# EPR and the double slit experiment

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*Abstract*

This paper brings together two fundamental strange behaviors of quantum mechanics, the double slit experiment and the EPR paradox. "We choose to examine a phenomenon, which is impossible, absolutely impossible, to explain in any classical way, and which has in it the heart of quantum mechanics" – Richard Feynman about the double slit experiment. " Spooky action at a distance "– Albert Einstein about quantum entanglement in the EPR paradox paper [1]. This paper will deeply look into the unique behavior of the double slit experiment when using entangled particles.

*Introduction*

Let's imagine a pair of entangled particles (in this paper we will refer to photons but the idea can be expanded to other elementary particles), travelling in two opposite directions. The photon travelling to the left will reach a double slit setup, but since the exact location (which way information) can be measured on the entangled photon travelling to the right, the photon on the left will pass through only one slit and there will be no interference pattern on the screen. Let's imagine Alice on the double slit side (the entangled photon travelling to the left) and Bob has a mirror that will interact with the entangled photon travelling to the right. As long as the mirror on Bob side reflects the photon travelling to the right to a "which slit" detector, Alice will receive a two slits pattern (no interference pattern) on her screen (figure 1) exactly as if she made herself a which slit measurement on the double slit setup on her side (due to the entanglement between the two photons and even though she did not measure herself through which slit her photon passed through). Now imagine that Bob tilts the mirror in a way that the entangled photon travelling to the right is falling into a black hole (figure 2). If the which way information of the entangled photon travelling to the right is lost in the singularity of the black hole (as suggested in the black hole information paradox [2]), Alice will receive an interference pattern on her screen since now there is no way to know through which slit her photon has passed through, and she will know that Bob has tilted the mirror. This means that Bob can communicate with

Alice by tilting his mirror and influencing her double slit measurement results, faster than the speed of light and that is a paradox that contradicts with the Einstein special theory of relativity. In order to avoid the paradox we need to conclude that the information of the entangled photon travelling to the right and entered the black hole was never lost and the entanglement bonding between the pair survived the black hole extreme curvature in space-time.

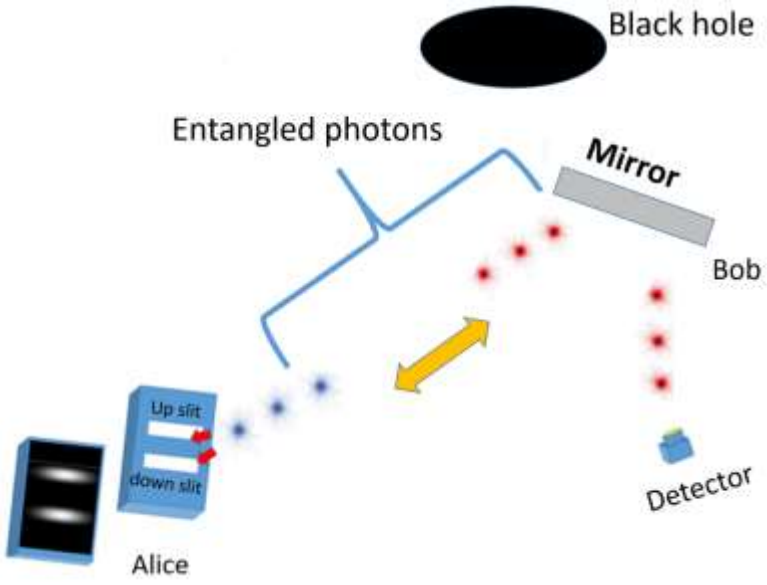


Figure 1: Entangled photons traveling in two opposite directions towards Alice and Bob. The photons travelling to the left will pass through a double slit setup and will be detected on Alice screen. As long as Bob tilts the mirror in the direction that will reflect the entangled photons travelling to the right to a position detector, Alice will see a non-interference pattern on her screen.

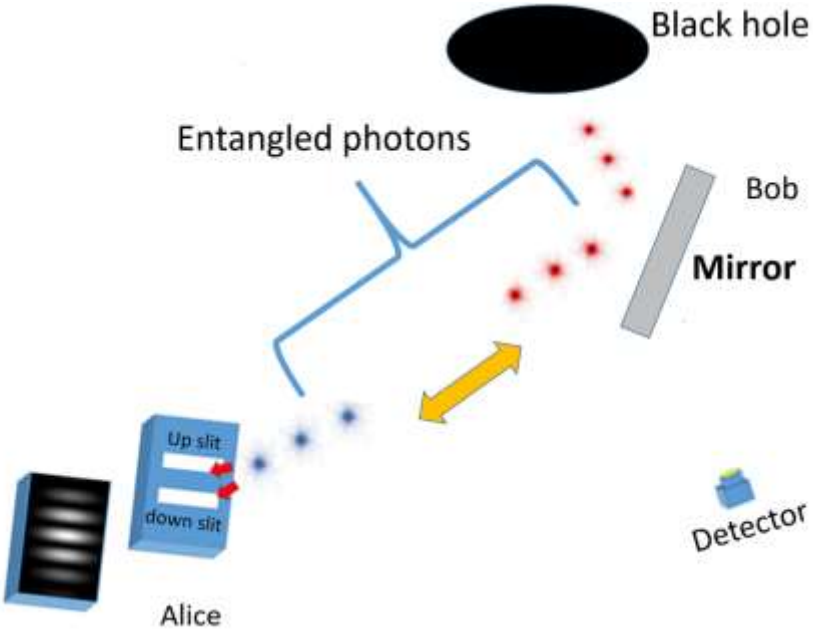

Figure 2: Entangled photons traveling in two opposite directions. The photons travelling to the left will pass through Alice double slit setup and will be detected on Alice screen. Bob tilts the mirror in the direction that will reflect the entangled photons travelling to the right to a black hole. if the which slit information is lost in the black hole singularity, Alice will see an interference pattern on her screen (her non entangled photon passed through both slits, since she has no way to know through which slit it has passed through) and will know that Bob has changed the position of the mirror . This means that if Bob's distance from the black hole is shorter than his distance from Alice and they share the same frame of reference, they can conclude that they can communicate faster than the speed of light by tilting Bob's mirror, and that is a fundamental paradox that contradicts special relativity.

*Conclusion*

If information is lost once falling into a black hole, then by a setup based on the double slit experiment, a pair of entangled particles and a mirror Bob can send Alice information faster than the speed of light as detailed above. If we do not want to violate Einstein's special relativity we must conclude that information is not lost when falling into a black hole. If information is not lost in the black hole, it must be located on the surface of the event horizon. Based on the Bekenstein – Hawking formula [3], the amount of information bits (S) on the surface of the event horizon is proportional to the surface area of the event horizon (A) multiplied by Boltzmann constant ( $K_B$ ) and divided by four times quantized units in the area of the square of Planck length ($l_p^2$).

$$S = \frac{K_B A}{4 l_p^2}$$

This leads to the idea that space is quantized into local units in the size of Planck's length in each of the three space dimensions (also time might be quantized to units in the size of Planck time). Like any other three dimensional shaped quantized pattern, between these units lays an extra non-local grid shaped dimension dividing the three dimensional quantized units from one another. From the Bekenstein – Hawking formula, this paper suggests that for each volume of space the information is located in the grid dimension on the surrounding surface of this volume of space (figure 3). This leads to the holographic principle [4]. Due to the Heisenberg uncertainty principle [5], the information pops in and out of existence from the grid dimension to the quantized space through the virtual particles that generate the Hawking radiation [6] and which can be measured by the Casimir effect [7].The information regarding which slit the particle will pass at Bob's side is kept on the grid dimension which is spread on the event horizon and it will eventually evaporate back to space due to the virtual particles that transform to the Hawking radiation. That is

why Bob cannot signal faster than the speed of light to Alice by sending the entangled photon to be lost forever in the singularity of the black hole, since information is not lost, it is located on the grid dimension spread on the event horizon and radiated back through the Hawking radiation. Alice will receive a two slits pattern on her screen and will never receive an interference pattern (not as described in figure 2). She can receive from Bob an instantaneous message only if he can tear apart the entanglement bonding, but since it is entangled through the non-local grid dimension ("spooky action at a distance") nothing that Bob can do in the quantized units of space time can tear this entanglement apart. Not even the extreme curvature in space-time of a black hole. The non-locality of the grid dimension connects all the quantized space time units together and that leads to quantum entanglement, quantum tunneling [8] and the Feynman path integral formulation [9].

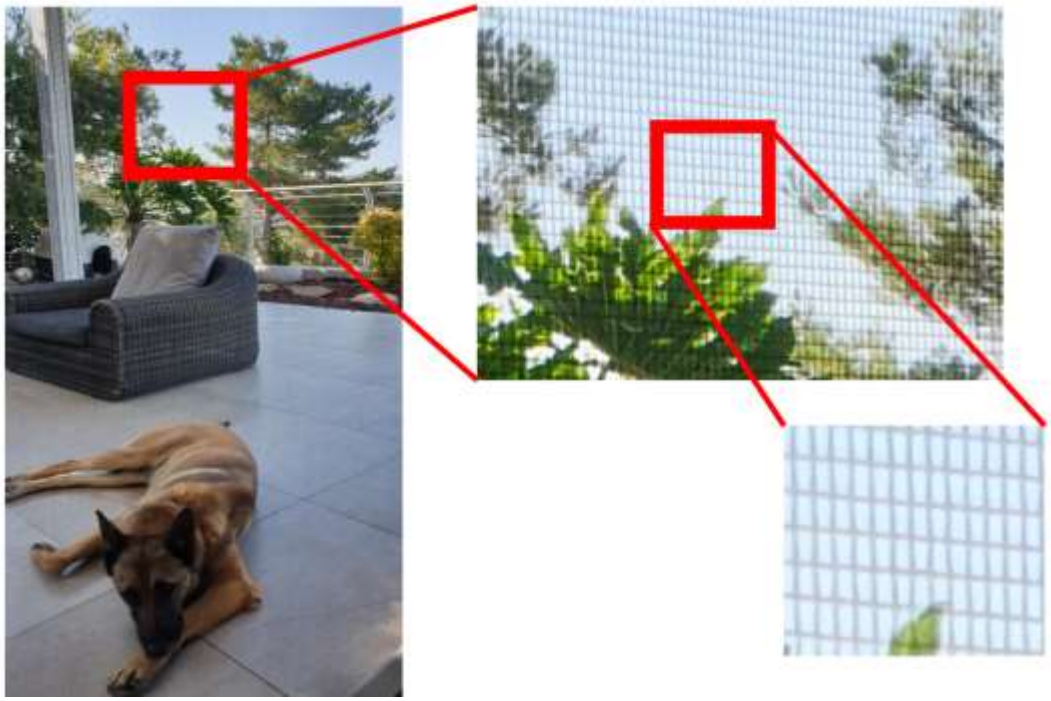

Figure 3: When looking closer at the image below we can notice a grid dividing the image into two dimensional rectangles which illustrate the quantized units of space. The grid illustrates the extra grid dimension. For each volume of space the information within it, is located in the grid dimension on its surrounding surface (the holographic principle). The non-local grid dimension connects all the local quantized units of space together enabling non local connection between entangled particles ("spooky action at a distance" – Albert Einstein) and it is the core explanation for the Feynman path integral formulation.

**REFERENCES:**


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[9] https://en.wikipedia.org/wiki/Path_integral_formulation