories.

In case A when the shutters are closed, we find two independent sets of trajectories. One set arises from atoms that pass through the top slit, the other from the atoms that pass through the bottom slit. Neither set shows any interference effects. Notice that in this case atoms do actually cross the horizontal axis of symmetry, equal numbers crossing in both directions.

In the second case, B, an examination of the two sets of trajectories plotted in figure 3 and 4 show that, in each case, interference is present. If we superimpose the two sets of trajectories as demonstrated in figure 5, we see that we get a uniform distribution of atoms arriving at the screen suggesting no interference present. Nevertheless interference is present but is hidden by superimposing the fringe and anti-fringe patterns as pointed out by SEW. Notice that in both figures 3 and 4 no trajectory crosses the symmetry axis. This shows that very different sets of particle evolution can give rise to what looks like the same interference-free pattern.

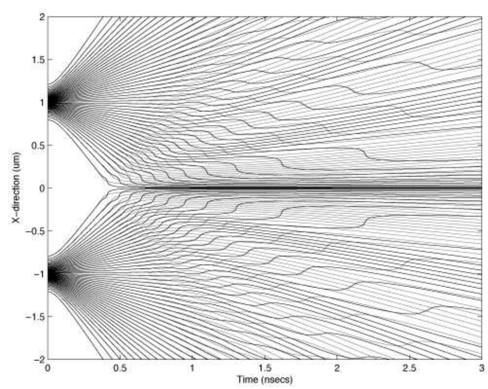

Figure 5: The superposition of trajectories corresponding to superposition of fringes and antifringes.

Now let us turn to the more interesting case in which we start the experiment with the shutters in place, case A, but then remove them at some later time t'. In order to get a clear account of the behaviour of individual atoms in this case, let us consider a very weak beam of atoms incident on the cavities so that at any one time there is only one atom passing through the apparatus.

Let us first consider the more straight forward situation when each atom is actually detected at the screen before the shutters are removed. Clearly once an atom has arrived at the screen and has been detected, any subsequent removal of the shutters will have no effect on the past behaviour of this atom. The atom has arrived and been detected and its past behaviour cannot be changed. This means that any subsequent destruction of WW information in the cavities will have no effect on how the atom got to the screen. In other words in this case, although the WW information for each atom has been 'erased', this in no way effects the dynamics because the dynamics is over as soon as each atom is detected.

We can now turn to the much more interesting case where an atom has passed through the cavity set up as in case A but is still in motion when the cavity shutters are removed at time t'. What will be the subsequent behaviour of the atom?

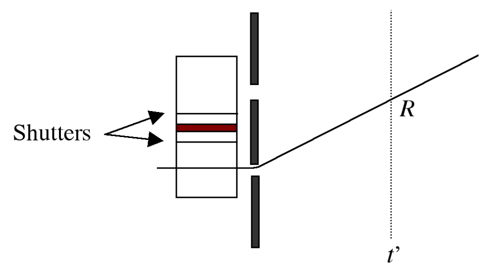

Figure 6: Particle reaches R at time t' when shutters are removed. The trajectory continues unchanged.

Suppose we consider the case where an atom follows a given trajectory and when the shutters are removed the atom has reached position R as shown in Figure 6. We have already argued in section 2 that the effective wave function for this particular atom is simply

$$\Psi(\mathbf{r}, \Phi, t) = \psi_2(\mathbf{r}, t)\Phi(\phi_0(\mathbf{r}', t), \eta_1(\mathbf{r}', t))|b\rangle \tag{16}$$

To understand the effect on the atom of removing the shutters at t', we must write this wave function in the form

$$\Psi(\mathbf{r}, \Phi, t) = \frac{1}{\sqrt{2}}\psi_2(\boldsymbol{r}, t)[\Phi_+ + \Phi_-]|d\rangle|b\rangle \tag{17}$$

where

$$\Phi_\pm = \frac{1}{2}\left[\Phi(\phi_0(\mathbf{r}', t), \eta_1(\mathbf{r}', t)) \pm \Phi(\phi_1(\boldsymbol{r}', t)\eta_0(\boldsymbol{r}', t)\right] \tag{18}$$

If the cavity detector fires when the shutters are removed, the effective wave function is

$$\Psi(\mathbf{r}, \Phi, t) = \psi_2(\boldsymbol{r}, t)|0_1 0_2\rangle|f\rangle|b\rangle \qquad t > t' \tag{19}$$

Using the wave function given in (19), we see that the atom must continue on its straight line trajectory since its centre of mass wave function ψ_2 is unchanged and there is no contribution from ψ_1. A corresponding argument can be made for an atom passing through the top slit.

To sum up then, the BI shows clearly that although the WW information is erased, the past dynamics of each atom is not changed and, furthermore, the future dynamics is not changed either. In other words the interference has not been restored in the sense that the dynamics of the individual atoms has been changed. All that one can do with this delayed information is to divide the atom arrival positions on the screen into two sub-ensembles, one set being identified with the firing of the cavity detector while the other is identified with its non-firing.

Thus the use of the word 'eraser' does not seem to capture the essence of what is going on here. In one sense the word is misleading because it tends to imply that somehow the past dynamics is changed and the interference pattern has been 'restored' but nothing of the sort has happened. Our "erasing" the WW information has had no effect on the behaviour of the atoms that have already passed through the cavities and the slits.

5 CONCLUSIONS

By using the Bohm interpretation we have shown that once the atoms have passed through the slits, any subsequent erasure of the 'which way' (WW) information has no effect either on the past nor future dynamics of the atoms. Thus we have come to the opposite conclusion reached by Scully et al.(SEW)[8] who claimed that "the interference effects can be restored by manipulating the WW detectors *long after* the atoms have passed."

The apparent re-appearence of interference arises because it is possible to have different underlying dynamics to produce the same final probability distributions. This was brought out clearly in figures 2 and 5. In figure 2 the atoms cross the horizontal axis of symmetry contrary to figure 5 where no atoms cross this axis at all, yet the final distribution shows no signs of interference.

What figure 5 does show is that if we identify the arrival points of atoms on the screen with the subsequent firing/non-firing of the cavity detector, we can separate out these points into two sub-ensembles. If we take either sub-ensemble it will look as if interference has somehow 're-appeared'. However the significant point is that the two sub-ensembles could have arisen if the experiment had been run with the cavity shutters removed from the very beginning. Thus it is not the erasing of the WW information *per se* that *restores* the interference.

It is easy to miss this point in SQM because strictly there is no way of analysing what is going on between measurements. We may be able to obtain more information by representing the atoms by small wave packets, but even here we can only talk about potential behaviour under exactly specified experimental conditions. When the experimental conditions are changed, the potential outcomes are changed, but according to Bohr(14), there is no way to picture any possible underlying dynamics.

On the other hand the BI presents a clear unambiguous picture of the underlying dynamics. One can build information about the overall experimental conditions into the quantum potential, and show how these experimental conditions affect the behaviour of individual atoms. It is the fact that the quantum potential contains this information about the experimental conditions that ensures that at the level of probabilities there is no difference between SQM and the BI.

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