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Causal Classical Physics in Time Symmetric Quantum Mechanics

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Abstract: The letter submitted is an executive summary of our previous paper. To solve the Einstein Podolsky Rosen "paradox" the two boundary quantum mechanics developed by Aharonov and coworkers and others is taken as self consistent interpretation of quantum mechanics. The difficulty with this interpretation is to reconcile it with classical physics. To avoid classical backward causation two "corresponding transition rules" are formulated which specify needed properties of macroscopic observations and manipulations. The apparent classical causal decision tree requires to understand the classically unchosen options. They are taken to occur with an "incomplete knowledge" of the boundary states obvious in macroscopic considerations. The precise boundary conditions with given phases then select the actual measured path and this selection is mistaken to happen at the time of measurement. The apparent time direction of the decision tree originates in an assumed relative proximity to the initial state. Only the far away final state allows for classically distinct options to be selected from. Cosmological the picture could correspond to a big bang initial and a hugely extended final state scenario. It is speculated that it might also under certain condition work for a big bang/big crunch world. In this case the Born probability postulate could find a natural explanation if we coexist in the expanding and the correlated CPT conjugate contracting world.

Keywords: two boundary interpretations of quantum mechanics; time symmetry; causality in classical physics

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The Einstein Podolsky Rosen paradox [1] needs to be resolved (It is by no means esotheric, p.e. [2,3]). It is probably correct to conclude in an admittedly simple minded way [4] that the Hidden Variable [5,6] and the Guiding Fields [7–9] approaches do not work (see also [10]) and the most reasonable approach is still a Copenhagen interpretation [11] limiting the ontology of waves. We here study a self consistent alternative in which the wave functions are taken as real ontological objects [4,12]. To make sense somewhat far fetched assumptions will be required.

With real ontological wave functions the Einstein Podolsky Rosen paradox means instantaneous action over a large distance. Contrary to lore it does not violate the essence of special relativity which just prescribes boost transformations. However, using relativity instantaneous action means backward causation in a different Lorentz system which is widely considered inacceptable.

However it is not as bad as it seems. The physics which we really know (with 10 digits precision etc.) is quantum dynamics used to calculate amplitudes. Quantum dynamics contains no time arrow [13] and backward causation is not inacceptable.

The usual interpretation of quantum mechanics involves a fixed initial and asymmetrically an open final state and quantum jumps. The original initial state can, say, evolve to a state containing an electron with sidewards (say right) spin. If a Stern Gerlach like measurement finds an upward spin the original initial state is then replaced by the new one in a non unitary, non time symmetric jump.

The central point is that in a theory with backward causation the measurement outcome like the up/down decision can be done at a later time then fixing the observed earlier observation. It allows to apply a two boundary picture where the decision is made by a final state only consistent with the measurement decision. As for the jump the unitary quantum dynamics evolution has to be amended. One writes:

$$< \text{initial} \,|\, \text{Projection} \,|\, \text{final} > \, / < \text{initial} \,|\, \text{final} > \,.$$

to obtain a unit total probabilities. This two boundary formalism is well developed by Aharonov and coworkers [14] and others.

In contrast to the quantum world macroscopic considerations do not allow for distinct coexisting path ways. A large number of effective measuremens must reduce ambiguities to allow for a macroscopic description [15]. In the two boundary description these measurements must be stored largely in the final boundary. This means that the overlap

$$< \text{inital} \,|\, \text{final} > \sim 0.5^{\text{decisions}}$$

must be really tiny. But this is possible and as also claimed by Aharonov and Cohen [12] it is a self consistent, time symmetric interpretation of quantum mechanics.

The difficulty is to understand how the causal classical physics can arise in such a frame work. Without a solid mathematical framework we have largely to rely on intuitive considerations. Our paradigm is to accept quantum dynamics and consider classical physics just as effectively valid. It is somehow opposite to that of the "Cellular Automaton" advocated by 't Hooft [6].

To proceed we introduce *two transition rules* which prohibit simple backward causation in classical physics.

The first one is known as no 'post selection' with macroscopic devices. Consider a single photon state moving forward in a fiber. It is possible to split the fiber in two and join it again with a macroscopically prearranged relative phase. It is possible to close the forward going channel but this will not affect the initial creation probability of the photon. As a consequence of unitarity other channels (like reflection) have to open up.

The second rule states that states produced in a macroscopic distance have a random relative phase. Figure 1 considers two antennas in the focal points of an ellipsoid mirror. Within the antennae clocked electronics allows to create preselected situations. With a certain probability one so emits a radio frequency photon at $-\Delta T$ which is than absorbed at the other point at $+\Delta T$. If now both antennae synchronously emit at $-\Delta T$ and absorb at $+\Delta T$ in a symmetric way the probability is not effected. However if at $t = 0$ the mirror gets dark on an point of positive interference the emission probability at $-\Delta T$ is enhanced. This second order interference effect constitutes a violation of the second rule. The argument for the rule is that emissions with a synchronized phases and absorptions not averaging out enhancements and depletions are extremely rare in macroscopic situations and can therefore be ignored.

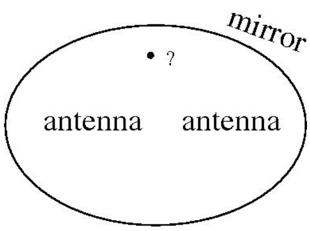

Figure 1. Second order interference.

In classical physics there is a *causal decision tree*. At each branching time a decision how the future evolves is made. The critical point in the considered framework is to understand the unchosen options. In a macroscopic consideration the quantum phases are averaged out. With the resulting "incomplete knowledge" of the boundary states many path ways can appear if the distant between the boundaries is sufficiently large.

The apparent time direction of the decision tree originates in an assumed relative proximity to the initial state. Given the initial and present macroscopic state there is even with incomplete knowledge only one path possible. It is not easy for macroscopically different states with lots of witnesses to reach the same final state. Only the much more distant final state allows for multiple options.

If now the exact boundary conditions with their given phases are implemented the actually taken path is determined. In a classical consideration this selection is mistaken to happen at the instant of measurement. So it appears that present decisions affects the future.

The *expanding universe* is source of the thermodynamic arrow [16]. The hugely extended final state and significant effectively interaction less regions make it plausible that all today macroscopic decisions can be encoded in the far away final state. However, many aspects of cosmology are not well known and it is not clear that in the limit of a large final time the final state grows faster then needed for the decision tree.

In a symmetric scenario with a big bang and a big crunch [17,18] it might be enough to have an extremely extended intermediate state at the turning point. If the initial and final state are identical any selection collapses as all matching paths contribute and no classical aspects appear. If they are almost orthogonal both forward and backward evolutions will produce two distinct extremely entangled intermediate states. It is concievable that considering the extreme extend of the intermediate state the entanglement rarely matches and that effectively only one intermediate state contributes.

The unfixed final state opens an amusing possibility. We consider the situation with an electron wave the time t in the forward moving world ($t < \frac{1}{2}T_{crunch}$) with spin in the rightward direction at and an identical one at $T_{\text{crunch}} - t$ in the opposite moving one. A component $\langle \text{rightward} \,|\, \text{upward} \rangle$ leads to an upward intermediate state. We asume this state then to be sufficiently traced in witnesses. The component which reaches the same intermediate state in the backward moving world is identical $\langle \text{rightward} \,|\, \text{upward} \rangle^{CPT}$. Given the witnesses the common final state allows for no mixed contributions. Averaging out unknown evolutions the probability of an upward spin is therefore

$$P(\text{sideward} \rightarrow \text{upward}) = |\, \langle \text{sideward} \,|\, \text{upward} \rangle \,|^2$$

and the Born rule is no longer a postulate but a consequence of the concept.

The seemingly statistical choice is no longer stored in a know-all final state but in an intricate miss match of both "initial" states. The overlap is

$$\begin{aligned} \langle bang| \quad & U(T_i, t) P_{up} \\ & \qquad U(t, T_{match}) P_{match} U(T_{match}, T_{crunch} - t) \\ & \qquad\qquad P_{up} U(T_{crunch} - t, T_{crunch}) \quad |crunch\rangle \end{aligned}$$

for the upward measurement. For the downward measurement the projections P_{up} are replaced by P_{down}. We consider now for both cases the central second line. Before normalization needed in the two boundary formalism the values are tiny say 10^{-huge} resp. $10^{-huge'}$. With 50% the value *huge* is "würfelt" (Einstein's term for dice) larger and given the extreme values natural variations $10^{-\sqrt{huge}}$ will lead to the needed exclusive dominance.

A polite letter ends with a greeting. So best wishes from a strange place with our wave function in the forward moving world and with our conjugate function eons apart in tidily correlated opposite moving one?

Conflicts of Interest: The authors declare no conflict of interest.

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