Are we living in a bidirectional big bang / big crunch universe?

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Abstract

The interrelation of macroscopic classical and usually microscopic quantum physics is considered. Arguments for fixed two state vector quantum mechanics are outlined in a somewhat pedagogic way. An heuristic concept is developed how something like classical physics could emerge in an early epoch of a finite universe with a compact initial state and an extremely extended final one. The concept contains no intrinsic paradoxes. However it can not incorporate free agents which are considered essential. To allow for something like free agents the fixed final state is replaced by a matching state of maximum extend between an expanding and a contracting universe. How a bidirectional macroscopic world with possible free agents could emerge in such a big bang / big crunch universe is the central point of the paper.

1 Introduction

The interplay of classical and quantum physics is in our opinion treated not sufficiently radical and we advocate a drastically new approach. We are aware that this is somewhat disrespectful. However we are convinced to have some valid points and appealing concept.

It is not meant as an exercise in resolving or hiding problems with nuanced words. Nevertheless two definitions seem necessary:

| QUANTUM DYNAMICS | MACROSCOPIA |
|------------------|-------------|
| := quantum mechanics \(-\) measurements \(\in\) relativistic quantum field theory | := classical mechanics + classical E.-dynamics + most of stat. mech. + most of gen. relativity |
The first one was coined by Sakurai. Quantum dynamics means QM without measurements. He pointed out that this is where all the spectacular successes of QM lie. Underlying Quantum Dynamics is of course relativistic quantum field theory. Quantum dynamics is taken as an approximation of relativistic quantum field theory valid in its region and not as a fundamentally separate world view. As for the second definition the meaning of macroscopia is obvious as indicated in the above right box.

Both world views differ in a central way. In quantum dynamics many coexisting paths can coexist while in macroscopia there is a unique path way. This unique path way is not always specified. Sometimes terms like partition functions parametrize ignorance, but on a fundamental level there is always one true configuration. This is different in quantum dynamics where coexisting distinct paths can exist. What is meant with distinct? Here we want to stay simple and shy away from topological terms. Paths going through the upper and the lower gap of a two slit experiment are taken as distinct. This specification will not be lost by going from a Feynman path description to some more integrated coarse grained macroscopic path way. We understand that this transition [33] is not simple but we are convinced there is no fundamental problem.

So the conclusion is hard: Both world views are incompatible! It was recognized early on [20][11]. Historically the basic premise seems to have been that something was missing in the young QM and that one had somehow to repair it. An example of such an attempt is de Broglie - Bohm guiding field theory [18][9][19]. Almost a century has passed and a lot of serious work was done [22][26][33][32][31][28][29][12][30][36][37] and also quite a number of physicists are now strongly convinced of various personally favored interpretations.

As outlined in a recent review of Wharton and Argaman [34] whatever one does on the quantum theoretical side certain aspects of macroscopia have to change as they disagree with Bell type experiments [8]. We here expand this to a more radical position. We consider most aspects we think to know about macroscopia as wrong and only approximately valid and only in our epoch in the universe while we consider quantum dynamics as exactly correct. Including astro physics quantum dynamics is the only theory confirmed on a 16 digit level (for QED anomalous moments [25]). So we take it as a safe base. Our task is then how something like macroscopia comes out of the unamended quantum dynamics.
2 Measurements

The traditional bridge between quantum dynamics and the macroscopic world are measurements. To understand the situation we consider the arrangement shown in figure 1. An electron with an “in the blackboard” spin get split in an inhomogeneous field. Its “up” resp. “down” component enters a drift chamber where lots of photons of various frequencies are produced and a few electrons are kicked of their atoms and collected. Suitable charge coupled electronics flushes “up” resp. “down” on displays.

In the proposed theory there is no true macroscopia but only an effective “for-all-practicel-purposes” one. Nevertheless empirically the rule: “effective macroscopia => no co-exiting pathways” has to hold. So there has to be a decision leading e.g. to figure 2.

What does this decision mean? Many authors consider locality as violated. In the framework of a relativistic theory this is not precise. Consider the needed
part of Bohm’s version of the Einstein-Rosen-Podolsky experiment [10]. A spin-
less ion emits two electrons to form a spin-less ground state. Both electrons
have to have opposite spins. If Bob measures the spin to be in “up” direction
the electron coming to Alice will have a spin in "down" direction and Alice will
measure it and vice versus. If Bob measures the spin sidewise independent of
his result the electron coming to Alice will not know whether Alice will measure
“up” or “down”. So Bob’s decision changes the nature of the electron coming to
Alice.

It is well known Bob is a relatively shy one so he will be at least twice as
far from the exited atom as Alice. So in some Lorentz system Alice will be just
a women of Bob’s past and with his measurement he influences a property of
an electron in his past. Hence what is questioned is causality [28]. It is not a
trivial point:

backward causality ∪ forward causality ⇒ non locality

but

non locality ⇒ backward light cone causality .

A possible defense is to deny ontological reality of the electron wave going
to Alice. One got used to the argument but it is not nice. Most physicist want
to know what is really going on. Nevertheless no-causality is hard to accept
and for the considered situations the Copenhagen interpretation seems most
reasonable. It was advocated by most physicists we admire.

However there are effects [15, 14, 13, 16] which in our opinion change the
conclusion [3]. As they are rarely discussed it will not be easy to convince you.
A quantum statistical effect in high energy heavy ion scattering called Bose Ein-
stein enhancement might be the best hope as it is closest to our background [1].

For non experts the description of high energy heavy ion scattering usually
involves a somewhat simple pictures mixing coordinate and momentum space.
It assumes - not really knowing the actually needed Hamiltonian - that both
incoming round nuclei are in the central Lorentz system both contracted to pane
cake shaped objects. The actual scattering is then assumed to take place when
the pancakes overlap in the narrow region shown as red in the figure 3.

![Figure 3: Two emitted π’s](image)

Lots of particles are produced including two say π⁺’s with the momenta
Q₁ and Q₂. We denote the amplitude as A(1, 2). As π⁺’s are bosons also the
\[ Q_{\text{inv}} = \sqrt{(p_1 - p_2)^2 - (E_1 - E_2)^2} \]

and

\[ C(Q_{\text{inv}}) = \frac{\rho_2(Q_{\text{inv}})}{\rho_{2\text{reference}}(Q_{\text{inv}})} \]

Figure 4: The statistical enhancement

crossed contribution shown as dashed line in the figure has to be included. The probability of such a process is then:

\[
\text{emission probability} =
\]

\[
= \frac{1}{2} |A(1, 2) + A(2, 1)|^2 = \begin{cases} 
2 \cdot |A(1, 2)|^2 & \text{for } Q_1 = Q_2 \\
1 \cdot |A(1, 2)|^2 & \text{for } Q_1 \neq Q_2 \text{ but } Q_1 \sim Q_2 
\end{cases}
\]

For \( Q_1 = Q_2 \) obviously both amplitudes are equal yielding the factor two. In the surrounding area the size of both amplitudes will typically not vary very much but their phase will usually change rapidly eliminating when averaged the interference contribution. The predicted \( Q_1 = Q_2 \) enhancement is observed experimentally as shown in figure 4. The data are from the STAR collaboration. \( Q_{\text{inv}} \) is the difference of the momenta in the center of mass system of the \( \pi^+ \)'s. The normalization of the two particle spectrum \( C(Q_{\text{inv}}) \) uses an estimate obtained by mixing similar events. The observation of the statistical enhancement shown is text book level and beyond doubt [27]. In the last 50 years there were many dozens of large collaborations seeing it.

As a gedanken experiment we consider the following modification. For central scattering the height of the emission area reflects the uncontracted size of the nuclei while the \( \pi^- \)-emission region has the size of a nucleon. One can therefore select events for which one \( \pi \) originates in the upper and one in the lower half. The particle emission is generally assumed to take less then 10 fm/c [21]. One considers an emission happening initially with an Bose enhanced probability. Later on at a time 1 m/c it is suddenly disturbed by a neutron at a suitable position so that the \( \pi \) originating in the lower half will be absorbed. The interference enhancement is gone and with a certain probability the emission has to be taken back:

\[ \implies \text{backward causation for particular emission probability} \]
 emission probability = $\frac{1}{2}|A(1, 2) + A(2, 1)|^2 \sim |A(1, 2)|^2$

Figure 5: Gedanken experiment

This leads us to conclude Copenhagen was not successful to avoid backward causation and it makes sense to change the tradeoff: to give in causality and in exchange to keep ontological real wave functions and fields. Some care has to be taken to exclude gauge choices.

A central ingredient in the backward causation argument is that the transition from the quantum world to macroscopia is somehow process dependent as it is usually assumed. In particle physics hadrons which are produced are commonly taken as macroscopic objects \[7\]. In this way the emission process acts as some kind of measurement procedure fixing the transition point.

An escape is to postpone the measurement collapse. In some form this is what will be advocated. To look at this we go back to our measurement shown in figure 2 and consider the dash dotted green line determining the border between quantum dynamics and fapp-macroscopia. It introduces a “fapp” or more appropriately „Ghirardi-Rimini-Weber“ scale. These authors proposed an exponential decay law process consecutively eliminating the coexisting states of the quantum world to reach a macroscopia without coexistence \[24\].

Our position is that such a scale is not possible. Depending on the situation the required value of this “decay constant” differs by many orders of magnitude. Around rescattering nuclei a femptometer range seems appropriate. In the considered experiment it would have to be in the 10 meter range. For an astronomical version of the interference experiment, the Hunbury-Brown Twiss observation, significant measuring settings corresponding to the introduction of the neutron can occur light years away.

To find a way out one needs to reconsider the situation more carefully and answer two central questions:

What does the measurement has to do?

- Identify states originating in the „up“ or „down“ choice.
- Select one choice, delete the deselected contributions.
- Renormalize the selected one to get a unit probability.
When does the measurement has act?

- Outside the quantum domain!
- Witnesses have to be around encoding the measurement results.

3 The scenario with an extended final state

Our position is that in truly “macroscopic” measurements some witnesses are around practically forever. This allows us to postpone the measurement to the “end of the universe” $\tau_f$. In this way wave function collapses are completely avoided in the „physical“ regions where one just has quantum dynamics.

To illustrate the argument consider Schrödinger’s cat.

If the cruel experiment is done in a perfectly enclosed box all ergodically accessible states will be visited before the end of the world is reached. Practically there is no possibility that specific witnesses can have survived.

In this way the final state at $\tau_f$ can not select a unique macroscopic path way. Macroscopia is an approximation and in the considered very special situation coexisting macroscopic states have to be considered as a given.

How is it really?

Measurable radio frequency fields indicate whether the cat is alive. Usually nobody talks about individual radio frequency photons. They carry an energy of something like unmeasurable $10^{-24}$ Joule.

Some of them will escape the box, the house, and the ionosphere reaching the final state in the sky at $\tau_f$ which then can backward in time select e.g. the macroscopic path with an alive cat and deselect the one with a dead cat.
The exact value of the chosen scale $\tau_f$ is not significant!

Around $\tau_f$ our universe is thin and rather non-interacting. So the witness evolution between $\tau_f$, $10\tau_f$, or $100\tau_f$ etc. is trivial. Obviously a scale choice is not avoided but its value is irrelevant.

**Effective basic rules:**

- The final measurement cannot select / deselect is a quantum path.
- For each macroscopic decision there are enough witnesses that the final measurements can select the complete unique macroscopic path way.

**Definition of an effective final state density matrix:**

The assumed postponement can be written as:

$$<i|U(t-t_i)M_{up}(t)U(\tau_f-t) =: <i|U(\tau_f-t_i)M_{up-evolved}(\tau_f)$$

where $M_{up}(t)$ is replaced by $M_{up-evolved}(\tau_f)$. Here $M$ stands just for the projection part i.e. $M = M \cdot N$ where $N$ is the normalization factor.

With suitable boundary states density matrices one obtains:

$$\text{probability}_M = \frac{Tr(\rho_{\tau_i,i} U(\tau_f-\tau_i) M' \rho_{f,f'} M' U^*(\tau_f'-\tau_{v'}))}{Tr(\rho_{\tau_i,i} U(\tau_f-\tau_i) \rho_{f,f'} U^*(\tau_f'-\tau_{v'}))}$$

Defining $\tilde{\rho}_{f,f'} = M' \rho_{f,f'} M'$ it simplifies to:

$$\text{probability}_M = \frac{Tr(\rho_{\tau_i,i} U(\tau_f-\tau_i) \tilde{\rho}_{f,f'} M' U^*(\tau_f'-\tau_{v'}))}{Tr(\rho_{\tau_i,i} U(\tau_f-\tau_i) \rho_{f,f'} U^*(\tau_f'-\tau_{v'}))}$$

Each of xilion branching of the macroscopic path way requires a "measurement" decision which can be again and again be accounted for in this way by a change of the effective final density matrix finally yielding $\tilde{\tilde{\rho}}_{f,f'}$.

**The dominant state vector approximation**

Without the normalization factor $N$ the effective final density matrix gets extremely tiny (something like $\sim 2^{-\# \text{of all binary decisions}}$). Assuming an expansion:

$$\tilde{\tilde{\rho}}_{f,f'} = c_1 \cdot |f_1><f_1| + c_2 \cdot |f_2><f_2| + c_3 \cdot |f_3><f_3| \cdots$$

one finds something like $c_1 \propto 2^{-\text{huge}}$ and $c_i \propto 2^{-\text{huge'}'}$. As $|\text{huge} - \text{huge'}|$ is of order huge or $\sqrt{\text{huge}}$ the largest term might suffice as indicated in the second line. The argument is of course not rigorous as it assumes e.g. reasonable convergence. The obtained factorization simplifies the description but it is not absolutely essential.

We assume that the same simplification can be applied to the initial state

$$\rho_{i,i'} = |i><i|$$
Relationship to Two State Vector Quantum Mechanics

The factorization postulated above leads to the Two State Vector description of Aharonov and collaborators [6, 5, 4]. This description was carefully investigated over many decades. It contains no paradoxes!

To obtain the Aharonov-Bergman-Lebowitz equation [2] we take all macroscopic measurements as given and accounted for in $|f>$ except for an additional measurement $M$:

$$\text{probability}_M = \frac{|\langle i|U(\tau_i - \tau)f\rangle|\langle i|U(\tau_f - \tau_f)f\rangle|^2}{|\langle i|U(\tau_f - \tau_i)f\rangle|^2}.$$ 

4 The time-ordered causal macroscopia

Causal macroscopia involves a decision tree shown in the figure 8. A decision at e.g. $D_1$ determines the future.

How can a non causal theory underlie such a macroscopic causal decision tree with a time direction?

To explain the proposed mechanism we start with a definition. A “Macroscopic State” $\{|q>\}$ lives in macroscopia and is defined as sum/integral over all states macroscopically indistinguishable from $|q>$. It includes all possible phases between different components and all unmeasurable individual low frequency photons etc.

$$\{|q>\} = \sum_{\text{all states macroscopically consistent with } |q>} |q_i>$$

The full initial and final quantum states allows one single macroscopic path. We now replace the initial and final quantum state by Macroscopic States. In purely classical physics there would be again one pathway from the initial to the hopefully fitting final state. The concept is that if the life time of the universe is extremely long the underlying QM allows for many pathways consistent with macroscopic initial and final states yielding a situation depicted in figure 9.
The source of our causal time direction is our asymmetric position in the universe, i.e. \((\tau_{\text{now}} - \tau_{\text{big bang}}) \ll (\tau_{\text{end}} - \tau_{\text{now}})\). Consider the resulting situation for both directions.

The past evolution is assumed to be too short to allow multiple pathways. With the known cosmic microwave background, with the known distribution of galaxies, and with the largely known astrophysical mechanisms the backward evolution is pretty much determined at least up to the freeze out. The hypothesis is that if all macroscopic details of the present universe - with all the atoms in all the stars in all the galaxies - would be known the past could be determined in an essentially unambiguous way.

The situation of the future is assumed to be long enough to allow for multiple pathways. Driving on the highway one can turn right to Dortmund or left to Frankfurt and one can make a mess in Frankfurt and this will have obvious consequences afterward. That the fixed final macroscopic state at the end of the universe limits what one can possibly do is practically irrelevant.

In reality there are quantum boundary states (i.e. without the \{ \}’s) which yield a unique macroscopic path way. All decisions are actually encoded in the final state which obviously can not contain a time direction. That they happen at the bifurcation points denoted by „D“ is an illusion *faking the causal direction.*
Problems with the fixed final state model

There are no intrinsic paradoxes in the fixed final state model. But some aspects of it are hard to accept:

- The fixed randomness within the final state!
  To maintain Born’s Rule the final state can not bias quantum decisions. It has to be fixed in a random way which is clearly uglier than the random decisions during measurement processes disliked by Einstein.
- Willful agents cannot exist!
  If a chairman wants to signal that a speaker have just 10 minutes left he - as willful agent - has to adjust the final state at the end of the universe in a practically incalculable way. To drop the concept of willful agents is hard to accept. It is not just philosophical. Without a willful chair person a speaker could go on forever.

5 The bidirectional scenario

There is an appealing way out. The basic idea to avoid the fixed final state is to replace it just by a matching one. We here discuss it in a cosmological frame of a bidirectional universe.

Nobody understands dark energy. The observed accelerated expansion can be expected to eventually reverse yielding a possibly topologically complicated

\[ \text{big bang} / \text{big crunch universe.} \]

To avoid hopefully irrelevant complications we consider a simple configuration. The total age of the universe is taken to be \( \tau \) and both the expanding and the contracting phase is assumed to last for \( \frac{\tau}{2} \).

As above all quantum decisions are stored in the initial and final state. Their overlap:

\[
< \text{bang} | \text{crunch} > = \left( \begin{array}{c} \text{evolved} \\
\frac{\tau}{2} - \epsilon \\
\text{bang} \end{array} \right) \left( \begin{array}{c} \text{revolved} \\
\frac{\tau}{2} + \epsilon \\
\text{crunch} \end{array} \right) = \left( \begin{array}{c} \text{extremely} \\
tiny \end{array} \right)
\]

is again something like \( 2^{# \text{all decisions both directions}} \). It also holds for the overlap of the from them unitarily evolved border states at maximum extend.

No „fine tuning“ is involved as no big number is created dynamically. At the border the extremely extended universe has only a tiny fraction of occupied states. So matching is extremely rare. Both strongly entangled evolved states should miss common entanglement pairs. So coexisting path ways are largely excluded.
We assume that for the state of maximum extend one can define something like density function connecting the incoming and outgoing states:

\[ \rho_{\text{max. extend}} = \sum_{i,j} \rho(i, j) |\text{max. extend } (i) > < \text{max. extend } (j)| \]

As the Hamiltonian describing the evolution is hermitian \( \rho_{\text{max. extend}} \) is diagonalizable. With the above argument its smallness means that only a single component dominates, i.e. we can just approximate it as:

\[ \rho_{\text{max. extend}} \sim |\text{border } > < \text{border}| . \]

For the total evolution it leaves two factors:

\[ < \text{bang } | U | \text{border } > \otimes < \text{border } | U | \text{crunch } > \]

No time arrow is accepted, so the expanding world is analogous to the contracting one. For both the „expanding“ and the „contracting“ phases the border state is an effective final quantum state determining the macroscopic pathways. Those the common quantum border state has the consequence:

The expanding and contracting macroscopic pathways are identical.

This result allows an obvious interpretation.

**Injection hypothesis**

To avoid strange partnerships we postulate:

- The quantum states are defined in \([0, \tau]\).
- Macroscopia is taken to extend from \([0, \tau/2]\).

Macroscopic objects (like us) then live

- with their wave function \( \psi \) in the „expanding“ phase \([0, \tau/2]\)
- with their conjugate wave function \( \psi^{\text{CPT}} \) in the „contracting“ phase \([\tau/2, \tau]\).

The proposition has a number of attractive consequences.

**A will-full agent is now possible.**

At the macroscopic time \( t \) corresponding to the quantum times \( t \) and \( \tau - t \) a manipulating agent introduces an operator:

\[ \psi(t) \mapsto \tilde{\psi}(t) = \text{Operator}[\psi(t)] \]
\[ \psi(\tau - t) \mapsto \tilde{\psi}(\tau - t) = \text{Operator}[\psi(\tau - t)] \]

Here \( \tilde{\psi} \) determines the the wave function for \( t < t' < \tau - t \). The manipulation does not introduce a fundamentally new time direction. The asymmetric effect arises from our position in the universe. As \( t \ll \tau \) the added operator does
not affect $\psi(< t)$ and $\psi(> \tau - t)$ but its consequence lies in the macroscopic "future" i.e. $\psi(\in [t, \tau - t])$. After the manipulation a new border component will dominate:

$$\psi(\text{border}) \mapsto \tilde{\psi}(\text{border})$$

automatically reflecting the manipulation. No unusual action of the agent is required.

**Stern-Gerlach experiment**

An agent can prepare a "Stern-Gerlach experiment":

As the drift chambers create macroscopic traces with a large number of witnesses mixed "up"/"down" contributions are excluded.

One can now compare the red and yellow contributions:

$$\text{contributions} \propto \begin{cases} 2^{-\text{decision on paths I and I'}} = 2^{-\text{huge}} \\ 2^{-\text{decision on paths II and II'}} = 2^{-\text{huge}'} \end{cases}$$

As statistically $|\text{huge} - \text{huge}'| \sim \sqrt{\text{huge} + \text{huge}'}$ one contribution will dominate. The choice reflects unknown properties of the available path. The randomness disliked by Einstein found a fundamentally deterministic explanation.

Averaged both contributions are equal:

$$\text{probability (huge > huge')} = \text{probability (huge < huge')}$$

In consequence:

$$\text{prob.} [e_{\uparrow}] = \left( \begin{array}{c} \text{expanding component} \\ e \otimes \end{array} \right) \left( \begin{array}{c} \text{contracting component} \\ e \end{array} \right) = |<e_{\uparrow}|e|>|^2 \quad \text{prob.} [e_{\downarrow}] = \left( \begin{array}{c} \text{expanding component} \\ e \otimes \end{array} \right) \left( \begin{array}{c} \text{contracting component} \\ e \end{array} \right) = |<e_{\downarrow}|e|>|^2$$

the "Born rule" holds. It is no longer a quantity of matching mathematical properties but a direct consequence of the physical process.
Important cosmological consequences

In the cosmological development there can be special situations or early periods where the remoteness of the final state does not allow a macroscopic description.

It demystifies paradoxes. In a closed box Schrödinger’s cat can be dead and alive. The same applies for the grandpa in a general relativity loop used in arguments against backward causation.

It also could affect the view of the early cosmological development. Before QED freeze out the universe is heavily interacting and it is to be expected that there are sooner or later no longer surviving witnesses to fix a unique macroscopic path way to eliminate macroscopic coexistence.

A macroscopic description of the earlier universe could be unacceptable. Even to use a unique macroscopic Hubble parameter H(t) as it used in the Friedmann - Gleichung might be questionable.

Homogeneity of the early universe

At the transition from a period with coexisting macroscopic contributions to one without them unusual components will be deselected and only components close to the average will collectively produce a contribution. In this way a homogeneous contribution is strongly favored.

The initial big bang state in our central causality argument then has to be replaced by this initial homogeneous state. The basic initial state / border state asymmetry needed for the argument stays unchanged.

The universe is actually more homogeneous then expected from simple estimates. It is usually attributed to a limited horizon caused by a rapid expansion of the universe due to inflation. The bidirectional quantum dynamics might offer a way to avoid the complicated requirements of inflation models.

Inflation models have according to a recent work of Chowdhury et al. [17] a serious fundamental problem within the Copenhagen quantum mechanics. One needs to come from an initially coherent state to one allowing for temperature fluctuations. Quantum jumps would do the trick but they are not possible in inflation models as the universe is taken as a closed system without an external observational macroscopia.

Acknowledgments

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Appendix with five simple comments

How decisions come about?

Without willful agents all decision were still encoded in
- the initial state of the expanding universe and
- the initial (i.e. the usual final) state of the contracting one.
They can be random or they may reflect some destiny.
A willful agent breaks the predictability.
This is then exactly the situation of classical physics.

Coexisting quantum paths

A simple example that a final measurement $M'(e_\oplus)$ cannot observe quantum paths is:

Something is Missing in the Lasing Equation?

Textbooks just considering emission and absorption in a differential lasing equation seems to have two manifest shortcomings:
- Why is there no Bose-Einstein enhancement considered?
- How is the coherency and the precise forward direction enforced?

Is something central missing? Considering the spins a rather broad angular region for the emitted photon can be expected.

The transition from QM to macroscopy has to disallow macroscopic backward causation. It requires an effective “correspondence transition rule” stating that phase effects are averaged out if “true” macroscopic quantities are considered.

The differential lasing equation stays in a macroscopic domain. Therefore the rule explains why the simple consideration ignoring phase effects is valid.
De-Broglie-Bohm leads to different predictions

Quantum statistic allows an arrangement where the De-Broglie-Bohm theory and QM lead to different predictions.

Consider a Hunbury-Brown Twiss measurement in which a special star emits photons at two hot spots. The star is looked at light years away with two telescopes. One of them observes one photon. Depending on $\Delta$ the interference contribution will enhance or deplete the normal emission probabilities of a second photon into the second telescope.

To avoid macroscopic backward causation the “correspondence transition rule” mentioned above states the both effects compensate if averaged over a range in $\Delta$. The rule comes out automatically in a De-Broglie-Bohm theory when the photon-particles are produced classically and when the guiding field $\psi$ created by both photons

\[
(\psi^*\psi) \cdot \frac{d\vec{Q}}{dt} = \frac{\hbar}{m_i} (\psi^* \nabla \psi) \text{ for all points on path } Q(t) \]

just pulls the photons out of the depleted region into the enhanced one.

To obtain the decisive arrangement the position of the detectors has to be modified in the enhanced region ($\Delta \sim 0$). The second telescope is moved back to twice the distance adjusting the aperture correspondingly. In its new position it now selects just photons from the upper hot spot.

In the De-Broglie-Bohm theory the pull in the enhanced region is unchanged and one photon will reach the far away detector depending on its origin with 50% of the enhanced probability. In QM the measurement settings abolishes the interference contribution. The probability is now 50% of the normal two photon emission.
Everett’s and fixed-final-state-vector interpretationseens are almost equivalent

Our universe is within the multiversum defined by a community of observers haven witnessed the same quantum decisions.

To have it defined up to the end i.e. \( \tau_f \) our community needs observers until that time. His or her observation fixes the final state. The fate of \multiversum\ equals our universe

is then irrelevant.

If the initial and final state can be written as state vector the last observer changes nothing if he introduces a projection

\[ |\text{final} \rangle < \text{final} \mid. \]

In this way he obtains Aharonov’s TSVF for the universe defined by our observers.
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