The Origins of Quantum Mechanics

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Abstract

A speculation about the nature of quantum mechanics and wave-function collapse. The speculation is that graviation is central to wave-function collapse, and that, perhaps the mechanism of collapse resembles the mechanism of QCD confinement. That is, quantum states cannot be observed for physical systems larger than the order of 1/G, where G is the gravitational coupling (inverse Plank mass). Its hypothesized that entanglement resembles the superfluid state.

This is an attempt to do physics, i.e. to argue with words, instead of doing math. No formulas, just some postulates of things that seem like they are true or should be true. Fairly random and disorganized thoughts.

Intro

So, this is an attempt to unify quantum mechanics with gravitation. Its primarily a discussion of principles that seem like they should guide such a unification. This means few or no equations. Some of these principles may be controversial, and surely some readers will think they're wrong. They might be, but its the groundwork.

This also begins by (almost) completely ignoring the work of others on quantum gravity and strings and Penrose and ER=EPR and AdS/CFT and so-on. I want to state what seem to be "first principles", whereas these existing theories have already made explicit or implicit assumptions about first principles that are (possibly) in contradiction with what I'm pondering. This does not mean that these alternative theories are wrong; but rather, if we start with them, the conflicting principles results in trouble. Thus, I'm trying to start with a clean slate.

Principle: Quantum post facto The concept of quantum mechanics should come out of the unification of QM and gravity, rather than being one of the ingredients going into it. In particular, the Feynman functional integral should be something that comes out of the theory, as an unavoidable result, rather than going into it.

Principle: Quantum is primarily microscopic This is a rejection of the Schroedinger-Cat paradox. I'm not sure, it may be equivalent to a rejection of Many-Worlds. Its a statement about wave-function collapse. The idea is that any quantum effect (e.g. quantum measurement) that causes sufficiently large perturbations in its surroundings causes a "wave-function collapse". The cut-off point seems to be the Planck mass. That is, when the decaying nucleus that kills the cat fires off, it is in a superposition, but only to the point that about one Planck-mass of detector atoms are involved. After that, alternative histories either converge or spontaneously evaporate. So, for example, although there are and continue to be "many worlds" at the quantum scale, once some of these interact with the macroscopic scale, the probabilities of the alternative worlds shrink exponentially to zero.

The argument is that gravitation is too weak to have any significant effect on the microscopic scale, and the fact that an electron might be in many places at once has vanishing gravitational effect, up to the point that the electron has disturbed about 10^{18} atoms, at which point, gravitational effects can no longer be ignored. That is, gravitation remains classical, and there is a single unique space-time geometry at the macroscopic scale. Put another way: if Schrödinger cat is alive, space-time curves one way, and if the cat is dead, then space-time curves another way. There is no superposition of different space-time curvatures. There are not many-worlds of parallel space-times.

Supporting argument: See "Macroscopic states have no phase", below.

Objection: Bose-Einstein states If wave-function collapse occurs at the 10^{18} atom scale, then how does one explain superfluidity, which involves more than that many atoms? Conditional answer: because "true collapse" involves only fermions...

Speculation: Wave-function collapse is like QCD confinement! The speculation here is that wave-function collapse, driven by gravitation, is essentially driven by the same mechanism as QCD confinement, except that the characteristic scale is completely different: systems with more than 10^{18} atoms break up into domains where classical physics dominates, whereas smaller systems can have QM superposition effects run freely inside of them.

The argument here is that QCD confinement occurs for *any* Yang-Mills theory for which the structure group is more complicated than U(1). This certainly should then apply to a spin-2 gauge particle (graviton) with a Yang-Mills type self-coupling in the field-strength term in the action, viz. with structure group SO(3,1) or Spin(4). However, since gravitation is so weak, the scale of the confined region is much much larger, in proportion to the inverse of the coupling.

We seem to kill two birds with one stone: this provides both the mechanism of the collapse, and also to characteristic scale for it. Gravitation provides a scale factor of the appropriate size, confinement provides the mechanism.

Note that QCD confinement remains a Millenium-prize problem.

Speculation: Entanglement is like superconductivity Specifically, that the entangled state of two qubits is like the entangled state of BCS pairs. Long-range order.

There is not one, but two plausibility arguments for this. First, we know from RHIC experiments that the QCD plasma behaves like a superfluid. By analogy, if wave-function collapse is like QCD confinement, then the entangled-state needs to be superfluid-like.

A second plausibility argument is the recent work on treating the surface of black holes as a superfluid; this was in pop press, need to track down the reference.

What is the order parameter? The phenomenology of the two-state vector formalism suggests that the order parameter is some ratio of qubits to classical bits. See, for example, SIC-POVM (symmetric, informationally complete, positive operator valued measure).

Practical: Entanglement is conserved Entanglement is in some sense quasi-conserved, up to the point where its broken.

Is there an "entanglement current"? i.e. what if entanglement is like a conserved charge, is there a corresponding current, where the entanglement "leaked away" during a measurement?

Is there an index-theorem for entanglement? Some generalized Atiyah-Singer-ish thingy?

See above, paragraph "Collapse is Confinement": Entanglement is "conserved" just like superconductivity is "conserved" inside of the region of space where the temperature is low enough. In this case, entanglement "flows freely" in regions of 10^{18} or fewer atoms, and is broken for larger regions.

The analogy suggests that, just like superfluids are a mixture of "normal" and "superfluid" states, then perhaps quantum states can be mixtures of classical and quantum states. Entanglement is the "superfluid" state.

Principle: Space-time is emergent This is kind of a reversal of Verlinde's ideas. The concept of Lorentz invariance isn't possible, until one is working at a scale where spacetime exists. The core issue here is that all of our clocks and rulers are microscopic and quantum mechanical: we measure time by vibrations of some quantum device. We measure space by counting wavelengths. The proposed redefinition of mass in the SI system will also be quantum based.

Phenomenology: Two-state vector formalism The work on weak measurements suggests that the two-state vector formalism (TSVF) seems to be the correct formalism for describing quantum mechanics. The explicit dependence on the future seems to be consistent with the "transactional interprettion of quantum mechanics", where a measurement at the current time seems to reach back in time, to twiddle and reconcile qubits in the past.

From what I can tell, the correctness of the TVSF is embraced in the quantum-computing world, where the positive-operator valued measure (POVM) is the defacto technique by which quantum computing is formulated.

This is meant to provide support for the principle that space-time is emergent. That is, quantum phenomena are not localized in either space, nor in time. The former, we've gotten used to, the latter, specifically, the acausal-like nature of wave-function collapse, still grates on many, but we have to accept it; we even have to accept a "strong" version of it: the future alters the past. However, this "acausality" is limited explicitly to qubits only. Future measurements alter qubits in the past, but cannot alter classical bits, which still flow in a causal, timelike fashion.

Phenomenology: there are no electrically charged bosons Well, there are: W+/-, but that's beside the point, the point being that electrons have spin half and that the spin is the ultimate source for the quantum effects, when coupled to the electric field. Viz spin is a twisting up of space. Rather than treating spin as a representation of the rotational symmetry of space, we should treat spin as a certain tangling up of multiple paths (e.g. paths in the sense of functional integral, or in the sense of Hamilton-Jacobi variational principle) so that we should envision these paths as a kind-of-like Hopf fibration – the paths are the fibers, the resulting fibration is an object that belongs to the 2 representation of SU(2).

That is, we treat quantum paths as if they were fibers, and then ask: how can we tangle them up, so that the grand-total holonomy behaves as if it were a spin-1/2 object? I suspect that such a tangling is impossible, without also pairing the object with a second one, i.e. in the sense of "quantum entanglement".

What does electric charge have to do with this? The idea here is that the electric charge at large distances looks like central-force attractive/repulsive, and so one can ask about the geodesics of the free-falling electrically-charged observer. The free-falling observer does fine, until he gets within a Compton-length of the electron, in which case there's a fibration of multiple paths that become possible.

That is, the point-like nature of the observer/geodesic becomes replaced by a spray(??) so that instead of saying "a single thing is in multiple locations" (as is normally done in QM), we should instead say "there are multiple locations associated with a single thing" (which seems to be the same sentence, but is not): i.e. that spacetime no longer has a simple structure at the microscopic level. The concept of "location" becomes flawed in some certain way.

Nonetheless, Minkowski space seems valid enough between the merely microscopic, and the Planck length, which is truly minuscule. Why?

Phenomenology: Macroscopic states have no phase There is a persistent confusion about the Schrödinger Cat state, which can be resolved by observing that there is no practical way of changing the phase of macroscopic states. There is no device that can do this.

That is, it is commonly suggested that the Schrödinger cat state can be written as

$$|Z\rangle = \frac{1}{\sqrt{2}}\left(|\psi_{\text{dead}}\rangle + |\psi_{\text{alive}}\rangle\right)$$

but the problem/fallacy of the above expression is that there is no practical way of rotating the phase of either "wave-function", e.g. by applying some quantum gate. This implies that there is no way to construct the states

$$|X\rangle = \frac{1}{\sqrt{2}}\left(|\psi_{\text{dead}}\rangle - |\psi_{\text{alive}}\rangle\right)$$

or

$$|Y\rangle = \frac{1}{\sqrt{2}}\left(|\psi_{\text{dead}}\rangle + i\,|\psi_{\text{alive}}\rangle\right)$$

which thus prevents measurements along any other qubit axes than the Z axis. This suggests that the Schrödinger cat "state" is not really a quantum state at all. If one cannot manipulate it as a true qubit, then, by what abstraction are we allowed to pretend that its an actual qubit?

Phenomenology: The nature of a measurement There seems to be a lot of confusion about the nature of a measurement. The quantum eraser seems to highlight that confusion most clearly. The point is this: taking a quantum state, and sending it to two different physical locations, based on projections of its state, is not a “measurement”; it is merely the creation of entangled pairs with spatial separation. So: sending a photon through a birefringent crystal does not constitute a “measurement”; rather, its a just a variation of a two-slit experiment; phase coherence is not destroyed, and the two arms can be treated as the arms of an interferometer; the beams recombined. Similar remarks apply to the Stern-Gerlach magnets: in principle, if the magnetic fields and beam direction were precisely controlled, the phases would not be randomized. There remarks apply, in particular, to the quarter-wave plates and polarizers of the quantum eraser: they are marking, not measuring.

The measurement occurs when the particle interacts with the detector; it is at this point that phase coherence is destroyed, and the situation turns into a Schrödinger-cat situation: there are no devices, no quantum-gates that can rotate a detection+non-detection state into some other orthogonal direction.

Phenomenology: classical approximations of the qubit The use of entangled particles in a quantum eraser setup allows one to at least partly “fake it”: given enough measurements, one can use the record of the measurements, recorded as classical bits, to reconstruct interference patterns, or not, by selectively ignoring certain measurements (i.e. by ignoring certain bit-streams, those bit-streams of classical bits that recorded certain detections corresponding to certain placements of polarizers and quarter-wave places). However, this reconstruction and erasure of interference patterns from classical bits can only be done at certain phase angles: the collected data is not enough to alter the phase, post-facto to any arbitrary value. That is, the quantum eraser setup (with an entangled pair) is enough to classically emulate $|0\rangle + |1\rangle$ but is not enough to emulate $|0\rangle + e^{i\phi}|1\rangle$ for any arbitrary phase ϕ, post-facto (after the measurement).

This does suggest that a tripartite entanglement, e.g. a GHZ state, used in a quantum-eraser setup, might allow one to build a better approximation of a qubit by multiple classical measurements, e.g. at phases at multiples of $2\pi/3$. Continuing in this direction, an entangled state of N particles can be used to approximate a (single) qubit at phase angles of $2\pi/N$.

Continuing in this train of thought, the large-N limit of entanglement perhaps resembles a very highly mixed black hole. This suggests that a series of quantum-eraser-style measurements against such a black hole allows one to model the full Bloch sphere (or a single qubit) with the classical bits recording the results of measurements: in a sense, a single black hole, being the large-N limit, could be taken to represent (or “be”) a single qubit, thus supporting the ER=EPR conjecture.

Speculative framework: fibration Taking the idea that a wave function is a “particle in multiple places at once”, consider then a fibration where the fibres are the different space-time locations for the particle. The base space consists of particles, themselves. Specifically, the base-space is some very high-dimensional representation of a Lie algebra, and the "particles" are the decompisition of that rep into varius irreducible reps. Obvious stumbling blocks: in what sense can a rep be a "space"?

Other stuff Unsorted ideas: mass is an emergent property as well....

Poincare: Poincare - instantaneous acceleration is not directly measurable.

Second Law of Thermodynamics The Second Law of Thermodynamics says that entropy is increasing, and Boltzmann's constant says entropy is mass but this is "upside down" from hawking radiation/entropy. So, there seem to be conflicting ideas: the mass of thermodynamic systems goes up in proportion to the heat energy (see Planck, Max (1907), "Zur Dynamik bewegter Systeme", Sitzungsberichte der Königlich-Preussischen Akademie der Wissenschaften, Berlin, Erster Halbband (29): 542–570 English Wikisource translation: On the Dynamics of Moving Systems) ... so if you melt ice, the mass of the melt-water is greater than that of the original ice. Relatedly, there's a mass loss from binding energy. However, the relation of binding energy to entropy is opaque: when a system is bound, did the number of accessible states decrease? It would seem so: the ionized state is not accessible to the system. However, one does not normally associate an entropy with a QM system, but the goal is to argue that the entropy of hydrogen is less than that of ionized hydrogen.

Hauptvermutung The Hauptvermutung of geometric topology hypothesises that any two triangulations of space are equivalent. It only holds in 2,3 dimensions, but is false in higher dimensions. A necessary condition for it's failing is that the Reidmeister torsion be non-zero for H^3.

The primary idea is that there are some "wild spheres" – fractal, hyperbolic spheres which have boundary-handles that are tangled into knots about each-other. (See the Edwards notes for a construction, see notes by Steve Ferry, chapter 24 for another construction)

If the nature of QCD confinement is that, to the quarks, space looks hyperbolic, so that the surface of the proton appears to be infinitely far away, then the question is, what is the geometry of that surface? Is it some wild sphere? If wave-function collapse appears to be similar to confinement, then the same question applies: are collapsed regions topologically wild?