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Test of Quantum Physics from Earth-Moon correlations.

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Abstract

Standard Quantum Physics states that the outcome of measurements for some distant entangled subsystems are instantaneously statistically correlated, whatever their mutual distance. This correlation presents itself as if there were a correlation at a distance with infinite speed. It has been experimentally verified over distances up to 18 km with a time resolution of a few picosecond, which can be translated into an apparent effective correlation speed larger than 10^7c. Here we discuss the scientific interest and the feasibility to extend the correlation distance up to the Earth-Moon distance, i.e. 2 10^4 times larger than in present experiments. We are thus led to propose to install on the Moon a polarimter and a high performance photon detector with a high temporal resolution.

1. Introduction

Quantum physics is presently the most robust Fundamental Theory. Contrary to General Relativity which is at the verge to be modified if Dark Energy is confirmed, it has remain unchanged since its creation in the late 20's, in spite of several attempts to modify it But quantum measurement raises the most profound question in Physics. Its paradoxical nature has appeared with the Born principle that the outcome is not predictible. This has as consequence that the outcome of measurements on two subsystems of a system are correlated in a non classical way. Non classical means here that the hypothesis of local hidden variables leads to predictions in contradiction with standard Quantum Physics.

2. The present experimental situation

There is no internal logical contradiction in Quantum Physics and up to now no contradiction with experimental results. The problem of Quantum Physics raised by several physicists rather resides in the contradictions between Quantum Measurement Theory and everyday life intuition and some philosophical prejudices. One of the paradoxes is the description of a measurement coming from the Von Meuman state vector reduction axiom. If the measuring apparatus is described as a physical system represented by a state vector and the measurement by an interaction represented by an interaction hamiltonian, the final state of the apparatus is a superposition of states representing the measurement results, contrary to the fact that single measurements have single outcomes.

This situation has led to several alternative theories such as the Bohm-Vigier theory of non local hidden variable carried by a « sub-quantume» medium and the « spontaneous collapse » theory [1]. In a vein completely different from a Bohmian-like Theory, let us mention the possibility of a gravitationally induced collapse of the state vector [2]. It touches the rôle of classical space in Quantum Theory, one of the most profond aspects of Quantum Theory, This unclear relation between classical space and Quantum Physics was already pointed by N. Bohr's claims that « Quantum Physics transcends [classical] space and time ». This would have probable consequences for a quantum treatment of gravity.

According the standard Quantum Physics postulates, there is no limit in the above mentionned correlation distance. The correlation at-a-distance has been experimentally proven up to 18 km [3]. The question one may raise is « does the validity of the correlation at a distance hold for any distance up to infinity, or is there a limiting distance? » A limiting distance would constitute a new Fundamental Constant and would force to change these postulates.

It is not unreasonable to consider the possibility that at some distance instantaneous correlations may disappear. Are we indeed really ready to accept that it is valid up to infinity? In the Bohm-Vigier theory where correlations are carried by a « sub-quantum » medium, the only constraint is that the transportation speed is larger than the present experimental limit (10^7 c in case of the Salart et al. Experiment [3]). There is no fundamental principle in the Bohm-Vgier theory requiring that this speed is infinite.

Salart et al. [3] express the correlation in terms of speed of some propagation, which would imply that « something » propagates. But from a conceptual point of view one has to dissociate a propagation speed V from a possible distance upper limit D. Four options are a priori possible:

- Correlation distance extended up to infinity, instanteneously (i.e. with zero time delay): it is the prediction of standard Quantum Theory, but also possible for instance in a Bohmian Theory.
- Instantaneous correlation distance limited to some value D (with for instance a correlation factor damping exponentially with a length scale D). The « speed of propagation » of correlation would then be infinite.
- Infinite correlation distance, but with a finite speed of propagation V.
- Finite correlation distance, with a finite speed of propagation V

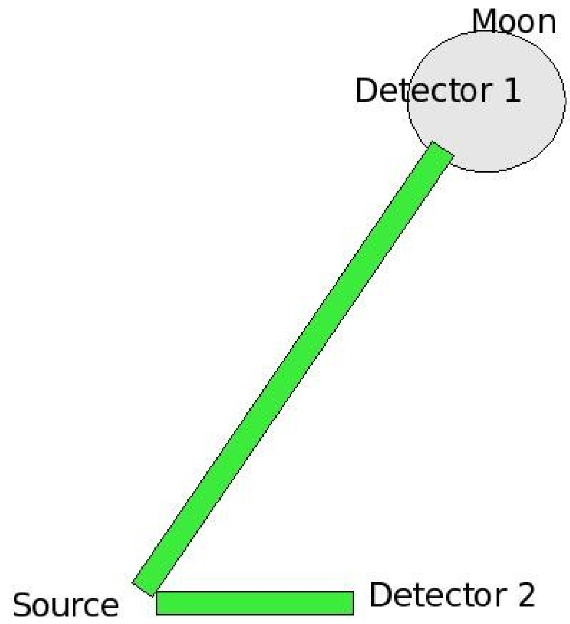

Figure 1: The experiment consist in measuring correlation of photon polarization states in detecors 1 and 2, in a Bell-type experiment

A Bohmian-like Theory would be compatible with the last three options.

3. A proposed experiment from the Moon.

Here we propose to use a **Lunar base** to make similar experiments. The gain in distance compared to ground-based experimenys would be a factor 20,000.

In the proposed set-up, a powerful laser source is installed on Earth, with one branch pointing toward the Moon. In a future Lunar base a polarimeter and a photo detector to be installed on the Moon. The other branch, with a second polarimeter and detector would be on Earth. The experiment would consist in measuring the statistical correlation between photons counts as a function of the relative orientation of polarizers, like in the classical Salert et al . experiment [3]. See Fig. 1.

The detector on the Moon would not require a full Lunar Base. It could be an automatic photon detector and tunable polarizer with a total mass of a few tens of kilogrammes (including the power supply).

References

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