Quantum Mechanics, preonic vacuum and space-time contradiction

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In a previous paper, we pointed out that the mathematical properties of a spinorial space-time (SST) can have strong implications for Quantum Mechanics and even be its real origin. In the example presented, the function of space-time associated to the extended internal structure of a standard spin-1/2 particle at very small distances turned out to be potentially incompatible with a continuous motion. Such an incompatibility would be due to the overlap in the time variable between internal structure functions, generated by continuous motion. Discrete motion enforced by vacuum dynamics can then lead to a situation close to that described by the Feynman path integral at larger scale distances. We discuss here this phenomenon on more general grounds, and emphasize that it can be present in a wide variety of preonic patterns involving new space-time geometries at the smallest scales inside the standard "elementary" particles. Potential experimental implications and checks of such an alternative to standard renormalization and Quantum Gravity are also briefly discussed.

1. Introduction

The origin and the ultimate nature of Quantum Mechanics stay by now unknown. It remains, in particular, to be understood whether Quantum Mechanics is really an ultimate fundamental property of matter or a consequence of a deeper (preonic) dynamics.

In [1], we presented an explicit attempt to enforce Quantum Mechanics starting from a more fundamental scenario. A spinorial space-time (SST) with a pre-existing vacuum dynamics involving a preonic picture was used to provide an explicit example of such a possibility. Quantum Mechanics can then be a direct consequence of an original spinorial time uncertainty.

We point out here that, even if some properties of the SST seem compelling, the basic features of the situation described in [1] appear to be more general in preonic and similar patterns.

In the SST, the time spread of a spinorial extended function was shown to generate an overlap between solutions "centered" at different times. Such an overlap can lead to an overall structure incompatible with the same dynamics that produces an isolated single particle solution to the basic vacuum equations for a given "central" time. This incompatibility would prevent continuous motion of standard particles.

How general can be the kind of mechanism developed in [1], and what is its basic content beyond SST? Why should the ultimate structure of matter follow automatically the cosmic and macroscopic definition of space and time, instead of generating locally its own independent space-time at very small distance and time scales as suggested in the SST example?

In standard Physics with a standard flat space-time, there is no obvious contradiction between the macroscopic space-time and the space-time felt by ultimate matter at very small scales. But the situation can be radically different if the macroscopic space-time incorporates a curved space and a time origin of the Universe, and if simultaneously an ultimate structure of matter exists beyond standard particles at very small scales. Quantum Mechanics can then be the dynamical expression of a contradiction between the two space-time structures.

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2. The spinorial space-time (SST)

The SST geometry was introduced in 1996-97 [2, 3] to describe a real world where fermions exist and must be actual representations of the group of space rotations. It naturally incorporates spatial rotation invariance, but not necessarily special relativity that can be viewed as a property of standard matter rather than a fundamental space-time symmetry [4, 5].

A space-time with SU(2) and two complex coordinates replaces then the four standard real space-time coordinates and the rotation group SO(3). Its properties, including possible cosmological implications, have been discussed in several papers such as [6, 7], [8, 9] and [10].

If ξ is a cosmic SU(2) spinor in the SST, the cosmic time is obtained through the positive SU(2) scalar $\mid \xi \mid$ such that $\mid \xi \mid^2 = \xi^\dagger \xi$ where the dagger stands for hermitic conjugate. A possible definition of the cosmic time, in principle equivalent to the age of the Universe, can then be $t = \mid \xi \mid$ with an associated space given by the S^3 hypersphere $\mid \xi \mid = t$ incorporating an additional spinorial structure that does not exist in the standard space. A brief reminder of the SST geometry can also be found in [1].

2.1. The space-time contradiction

In [1, 10], we assumed that, similarly to the cosmic SST with the associated SU(2), a local spinorial space-time with its own SU(2) group can be considered for each point ξ_0 in the SST, taking ξ_0 as the local origin. The internal properties of the standard "elementary" particles would then be described by internal structure functions taking values in the local SST.

Then, a contradiction between the space and time coordinates as defined by the local SST and those generated by the cosmic SST immediately appears. The local arrow of time can even be opposite to the cosmic one. To handle this situation, we considered in [1, 10], for spin-1/2 particles (electron...), internal structure functions Ψ_{sp} $(\xi - \xi_0)$ taking values in a four-dimensional space-time domain around ξ_0. But similar problems would arise trying to use structure functions with values in a three-dimensional, ill-defined, space domain.

To avoid such a space-time contradiction leading to a time overlap between solutions of the fundamental equations, the vacuum dynamics can forbid continuous motion and enforce in practice a discrete motion leading at larger distance scales to a situation similar to that described by the Feynman path integral. This would then be the dynamical (preonic) origin of Quantum Mechanics.

3. Preonic patterns and the definition of time

If the standard "elementary" particles are actually excitations of a more fundamental preonic structure, we do not expect the critical speed of preons to be equal to the speed of light c . Just as c is much larger than the speed of sound in condensed matter, the critical speed of preons will normally be much larger than that of light [11, 12]. Superluminal preons (superbradyons) inside vacuum can "see" space and time in a different way from standard matter.

3.1. Superbradyons and space-time

Assuming superbradyons can also exist as free particles in our Universe with a critical speed c_s much larger than the speed of light c, it was already pointed out in [3] that:

"A superluminal particle moving at speed $\vec{\mathbf{v}}$ with respect to the vacuum rest frame, and emitted by an astrophysical object, can reach an observer, moving with laboratory speed $\vec{\mathbf{V}}$ with respect to the same frame, at a time (as measured by the observer) previous to the emission time. Such a phenomenon will happen if $\vec{\mathbf{v}}.\vec{\mathbf{V}} \; > \; c^2$, and the emitted particle will be seen to evolve backward in time (but it evolves forward in time in the vacuum rest frame)."

(end of quote)

This conclusion was based on a simple calculation. In the rest frame of a standard particle moving with speed $\vec{\mathbf{V}}$ with respect to the vacuum rest frame, if $\vec{\mathbf{v}}$ is the speed of the superluminal particle with respect to the vacuum rest frame and assuming for simplicity $\vec{\mathbf{v}}$ to be parallel to $\vec{\mathbf{V}}$, the speed $\vec{\mathbf{v}'}$ of the superluminal particle in the rest frame of the standard particle (the laboratory frame) is given by:

$$\vec{\mathbf{v}'} \ = \ (\vec{\mathbf{v}}_i \ - \ \vec{\mathbf{V}}) \, (1 \ - \ \vec{\mathbf{v}}_i.\vec{\mathbf{V}} \, c^{-2})^{-1} \quad (1)$$

leading to a singularity at $\vec{\mathbf{v}}_i.\vec{\mathbf{V}} \ = \ c^2$ which corresponds to a change in the arrow of time

At $v \ > \ c^2 \, V^{-1}$, a superluminal particle moving forward in time in the vacuum rest frame appears as moving backward in time to an observer made of ordinary matter and moving with speed $\vec{\mathbf{V}}$ in the same frame.

It clearly follows from this explicit example that the mathematical connection between macroscopic and preonic time is far from trivial and can involve significant contradictions. In general, we do not expect to find superbradyons traveling around us at a speed larger than c because of their "Cherenkov" decay in vacuum [7, 11]. Free superbradyons are expected to interact weakly with standard matter. They may have kept a speed close to c or lost energy in further collisions with "ordinary" particles. They can in any case be a significant part of the cosmic and galactic dark matter.

High-energy astrophysical events can involve superbradyon emission at speeds larger than c .

4. Preonic vacuum and space-time

Standard Quantum Field Theory (SQFT) develops a purely phenomenological approach to vacuum structure, where the only relevant information concerns boson condensates and the bosonic zero modes. Nothing is known in SQFT about a possible underlying preonic structure that can in particular replace such boson condensates and zero modes at the high energy scales and naturally solve in this way the cosmological constant problem [6, 7].

4.1. Preons and Quantum Field Theory

Obviously, the theory of Quantum Gravity would be strongly modified by a preonic scenario that would invalidate the standard role of the Planck scale, by dynamically generating Quantum Mechanics at a lower energy scale and at larger space and distance scales.

SQFT would also be undergo increasing modifications as the distance scale decreases and the effects of the underlying preonic structure become more able to influence dynamics and calculations [6, 7]. Renormalization may thus become an easier task for unsolved problems.

4.2. Open questions

A first question that can be raised is that of the vacuum rest frame (VRF), already considered in [11, 12] when formulating the superbradyon hypothesis. The natural assumption is to identify the VRF with the reference frame of the cosmic microwave background radiation that can in turn be identified with the associated comoving frame of the cosmic SST.

But, strictly speaking, this astrophysical determination of the VRF is based only on standard matter measurements and it is not certain that it would correspond exactly to the internal rest frame of a preonic vacuum.

The internal space-time structure of the preonic vacuum is expected to incorporate some crucial aspects of the SST, so as to be able to generate and describe spin-1/2 standard particles. But apart from this requirement, a more general view of space and time is in principle allowed and can lead to a similar birth of Quantum Mechanics from a space-time contradiction between the fundamental preon dynamics and the macroscopic world.

5. Some experimental considerations

The possible tests of standard basic principles with ultra-high energy cosmic-ray (UHECR) data has already been discussed in previous papers [10, 13], including possible deformations of Quantum Mechanics [14]. But the experimental and instrumental achievements of the recent period can also make feasible some direct searches for free superbradyons.

Thirty years ago, Goodman and Witten suggested [15] dark matter detection through nucleus recoil, the maximum recoil energy being $\epsilon = 4\ E\ m/M$ where E and m are the kinetic energy and the mass of the incoming particle, and M the mass of the target nucleus. Detectors developed for this goal include superheated superconducting granules [16, 17], crystal scintillators [18] presently used by DAMA/LIBRA [19] or the luminescent bolometer [20, 21] currently used by CRESST [22].

For a dark matter superbradyon with speed c [7], the same formula used by Goodman and Witten would yield $\epsilon = 8\ E^2\ (Mc^2)^{-1}$ for an incoming momentum $p = 2\ E\ c^{-1}$. But the most interesting signature in this case would possibly be the explosion of a target nucleus due to an energy transfer or the order of 1 GeV or larger.

Superbradyon production at high-energy accelerators should also be considered, looking for atypical events with a large missing energy without a significant missing momentum. The rest energy $m\ c_s^2$ where m is the superbradyon mass, or the superbradyon kinetic energy, would be much larger than $p\ c$ where p is the momentum of the produced particle. A spontaneous decay of the particle may complete such a signature.

Detecting a high-speed superbradyon (with velocity $v \gg c$) emitted by an astrophysical explosion or a similar event would be a unique scientific opportunity. But the probability of such a performance seems difficult to estimate.

Cosmology can possibly provide an additional signature, with a preonic era replacing the Big Bang + inflation scenario [5, 12].

6. Conclusion and comments

In [1], a possible fundamental origin of Quantum Mechanics was suggested using the SST geometric structure together with the internal dynamics of a preonic vacuum. The time dispersion of the spinorial extended objects played a crucial role in the new mechanism considered, to prevent a continuous motion of standard spin-1/2 particles and enforce Quantum Mechanics.

We point out here that such a basic mechanism, originating in a local preonic arrow of time different from the cosmic one, can actually be generated in a larger variety of vacuum structures with various internal space-time geometries generalizing the SST example. The concept of space-time contradiction between the preonic vacuum and the macroscopic world applies to all these situations.

A crucial question concerning the mathematical space-time structure of the preonic vacuum is that of the critical speed of preons. In connection with this basic interrogation, the direct experimental search for free superbradyons becomes an important and essential subject.

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