THE WORLD COULD NOT BE BORN FROM A FLUCTUATION OF A QUANTUM VACUUM

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ABSTRACT. The thesis of the title is an ineluctable consequence of the essential role which is played in quantum theory by the effectual measuring acts. (Role particularly emphasized by Bohr and Heisenberg).

Summary – **1**, **2**. Introductory considerations. – **3**, **4**. The vacuum fluctuations in quantum theory and the role of the measuring apparatuses. – **5**. In the absence of any experimenter the vacuum fluctuations of a potential universe cannot give origin to a real universe. – *Appendix*: On Friedmann's universes. – *Parergon*: On a Bohr's remark. –

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1. – A preliminary consideration, *ad usum Delphini.* The *a priori* probability that throwing a die a given face F comes out is equal to $1/6$, as it is well known. Obviously, for the face F to actually come out, it is necessary that a player throws the die. Spontaneously, no face of the die can come out: the dice do not possess the property of self-throwing. (The concept of *a priori* probability must not be confused with the concept of statistical frequency).

2. – It has been suggested [1] that the universe could be born by virtue of a fluctuation of the vacuum as it is defined in the quantum theory of fields. We intend to show that this hypothesis is actually *in contradiction* with a fundamental concept of quantum theory, and it is thus untenable.

3. – As it was remarked by Heisenberg in 1934 [2], in quantum electrodynamics the electric-charge operator of a charge contained in a volume element does not commute with the total-energy operator, and therefore, in the state of lowest energy – which represents *by definition* the vacuum – there exists a certain *a priori* probability that the charge in a volume element has values different from zero. This means that *if – and only if – we perform some appropriate measurements*, observable values of the charge can be actually found. In the absence of any experimenter – or of any suitably prepared measuring apparatus –, no observable charge can really appear.

4. – In more general terms (see, *e.g.*, Heitler [2]), the vacuum fluctuations of quantum electrodynamics are a consequence of the fact that we have a pair-creating interaction H_{int}, and that a complete absence of free (*i.e.*, non-interacting) electrons, positrons, and photons is *not* an energy eigenstate. The eigenstate of lowest energy – *the vacuum* – can be expanded in a series of states of non-interacting particles, which contain virtual photons and virtual electron-positron pairs. Accordingly, we can say that there is a given *a priori* probability to find some *real* particles in space at any time. However, any practical realization of this theoretical result requires that *we perform some suitable measurements*. *Sponte sua*, no real particle will ever appear.

5. – If we make the hypothesis that prior to the first instant of a postulated big-bang, we had a potential (in the Aristotelian meaning) universe in the vacuum state (as defined by a perturbative quantum field theory), we can affirm that, by virtue of the quantum fluctuations, there existed a certain *a priori* probability for the occurrence of some *real* particles in space at any time. However, in the absence of any real experimenter and of any real measuring apparatus, no measurement could be obviously carried out, and therefore *our potential universe was doomed to remain in the surmised vacuum state.* –

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Appendix

$\boldsymbol{\alpha}$) As it is well known, the mathematical basis of any big-bang model of universe is given by Friedmann's equations, which tell us that we have a *monotonic expansion* if the curvature of the space sections $t = \text{const}$ is zero or negative, and a *periodic oscillation* if this curvature is positive. These general-relativistic models are *isomorphic* to corresponding Newtonian models [4], for which there is a monotonic expansion if the total energy is zero or positive and a periodic oscillation if this energy is negative.All models start from a point singularity of infinitely high density. The existence of a periodic-oscillation solution shows that there is no need of a separate mechanism by which the universe "bounces back" from a contraction. (A contrary opinion was affirmed in [1]).

The mentioned isomorphism implies significant consequences with regard to BH's and GW's [4]. From the cosmological point of view, the great simplicity of the Newtonian analogues warns us against the attribution of an eminent physical meaning to Friedmann's universes, –

β) In general relativity the metric tensor "is" the physical spacetime. Now, no spacetime exists in Friedmann's models prior to the big-bang. On the other hand, if we consider the vacuum of a quantum field theory as a potential universe, we postulate consequently the contemporaneous existence of a Minkowskian spacetime: a strong characterization for a universe that is still non-existent.

Parergon

In sect. **4** of Heisenberg's book quoted in [2] we find a striking instance of the decisive role of the measuring acts in quantum theory. Let us consider a hydrogen atom in its lowest stationary state; the probability density $|\Psi(r)|^2$ decreases exponentially with the increase of the distance of the electron from the proton. There is always a *finite* probability to find the electron also at *great* distances from the atomic nucleus. The sum of the positive kinetic energy and of the negative potential energy (which is very small, in absolute terms, if the electron is very far from the proton) is positive, while the total energy of the considered stationary state is always negative. This paradox can be simply solved as follows: the violation of the energy conservation is only apparent, because it is necessary to take into account also the energy of the photon which we employ for measuring the position of the electron. Now, the energy that the photon imparts to the electron is remarkably greater than the ionization energy of the atom, and it assures the validity of the energy conservation – see the theory of the Compton effect. As it was emphasized by Bohr, the above paradox tells us that the statistical assertions of quantum theory must not be understood in a cursory way. –

References

[1] E. P. Tryon, *Nature*, **246** (1973) 396.

[2] W. Heisenberg, *Ber. Sachs. Akad. Wiss* (1934) 217. In sect. **4** – "The uncertainty relations and the measuring apparatuses" – of *Die physikalischen Prinzipien der Quantentheorie* (S. Hirzel Verlag, Leipzig – 1930) Heisenberg wrote: "The statistical assertions of quantum theory have [...]a meaning only in connection with the experiments that make an observation actually possible ..." (English translation by A.L.).

[3] W. Heither, *The Quantum Theory of Radiation*, Third Edition (The Clarendon Press, Oxford) 1954, sect. **28**; and also N. Bohr and L. Rosenfeld, *Det. Kgl. Dansk. Vid. Selskab.*, XII (1933) Nr.8; *Phys. Rev.*, **78** (1950) 794. See further N.N. Bogoliubov and

D.V. Shirkov, *Quantum Fields* (The Benjamin/Cummings Publ. Comp., Inc., Reading, Mass.; *etc.*) 1983, Chapt. VIII.

[4] A. Loinger, *arXiv:physics/0504018* – April 3rd, 2005. As it is known, Friedmann's models and their corresponding Newtonian models can be modified with the addition of a *cosmological term*.

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