MARBLEWOOD: A GENTLE UNIFICATION OF QUANTUM THEORY AND GENERAL RELATIVITY

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Abstract. I propose a gentle[1] reconciliation of Quantum Theory and General Relativity. The program for obtaining this reconciliation is to show that:

- *It is impossible* to keep the wavefunction collapse as a discontinuity in the unitary evolution of a quantum system, without violating the local conservation laws.
- *It is ultimately possible*
  - to explain the apparent wavefunction collapse without appealing to discontinuous jumps
  - to account for the Bell correlations, without appealing to nonseparable states
  - to construct the quantum fields in a manner compatible with General Relativity, by using classical fields partitions
  - to clarify the quantum measurements and the interface between the quantum and classical levels
  - to have a nicely behaved energy-momentum tensor of the quantum fields (required by Einstein's equation, which connects the quantum fields with geometry)
  - to have a consistent theory of Gravity and Quantum Standard Model

In General Relativity, the fields should be continuous (even derivable, because the conservation laws are local), and local. I show that we can, in fact, explain the apparent collapse, and the apparent nonlocality associated with the entanglement, using *only continuous and separable solutions* of the Schrödinger equation. This allows Quantum Mechanics to be consistent with General Relativity.

The extension to Quantum Field Theory is realized by using classical fields partitions, which allow the construction of the state spaces and quantum operators needed in QFT, maintaining also the spatial separability. A key ingredient is the Principle of Integral Interactions, which allows only whole particles to be created or annihilated. This principle allows the construction of quantum fields from classical ones. It also helps explaining the quantum measurement problem, and the relation between the classical and quantum levels.

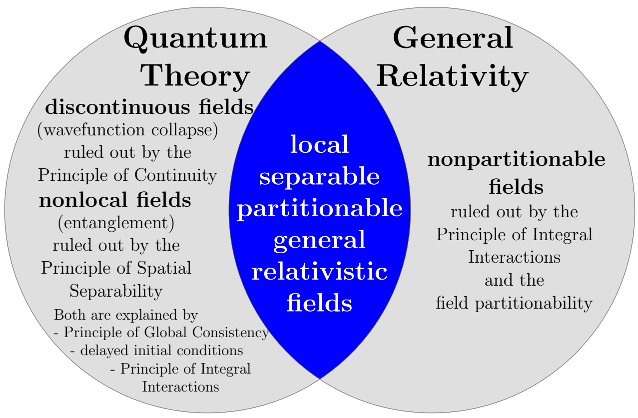

Figure 1. Unification plan for Quantum Theory and General Relativity.

The continuous and spatially separable version of Quantum Theory constructed this way can be easily made covariant. To obtain the unification with the General Relativity, we introduce in Einstein's equation the energy-momentum tensor of the fields partitions. It is then easy to show that we can describe in a unified and consistent way both Gravity and the Standard Model.

I will now detail this research program proposal, showing the steps done so far.

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[1]This unification is *gentle*, because it requires minimal changes to both theories.

1. Principle of Continuity

In Quantum Mechanics, the systems are represented as wavefunctions in a Hilbert space $\mathcal{H}$. They evolve according to Schrödinger's equation:

$$i\hbar\frac{\partial}{\partial t}|\psi(x,t)\rangle = \hat{H}|\psi(x,t)\rangle \tag{1}$$

The observables are Hermitian operators on $\mathcal{H}$. A measurement finds the system in a state described by an eigenvector of the observable. In general, two successive measurements of the same system impose conditions that cannot be satisfied by the same solution of (1). It seems like a discontinuous jump happens between the two measurements.

1.1. Conservation Laws Require Continuity.

The second quantization of Schrödinger's equation leads to a field operator $\hat{\varphi}$ and its canonical conjugate $\hat{\pi}_i = \delta\hat{\mathcal{L}}/\delta\hat{\varphi}_{;i}$. The energy-momentum operator

$$\hat{T}_{ij} = \hat{\mathcal{L}}g_{ij} - \hat{\pi}_i\hat{\varphi}_{;j} \tag{2}$$

has the mean value conserved

$$\langle T_{ij}\rangle_{;k} = 0. \tag{3}$$

The momentum operator is recovered, for a spacelike hypersurface Σ, from $\hat{P}_i = \int_\Sigma \hat{T}_{ij}n^j\mathrm{d}\sigma$. Any discontinuity in the wavefunction's evolution corresponds to a discontinuity in the quantum field, hence to a violation of the mean energy-momentum conservation (3), therefore of the momentum and energy[2]. In fact, at the beginnings of Quantum Mechanics, Bohr was thinking that the momentum conservation is broken, being valid only in average [1, 2, 3], but an experiment proposed [4] by Bothe and Geiger confirmed [5] the conservation.

Let's consider an isolated system made of two electrically charged particles, which initially have definite momenta. During the interaction between them, their momenta can become undefined, but the total system still is in an eigenstate of the momentum operator. Hence the momentum is conserved even if the subsystems are not always in a momentum eigenstate. When the momentum is undefined, we can still have conservation of its mean value and energy-momentum density. When one subsystem becomes again a momentum eigenstate, the total momentum eigenvalues "reassemble themselves from thin air", and the mean value coincides with the eigenvalue. Such a situation occurs *e.g.* if we measure the momentum of a particle, then the position (making the momentum of the particle undefined), and then again the momentum.

The collapse must be continuous, otherwise it violates the local momentum conservation.

1.2. Principle of Continuity.

Principle 1 (of Continuity)**.** The only admitted wavefunctions (in QM) or fields (in QFT) are continuous, and have continuous time evolution. Their partial derivatives are also required to exist and to be continuous, to the degree required by the PDE defining the fields.

For example, (3) requires the energy-momentum to be differentiable, therefore in general $|\psi\rangle$ should be twice differentiable.

This principle also rules out the observables having discontinuous eigenfunctions or distributions, such as the position operator.

But how can we account for the apparent collapse, in a continuous manner?

[2] Similar violations we obtain for other locally conserved quantities, like the electric current density, since they also depend locally on the field.

2. Principle of Global Consistency

2.1. **Delayed initial conditions.** Einstein hoped that, in the two-slit experiment (figure 2), the recoil of the wall containing the slits can tell through which slit the photon passed. But the recoil measurement prevents the interference to happen. Suppose we choose between detecting *which-way*, and the interference (*both-ways*), after the photon passes through the slits, according to Wheeler's delayed-choice version of this experiment. Our choice selects either the which-way past, with a definite recoil of the two-slit wall, or the both-ways past, with undefined recoil. As I showed in [6, 7, 8], in both cases the momentum conservation and the continuity of time evolution are respected, if we admit that the photon's past interactions were such that they fit our choice. By choosing both-ways, it seems that the state was

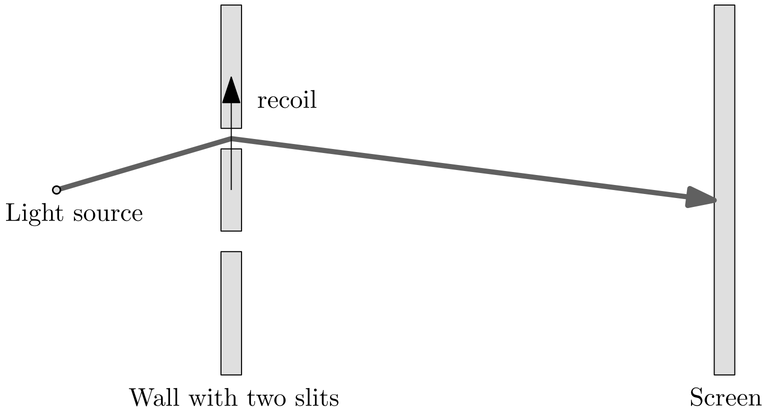

Figure 2. If the photon travels through the upper slit, the two-slits wall recoils upwards.

$$1/\sqrt{2}(|\text{photon up}\rangle \otimes |\text{recoil up}\rangle + |\text{photon down}\rangle \otimes |\text{recoil down}\rangle) \tag{4}$$

and for which-way the state was one of the two terms in the sum.

If the photon was already in a state consistent with our choice, then perhaps the entire past was so. If we pushed back in time the collapse, why not pushing it completely, to $-\infty$, making the evolution continuous? Generally, an observed particle interacted in its past with other systems (*e.g.* the preparation device) and it's entangled with them. The experiment simply chooses from the entanglement (which is a superposition) a solution that fits an eigenstate of the observable. In other words, the two-slits wall interacted with the photon to send it precisely in the needed state [6, 7, 8]. This way, the very *causality principle* seems to require the continuity. *But isn't the selection of the past to fit future choices a violation of causality?*

2.2. **Principle of Global Consistency.** How can our present choice of the observable be consistent with an wavefunction which evolved from an anterior state?

The answer is that both the observer making the choice and the observed system are parts of the same state vector $|\psi(t_1)\rangle$: they both evolved, as subsystems, from the same $|\psi(t_0)\rangle$. Think, as an analogy, at a complex holomorphic function f, which is analytically continuated to z_1 along two distinct paths. If the paths don't enclose singularities, the value of f at z_1 is path independent. Similarly, the same state vector $|\psi(t_0)\rangle$ is, when developed to t_1, responsible both *for the choice* of the observable, and of the initial condition of the *observed system*. Important is the field consistency.

Principle 2 (of Global Consistency)**.** The fields describing the matter should be globally consistent.

This principle is self-evident. I stated it because it contains the main intuition behind our idea of causality. We feel uncomfortable about delayed initial conditions, because we don't want a cause in the present to change the past. But what we really want is that the phenomena are consistent, and there is no reason to worry about this.

Think at a four dimensional spacetime – a block world equally containing the past, present and future. Why the conditions selecting $|\psi\rangle$ among the solutions of (1) be all at an initial time (whatever "initial" may mean), and not spread at various regions in spacetime[9]?

It is not important when the initial data of a field is defined, important is that the solution is globally self-consistent.

3. Principle of Spatial Separability

3.1. **Entanglement without Entanglement.** Two systems are *entangled*, if the composed system's state cannot be expressed as a simple tensor product of states $|\psi_1\rangle \otimes |\psi_2\rangle \in \mathcal{H}_1 \otimes \mathcal{H}_2$, but only as a superposition of at least two such products:

$$|\psi_1^1\rangle \otimes |\psi_2^1\rangle + \ldots + |\psi_1^n\rangle \otimes |\psi_2^n\rangle. \tag{5}$$

Superpositions of this form are also solutions of equation (1). Experimental tests of the violation of Bell's inequality [10, 11, 12, 13, 14] seem to confirm the reality of entanglement.

As in the Einstein-Podolsky-Rosen experiment, finding the first subsystem in the state $|\psi_1^k\rangle$ implies that the second subsystem is in $|\psi_2^k\rangle$. Since there is no discontinuous collapse, it follows that the two states were $|\psi_1^k\rangle$ and $|\psi_2^k\rangle$ even before the measurement. The Bell correlations[15, 16] can be obtained without really having entanglement. The EPR correlations are dictated by the momentum conservation, and not by the particles really being in a superposition of all possible outcomes with the same total momentum. If we can disentangle the particles by measurement, then they were not entangled at all, although they are Bell-correlated.

3.2. **Principle of Spatial Separability.**

Principle 3 (of Spatial Separability)**.** All admitted quantum states of composite systems are separable in space. The time evolution preserves the separability.

I specified *spatial separability*, because there are some states which are not separable, like the singlet state $\frac{1}{\sqrt{2}}(|\uparrow\rangle|\downarrow\rangle - |\downarrow\rangle|\uparrow\rangle)$, entangled in the spin space, or the meson $\pi^0 = \frac{1}{\sqrt{2}}(|u\bar{u}\rangle - |d\bar{d}\rangle)$, entangled in the quark space. The entanglement in these examples is in internal spaces; we accept it as physical, so long as the systems are separated in space.

I mentioned in the discussion of the two-slit experiment (see figure 2) that the interference is usually represented by the nonseparable state (4). In fact, the interference is also a classical wave phenomenon. The photon's wavefunction splits like a classical wave, and the state is in fact a *pseudo-superposition*

$$\left(\frac{1}{\sqrt{2}}|\text{photon up}\rangle + \frac{1}{\sqrt{2}}|\text{photon down}\rangle\right) \otimes \left(\frac{1}{\sqrt{2}}|\text{recoil up}\rangle + \frac{1}{\sqrt{2}}|\text{recoil down}\rangle\right), \tag{6}$$

being separable. The states (4) and (6) differ (except a constant factor) by two crossed terms that appear when we multiply the parentheses:

$$|\text{photon up}\rangle \otimes |\text{recoil down}\rangle + |\text{photon down}\rangle \otimes |\text{recoil up}\rangle.$$

The Hamiltonian contains the potential for the interaction between each pair of particles. The interaction is small for large distances, and for the $|\text{photon up}\rangle$ and the lower slit it can be neglected, hence the entangled state (4) evolves approximatively like (6). I claim that the correct description is given by (6). This works even for more complex molecules, like C60. We expect the differences between (4) and (6) to be visible for more complex systems, explaining why the superposition is not universally present.

3.3. **Hamiltonians and Separability.** Should we worry that two interacting particles can evolve from $|\psi_1(t_0)\rangle \otimes |\psi_2(t_0)\rangle \in \mathcal{H}_1 \otimes \mathcal{H}_2$ into a nonseparable state?

The total Hamiltonian is $\hat{H} = \hat{H}_1 + \hat{H}_2 + \hat{H}_{\text{int}}$. The free Hamiltonians $\hat{H}_1$ and $\hat{H}_2$ act on $\mathcal{H}_1$ and $\mathcal{H}_2$. The interaction Hamiltonian $\hat{H}_{\text{int}}$ acts on $\mathcal{H}_1 \otimes \mathcal{H}_2$ and has two parts:

$$\hat{H}_{\text{int}}(|\psi_1\rangle \otimes |\psi_2\rangle) = \hat{H}_{21}(|\psi_2\rangle)|\psi_1\rangle + \hat{H}_{12}(|\psi_1\rangle)|\psi_2\rangle,$$

where $\hat{H}_{21}(|\psi_2\rangle)$ acts on $\mathcal{H}_1$ and $\hat{H}_{12}(|\psi_1\rangle)$ on $\mathcal{H}_2$. We have the following coupled system

$$\begin{cases} i\hbar\frac{\partial}{\partial t}|\psi_1(t)\rangle = \left(\hat{H}_1 + \hat{H}_{21}(|\psi_2(t)\rangle)\right)|\psi_1(t)\rangle \\ i\hbar\frac{\partial}{\partial t}|\psi_2(t)\rangle = \left(\hat{H}_2 + \hat{H}_{12}(|\psi_1(t)\rangle)\right)|\psi_2(t)\rangle \end{cases} \tag{7}$$

which preserves separability, ensuring the Principle of Spatial Separability.

4. Quantum Fields, Spatial Separability, and Field Partitions

I show how we can quantize classical fields, maintaining separability, by using *field partitions.*

4.1. **Field Partitions.** Schrödinger equation is replaced by a relativistic field equation, *e.g.* Klein-Gordon or Dirac. The classical solutions can be expanded in Fourier series, in terms of negative and positive-frequency eigenstates of momenta. We obtain the particle and antiparticle Hilbert spaces $\mathcal{H}$ and $\overline{\mathcal{H}}$. We represent the system by the number of particles in each state of the orthonormal basis $(|e_i\rangle)_{i\in\mathbb{N}}$ of $\mathcal{H}$, by $|n_1, n_2, \ldots, n_k, \ldots\rangle$, $n_i \in \mathbb{N}$ for bosons, and $n_i \in \{0, 1\}$ for fermions. The creation/annihilation operators for bosons are defined by:

$$\hat{a}^\dagger(|e_k\rangle)|\ldots, n_k, \ldots\rangle = \sqrt{n_k + 1}|\ldots, n_k + 1, \ldots\rangle \tag{8a}$$

$$\hat{a}(|e_k\rangle)|\ldots, n_k, \ldots\rangle = \sqrt{n_k}|\ldots, n_k - 1, \ldots\rangle \tag{8b}$$

and obey the commutation relations

$$[\hat{a}^\dagger(|e_i\rangle), \hat{a}^\dagger(|e_j\rangle)] = [\hat{a}(|e_i\rangle), \hat{a}(|e_j\rangle)] = 0 \tag{9a}$$

$$[\hat{a}(|e_i\rangle), \hat{a}^\dagger(|e_j\rangle)] = \delta_{ij} \tag{9b}$$

The field operator is defined *e.g.* by $\hat{\varphi}(x) = \displaystyle\int \left(e^{-ik\cdot x}\hat{a}(k) + e^{ik\cdot x}\hat{a}^\dagger(k)\right) d^3k$, its conjugate momentum by $\hat{\pi}(x) = \delta\hat{\mathcal{L}}/\delta\hat{\varphi}_{;i}$, and all other observables derive from them. Any state can be obtained from the vacuum state $|0\rangle$ by superposing repeated applications of $\hat{a}^\dagger$.

We saw that we can consider the occupation number representation as primary, deriving the field operators from it. Principle 3 admits only separable states, which can be represented as **field partitions**. For example, $|n_1, n_2, \ldots, n_k, \ldots\rangle$ can be viewed as a classical field Ψ partitioned in the eigenfunctions $|e_i\rangle$

$$\Psi = \underbrace{|e_1\rangle \odot \ldots \odot |e_1\rangle}_{n_1 \text{ times}} \odot \ldots \odot \underbrace{|e_k\rangle \odot \ldots \odot |e_k\rangle}_{n_k \text{ times}} \odot \ldots$$

In general, a partition is specified by

$$\Psi = \underbrace{|\psi_1\rangle \odot \ldots \odot |\psi_1\rangle}_{n_1 \text{ times}} \odot \ldots \odot \underbrace{|\psi_k\rangle \odot \ldots \odot |\psi_k\rangle}_{n_k \text{ times}} \odot \ldots, \tag{10}$$

where $|\psi_k\rangle$ are state vectors of distinct directions from the Hilbert space of one particle $\mathcal{H}$. The symbol $\odot$ means here that the particle currents (*e.g.* for electron is $\bar{\psi}\gamma^k\psi$) are related by

$$j(\Psi) = n_1 j(|\psi_1\rangle) + \ldots + n_k j(|\psi_k\rangle) + \ldots$$

We do not require $|\psi_k\rangle$ to be linearly independent, only to have distinct directions in $\mathcal{H}$. A state vector $|\psi\rangle$ with $\int_\Sigma \rho(|\psi\rangle)\mathrm{d}\sigma = 1$ represents an *integral* particle. If all $|\psi_k\rangle$ are integral, we say that the partition is *integral.* Fields admitting an (integral) partition are named *(integrally) partitionable.* The partition is not unique, so the particles are not uniquely defined. Partitions may not be obvious in any basis, *e.g.* $|1,0\rangle\odot(\alpha|1,0\rangle+\beta|0,1\rangle)$, with $\alpha^2+\beta^2 = 1$, when expressed as $\alpha|2,0\rangle + \beta|1,0\rangle \odot |0,1\rangle$, appears to be a superposition. A partition of a classical field is not implicit in the field, nor in the equation, for the moment it can be considered as an extra structure. A partition of a classical field can be translated in time, by evolving the parts independently.

The second quantization seemed to be required by the negative energies and probability densities of the relativistic field equations. At the time, it seemed a good idea to reuse the canonical quantization, which worked for point-particles, to fields as systems with infinite degrees of freedom. The commutation relations required the field operators. But we can just partition the field into one-particle wavefunctions. We can consider the field partitions as fundamental, because they can be used to completely define the field operators.

The separable quantum fields can be viewed as classical field partitions.

If the quantum field is just a classical field partition, what causes the partition?

5.1. **Interactions.** For the interactions of the classical fields, we use coupled equations. They are described by each field's Lagrangians, plus the interaction Lagrangians, like:

$$\mathcal{L} = \underbrace{\underbrace{\bar{\psi}(i\gamma^k\partial_k - m)\psi}_{\text{Dirac}} \underbrace{-\frac{1}{4}F^{jk}F_{jk}}_{\text{Maxwell}}}_{\text{free}} \underbrace{+e\bar{\psi}\gamma^k A_k\psi}_{\text{interaction}}, \tag{11}$$

to which we add a gauge fixing for A_k, as is required by quantization (it is needed to partition the potential A_k in photons).

During the interaction the electron/positron field may lose quanta from its partition, and the photon field may gain, for example in the electron–positron annihilation $|e^+\rangle\odot|e^-\rangle \to |\gamma\rangle\odot|\gamma'\rangle$. This process is gradual, but the two fields correlate their partitions. Hence, there is an "exchange rate" between the parts of the interacting fields.

5.2. **Principle of Integral Interactions.** When we detect a photon – *e.g.* as passing through one of the two slits – we detect the whole photon, not just a fraction. The detection process changes the number of particles: the photon is absorbed by an atom, triggers a photomultiplier, causes ionizations, a chemical reaction in a photographic plate, anyway, during these processes the number and types of particles is changed (they are *particle-changing* processes).

A "half-photon" (*e.g.* the half transmitted or reflected by a beam splitter) can also interact. Obviously, it can be reflected or transmitted by a mirror, but this kind of interaction is not *particle-changing*. But aren't all interactions realized by exchanging bosons? A photon which is transmitted isn't, in terms of Feynman's theory, a sum over many absorptions and re-emissions? Well, these processes are virtual, they are Feynman diagrams from a perturbative expansion of the interaction in terms of idealized interactions between point-particles. The real process, the transmission, is similar to the classical one, although it can be expressed mathematically by summing Feynman diagrams. In general, if we are able to observe a particle-changing process, then the particles involved change integrally, not partially.

It seems natural to state that the only possible particle changing processes are integral.

Principle 4 (of Integral Interactions)**.** Particle-changing processes can annihilate or create only integral particles.

Particle-changing interactions help defining partitions, which are not necessarily the same as those defined by other particle-changing interactions. Distinct parts of a partition may interfere, combining in another particle of the same type. That's why different particles may interfere [17], despites Dirac's affirmation [18]:

> each photon interferes only with itself. Interference between different photons never occurs.

In every point of the space the field is composed by many individual wavefunctions, which are spread in space. Their interference manifests as fluctuations: when the amplitude reaches a given value, particle-antiparticle pairs may be created.

6.1. **Measurements.** A measurement device (apparatus) extracts information about a quantum system, by interacting with it. Interaction's effects should be stable enough so that we can read them. By construction, an apparatus can be in the following stable states:

- one state $|\text{wait}\rangle$, before performing the observation
- others $|\text{output} = \lambda_i\rangle$ corresponding to mutually orthogonal states of the observed system.

The apparatus can switch from $|\text{wait}\rangle$ to $|\text{output} = \lambda_i\rangle$ only by a particle-changing process. To be observed, a particle has to participate to such a process: it should impress a photographic plate, ionize some atoms, initiate a photomultiplication, *etc.*.

We can detect a particle in only one state, corresponding to one of the stable states of the apparatus. We cannot detect it in a superposition of such states, because the particle can participate only integrally to particle-changing interactions. Hence, the apparatus can be only in one stable state. This constrains the observed particle's initial conditions using the Principle of Global Consistency.

6.2. **The Classical World.** The particles seem governed by superpositions and collapses. *Why then exist objects which don't exhibit superpositions, and don't change discontinuously?*

The Principle of Continuity forbids discontinuous collapse even at the quantum level, and the Principle of Spatial Separability forbids nonlocal fields. But continuous local fields can be used to approximate very well states that look like nonseparable superpositions, as in equation (6). The difference is small for simple systems, as explained in §3, but for more complicated systems may become important.

We expect a world made of waves to look "ghostly". But the Principle of Integral Interactions imposes well-defined "nodes" in the evolution of the waves. These nodes are very distinct, significantly constraining and structuring the wave fields. An atom is stable because the equation governing it has stable solutions, but this doesn't prevent the atom's wavefunction being spread or split. Integral interactions provide interconnectivity of the waves in more structured matter. A four-dimensional view is that the objects are networks of waves, linked by integral interactions. Like Feynman graphs, but with edges being all kind of possible single particle states (which are waves), and the vertices governed by the Principle of Integral Interactions.

Figure 3. Integral interactions of wavefunctions.

Particles propagate and interact like waves, except for the particle-changing interactions, when they behave like indivisible quanta.

From this discussion we see that we can have macroscopic waves and interference, and even Schrödinger's "kittens", but they are in fact separable pseudo-superposition.

What about Schrödinger's cat, can it be in the superposition $|\text{dead}\rangle + |\text{alive}\rangle$? Standard Quantum Mechanics sees here no problem, because of linearity. On the other hand, in order to split Schrödinger's cat we need to have the Geiger counter in a state $|\text{click}\rangle + |\text{not click}\rangle$, which means "half of click", or "half of particle-changing interaction". Schrödinger's cat needs not to worry, because the Geiger counter cannot simultaneously detect and not detect radiation, because of the Principle of Integral Interactions.

7.1. **Field Partitions in Curved Spacetime.** For Special Relativistic fields, the vacuum solution is Poincaré invariant, and so is the Fourier decomposition of fields. But in noninertial frames, the things are different.

But by passing to a noninertial coordinate system, both the vacuum state and the decomposition are completely different. Particles' numbers and types depend therefore on the coordinate system. This may lead to Unruh effect and Hawking radiation.

The field equations (Dirac, Maxwell, Yang-Mills) are replaced on curved spacetime by their covariant versions. The Principles 1-4 can be extended without problems to curved spacetime:

- continuity and consistency are obviously the same as in flat spacetime
- field partitions remain field partitions
- the particles still remain separated, and the Principle of Spatial Separability still can be required without problems
- Principle 4, of Integral Interactions, still holds, because the property of a field to be integral is generally covariant.

7.2. **The Energy-Momentum Tensor.** One difficulty in QFT in curved spacetime is the problem of the backreaction. The spacetime geometry is related to the matter fields by Einstein equation

$$R_{ij} - \frac{1}{2}Rg_{ij} + \Lambda g_{ij} = \frac{8\pi G}{c^4}T_{ij} \tag{12}$$

where $R_{ij} = R^k_{ijk}$ is the Ricci curvature tensor, $R = R^i{}_i$ the scalar curvature, G, c, and Λ are respectively the gravitational constant, the speed of light, and the cosmological constant.

Because in standard QFT the fields are replaced by operator-valued distributions, in Einstein's equation the energy-momentum tensor is thought to be replaced by the expectation value of the corresponding operator, $\langle \hat{T}_{ij} \rangle$ (see *e.g.* [19]). But $\hat{T}_{ij}$ is expressed in terms of $\hat{\varphi}(x)$, and we have to multiply distributions running into problems that can be solved only by renormalization.

Instead, if we use field partitions, what we have is the classical field. It is exactly like a classical field, with the additional constrains that it is partitionable and satisfies the Principle of Integral Interactions. We can use in Einstein's equation its (classical) energy-momentum

$$T_{ij} = \mathcal{L}g_{ij} - \pi_i \varphi_{;j}. \tag{13}$$

Since the quantum fields are just integral partitions of classical ones, we obtain the desired unification between Quantum Mechanics and General Relativity.

7.3. **Quantizing Gravity.** The following remark of Dirac [20] contains the main reason for searching a quantization of gravity:

> There is no experimental evidence for the quantization of the gravitational field, but we believe quantization should apply to all the fields of physics. They all interact with each other, and it is difficult to see how some could be quantized and others not.

In the theory presented here, the source of gravity is the energy-momentum of the partitionable fields, to which quantization resumes. Any property the fields may have manifesting as quantization, there is a corresponding property of the Ricci tensor, and therefore of gravity.

Constraining an expression on which the curvature depends, we constrain the curvature, which in turn constrains the metric tensor, hence the geometry. In other words, *the metric should be such that its curvature corresponds, via Einstein equation, to partitionable fields.*

The spacetime is a four-dimensional semiriemannian spin manifold M with Lorentz metric g of signature $(+---)$. There is a spinor bundle over M, corresponding to the tangent bundle and the metric g, with the structure group $\mathrm{SL}(2,\mathbb{C})$, and a G_{SM}-bundle $G_{SM}(M) \to M$, where $G_{SM} = \mathrm{U}(1)_Y \times \mathrm{SU}(2) \times \mathrm{SU}(3)_C$ is the standard model group. The product of the two bundles is a $\mathrm{SL}(2,\mathbb{C}) \times G_{SM}$-bundle over M. The fundamental fermions (leptons and quarks) are sections in associated vector bundles, solutions of Dirac's equation. The forces come from potentials A^{μ} defined as connections on $G_{SM}(M)$, whose curvatures define the Yang-Mills and Maxwell fields $F^{\mu} = \mathrm{d}A^{\mu}$ (the electroweak and strong forces). The Bianchi identity provides half of the Yang-Mills and Maxwell equations, $\mathrm{d}F^{\mu} = 0$, the other half coupling the force fields with the Dirac fields $\mathrm{d}^{*}F^{\mu} = e\bar{\psi}^{\mu}\gamma^{k}\psi^{\mu}$.

The fields involved in these equations are partitionable. The partitions are defined locally by the Principle of Integral Interactions. The Principle of Integral Interactions is likely to have the origin in topological conditions imposed to the fields (examples of topological solutions are solitons, monopoles, and instantons). Starting from the field partitions, we can construct the occupation number representations and the operators needed in QFT. We admit only the spatially separable states. The Principle of Spatial Separability manifests as the classical field partition interpretation of quantization. Despite separability, entanglement-like effects still are allowed, but it turns out that the system was all the time in the separable state in which it is find by measurements. The continuity is also a necessary property of dealing with classical fields. The wavefunction collapse can happen continuously, by delayed initial conditions. From a temporal viewpoint, the wavefunction evolves continuously toward the eigenstate in which is detected. The Principle of Integral Interactions makes the measurement problem and the relation between the quantum and classical levels transparent.

The metric is determined, according to Einstein's equation (12), from the energy-momentum of the matter fields. There is no need for special quantization of gravity, since the energy-momentum tensor already contains the quantization of matter fields, in the form of field partitionability.

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I submit to the reader's attention my program of reconciliation between General Relativity, the classical level, and Quantum Theory.

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