Laboratory-Scale Test of de Broglie s Tired-Photon Model

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An experiment, feasible on a laboratory scale, to test the de Broglie tired-photon model is presented. This quantum model states that the photon, just like any quantum particle, is a real physical entity with inner complex structure. While traveling from a distant star the photon interacts with the medium, losing energy. The test of this aging possibility for the photon has deep implications both for the very foundations of quantum mechanics and for the model of the Big-Bang for the universe. The model allows a non ad hoc *explanation for the cosmological redshift without Doppler effect.*
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1. Introduction

The most common interpretation for the cosmological redshift is based on the Doppler effect arising from the Big Bang model in an expanding universe. Nevertheless, from its beginning this model has been challenged by many scientists. There are many other possible explanations for the cosmological redshift other than the Doppler effect.

In this paper I wish to present the model proposed some years ago by Louis de Broglie [2] for the tired photon. The problem with most alternative explanations for the cosmological redshift arises from the fact that they result from *ad hoc* assumptions. The model of de Broglie has none of the *ad hoc* character of which most tired-light mechanisms are accused: it follows from considerations at the fundamental level of his quantum theory [3]. It is only a corollary of his causal double solution theory, which stands almost side by side with the orthodox non causal theory for explanation and prediction of quantum phenomena. Another major advantage of this model is that it can be tested on a laboratory scale.

2. De Broglie Model for the Photon

According to de Broglie [4] what is called a quantum particle either a photon, electron, neutron, and so on is a real entity composed of an extended, yet finite, wave plus a singularity

$$\phi = \theta + \xi \tag{1}$$

where ϕ is a function, the solution of a non-linear Schrödinger master equation representing a quantum particle, ξ represents the singularity and θ the wave devoid of singularity, also called an empty wave. It is understood that both ξ and θ represent real physical entities. Usually the wave θ guides, probabilistically, the singularity through a non-linear process, the guidance principle, to the points of higher wave intensity. Practically all the particle s energy is carried by the singularity, which is responsible for the detection process. The energy carried by the wave θ is so negligible, that for all practical instances, the energy of the quantum particle comes only from the singularity. This is the reason why the very small amount of energy of the θ wave cannot be detected in a usual square energy detector. Only in very special circumstances [5] is it, in principle, possible to detect these real physical waves with such a small amount of energy.

From the previous assumptions of de Broglie s double solution one concludes, as a corollary, that the behaviour of the single θ wave devoid of singularity and the full ϕ wave representing the particle is different when interacting with the matter or the surrounding subquantum medium. Let us consider this conclusion in more detail.

Suppose that an empty wave impinges on a 50% beamsplitter. Since the θ wave is a real physical wave, half of it is reflected while the other half is transmitted. If this transmitted wave strikes another 50% beamsplitter, it is again reflected and transmitted. By placing successive beamsplitters, as shown in Fig. 1, the intensity of the transmitted wave is reduced to such a low level that in the end practically nothing is left, and it is mixed in with fluctuations of the subquantum medium, or vacuum fluctuations, as the phenomenon is sometimes called. This reduction in amplitude is given by

$$\theta = \theta_0 e^{-\mu n} \tag{2}$$

where n represents the number of beamsplitters and μ the attenuating factor, related to the transmission amplitude t by $\mu = -\log t$.

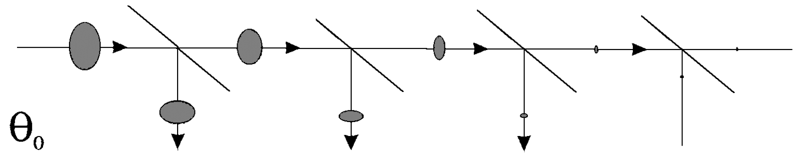

Fig. 1 The transmitted real wave devoid of singularity θ loses amplitude as it crosses successive beamsplitters, until it disappears mixed with vacuum fluctuations.

Following de Broglie s idea that every quantum particle is composed of a singularity plus the accompanying wave, the interaction of the full wave ϕ (wave with singularity) with the successive beamsplitters cannot be described in the same way. Had we accepted the same interaction mechanism, at the end of a sufficient number of beamsplitters, the accompanying wave would have vanished completely, with only the singularity remaining. This conclusion is unacceptable since it violates one of de Broglie s basic assumptions for a quantum particle, *i.e.* that *any quantum particle is composed of a wave plus the singularity*. In such conditions the interaction of the full wave with the beamsplitters can be described in two steps.

1) The full wave strikes the first beamsplitter and its amplitude is reduced by a certain factor, the same happening at the successive beamsplitters. This process continues to a certain threshold *k*.
2) After this point the accompanying wave, having reached the minimum level of energy compatible with the existence of the quantum particle, starts regenerating itself at the expense of energy from the singularity. From this point on the intensity of the accompanying wave remains practically constant, as long as the singularity keeps feeding it. The overall process can be described analytically in the following way,

$$\left\{\begin{array}{ll} \theta = \theta_0 e^{-\mu n}, & n \le k \\ \theta = \theta_0 e^{-\mu k} = const, & n \ge k \end{array}\right\} \qquad (3)$$

which is depicted in Fig.2.

As a direct consequence of this model, when the photon traveling from a distant star crosses space, the accompanying wave, due to interaction with the subquantum medium, loses energy to it. From this point on the guiding wave, having reached its minimum level of energy compatible with the existence of the quantum particle, starts acquiring energy from the singularity. Since the energy of the singularity is responsible for colour, it is no surprise to note that the photon, after traveling a long distance, loses energy and becomes redder. This model of an aging photon, the tired-photon model, rests on the assumption that the photon, like any other quantum particle, has an inner structure. When interacting with the subquantum medium, a quantum particle, being a real, very complex structure, naturally may lose energy.

In the past several attempts have been made to propose experiments to test these ideas [6]. Still, even though most of them are meaningful on an astronomical scale, they suffer from the handicap that they cannot be performed on a laboratory scale. The problems raised by this experimental situation are enormous. If we suppose, as a first approximation, that the cosmological redshift is only due to the aging photon, and assuming that the distance required for the guiding wave to reach the threshold level *k* is only of a few thousand kilometers, which is negligible when compared with the distance needed for a significant change in the energy of the singularity, we can estimate how far a photon would have to travel freely in empty space for its energy to change by about 10^{-5}.

Taking the previous assumptions into consideration, it is reasonable to describe the reduction in intensity of the singularity by

$$I = I_0 e^{-\alpha x}, \qquad (4)$$

or, using the usual conversion formula

$$\nu = \nu_0 e^{-\alpha x}. \qquad (5)$$

This expression is equivalent to the one presented by Gosh [8]. Using a linear approximation of this expression, and for $\alpha x \ll 1$ we have

$$\frac{\Delta\nu}{\nu_0} \approx \alpha x, \qquad (6)$$

or

$$\frac{\Delta\lambda}{\lambda_0} \approx \alpha x, \qquad (6)$$

with

$$\alpha \cong \frac{k}{c}, \qquad (7)$$

and k being Hubble s constant [8], which has an estimated value of about $k \approx 1.6 \times 10^{-18}$ s

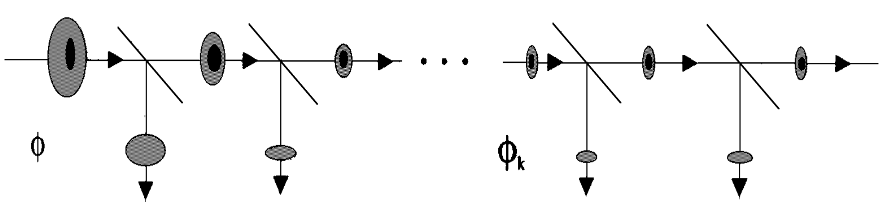

Fig.2 - The amplitude of the wave accompanying the singularity decreases as it crosses successive beamsplitters to a certain point. From this point on the amplitude remains, for all practical purposes, constant.

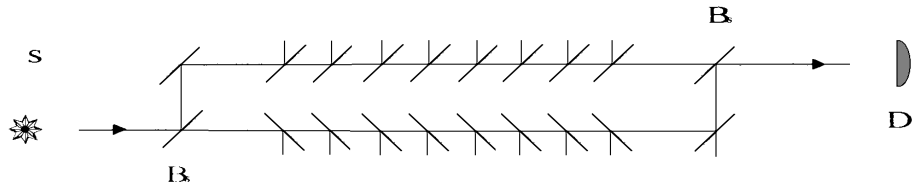

Fig.:3. The experiment. A Mach-Zender interferometer with an equal number of beamsplitters along both arms. Here *S* is a monophotonic source, *D* is a detector and B_s are 50% beamsplitters.

Replacing the value of the constant α in expression [5] one gets

$$\nu = \nu_0 e^{-10^{-26} x}. \qquad (5)$$

So the necessary path length for the photon, as it travels through empty space , to have a relative change in frequency of roughly in 10^{-5}, $\Delta\nu/\nu_0 \cong 10^{-5}$, is $x \cong 10^{21}\,\mathrm{m}$, that is of about the diameter of our Galaxy.

Even for this very small change in frequency, and assuming the cosmological redshift is due only to the aging of the photon, the necessary distance is of galactic scale.

A concrete experiment to test the reduction in amplitude of the wave θ, as it travels in empty space was done by Jeffers [9]. The results of the experiment were not conclusive for two reasons: Firstly, the source used in the experiment was not of monophotonic nature. but a laser source whose intensity was reduced. In this case, due to the bunching effects, the probability of having only one single photon at a time in the interferometer is practically zero. Secondly, the fact that the possible free travel path of the θ wave was, in the best case, on the order of 258.1 cm, which is very small for any effect to manifest itself. Even in the case of a free travel path of some hundred meters, the attenuation of the empty wave would hardly be noticed.

3. A Concrete, Feasible Laboratory Scale Experiment

In order to design a feasible laboratory scale experiment to test the nature of the photon, whether it possesses an inner complex structure or not, we can rely on the properties of the photon model derived from de Broglie s theory, represented by expressions (2) and (3). According to expression (2) the amplitude of the transmitted empty wave is reduced when it encounters the beamsplitter by an amount that depends on the transmissivity of the device. For instance, for a transmission factor of 1%, and for ten equal beamsplitters, the intensity of the final transmitted wave would be reduced by a factor of 10^{-20}. Such a substantial attenuation factor indicates that it is reasonable to assume that the threshold level *k* can be achieved on the laboratory scale. From this level on it is possible to test the tired photon model.

The concrete experiment consists of a Mach-Zehnder interferometer and a Mandel type single-photon source as shown in Fig. 3.

An equal number of beamsplitters are placed along both arms of the interferometer to reduce the amplitude of the θ waves. Suppose that a single photon is sent at a time from a monophotonic source. We can now see what the predictions for this experimental set-up will be.

4. Predictions of the Orthodox Theory

According to usual interpretation of quantum mechanics the two probability waves going through paths one and two of the interferometer behave precisely in the same way and undergo the same amplitude reduction. Since the transmissivity of the two arms of the interferometer is the same, the intensity of the final wave results from the mixing of the two transmitted waves with the same amplitude. Therefore the prediction for the expected intensity at the detector will be

$$I_u = \left|\psi_1 + \psi_2\right|^2, \qquad (8)$$

or

$$I_u \propto 1 + \cos\delta , \qquad (9)$$

where ψ_1, ψ_2 are the waves that come out from the arms 1 and 2 of the interferometer respectively, and δ is the relative phase shift between the two waves.

For this experiment the usual quantum mechanics predicts that, independently of the absolute intensity of the two overlapping waves, the visibility will be equal to one.

5. Predictions According to the Tired Photon Model of de Broglie

According to de Broglie s aging photon model, whose properties are summarized in expressions (2) and (3), which can be written for this particular case, assuming that the empty wave travels along one arm of the interferometer

$$\left.\begin{cases}\theta_1 = \theta_0 e^{-\mu k}, \\ \theta_2 = \theta_0 e^{-\mu n}.\end{cases}\right\} n \geq k \qquad (10)$$

Therefore, one obtains for the intensity

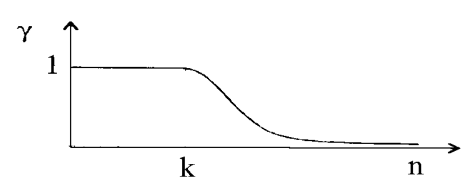

Fig.4 Predictions for the experiment. Solid line: de Broglie s aging photon model. Dotted line: orthodox theory.

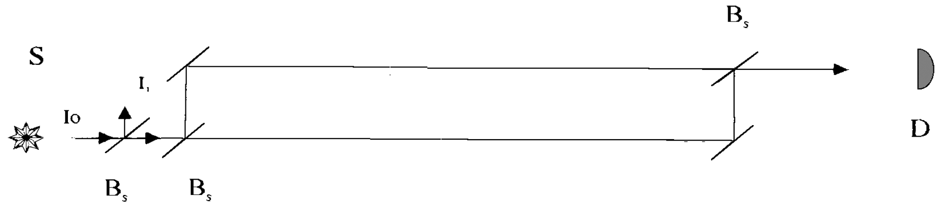

Fig.5. Experimental setup for visibility calibration of the interferometer as a function of intensity of entering beam.

$$\begin{aligned} I_c &= \left|\theta_1 + \theta_2\right|^2 = \\ &= \left|\theta_0\right|^2 \left(e^{-2\mu k} + e^{-2\mu n}\right)\left(1 + \gamma \cos\delta\right) \end{aligned}, \qquad (11)$$

where the expected visibility γ is given by

$$\gamma = \mathrm{sech}\mu\,(n - k) \qquad (12)$$

The predictions are precisely the same when the empty wave travels along the second path.

The predictions for the expected visibility of the two theories are shown in Fig. 4

As can be seen from Fig. 4, if the number of beamsplitters is less than *k*, the two waves undergo the same amplitude reduction, so the expected visibility is exactly the same in the two models. When the number n of beamsplitters is greater than k the visibility will decrease rapidly as $(n - k)$, as can be seen in Fig.4. It is worth remembering that the wave is regenerated only in the arm along which the singularity travels, not in the other.

6. Some Practical Considerations for the Concrete Experiment

Naturally, in an actual interferometric experiment, the experimental visibility always fails to reach 100%, even if predicted theoretically. This decrease in the expected fringe visibility is explained as a consequence of various causes: polychromatic light, imperfect alignment, instabilities in the interferometer, different temperature gradients, poor statistics, and other causes. So, it would not be correct to compare the theoretical results predicted by the usual quantum mechanics with the visibility predicted by relation (12) derived from the causal theory. In this situation, in order to achieve reliable experimental results, the actual experiment could be carried out in the following way:

After having properly aligned the interferometer, in order to maximize the visibility γ_0 for an incident monophotonic beam of intensity I_0, one reduces the intensity to I_1 of the entering beam by placing a beamsplitter in front of the interferometer and measuring the new visibility γ_1. By adding another beamsplitter, also before the interferometer, the intensity is further reduced to I_2, to which corresponds a visibility γ_2. This process of adding beamsplitters before the interferometer continues until it gives rise to an experimental correspondence between intensities and visibilities (I_0, γ_0), $(I_1, \gamma_1), \ldots, (I_n, \gamma_n)$.

The arrangement for the first beamsplitter is shown in Fig. 5

Now, after the visibility calibration on the interferometer, the experiment is performed by placing beamsplitters one-by-one in the arms of the interferometer. Then we compare the visibilities obtained when the beamsplitters are placed inside the Mach-Zehnder interferometer, with the visibilities obtained in the calibration process.

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