
The Double-Slit Experiment as a Test of the Nature of Reality

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Abstract – In this paper, after a brief presentation of two approaches to Quantum Theory that can be regarded as two opposing views of it, a new scenario is hypothesised. Taking into account a recent redefinition of imaginary numbers (seen as *infranumbers*), the use of which now appears indispensable for certain quantum calculations, in the presented scenario waves are as real as particles, but they are not entirely on the same plane of reality. The redefinition of imaginary numbers in fact suggests that there are various levels of reality, not all of them related to space. In the proposed scenario the apparent paradoxes in the results of the double-slit experiments, as well as the phenomenon of entanglement, could find an explanation. Entanglement appears as a phenomenon which happens between objects that are linked in a level of reality, here defined as *root-reality*, in which the physical space does not exist. Similarly, waves, even divided in space, can maintain a unity in this level of reality.

Keywords – Double-Slit Experiment, Entanglement, Faggin's Vision of Reality, Imaginary Numbers, "Root-Reality" and Reality.

I. INTRODUCTION

In his stimulating book "Helgoland", Rovelli [1] describes a Zeilinger experiment he witnessed, in which a beam of photons is separated into two parts that follow two different paths. They are then brought together and finally separated again to end up in two detectors. By leaving the two paths free, the photons all end up in one detector. By breaking one of the two paths, the photons split in half between the two detectors.

Rovelli, describing this experiment, writes that the wave of each photon splits into two small waves (which then come together), even though photons are always detected in only one of the two paths. However, in Rovelli's interpretation (quite similar in this to the so-called Copenhagen interpretation) the wave associated with a particle is not a physical wave, but rather a mathematical description of the probability of finding the particle in a certain state. On the contrary, Selleri [2], commenting on other double-slit experiments, had stated that the phenomena exhibited by these experiments can be explained by following Einstein and De Broglie's approach [3] "on the concept of duality, i.e. on the concrete association, on an ontological level, of wave and corpuscle" (translation from Italian text [2]).

Here we suggest a hypothesis that introduces a different approach: the two small waves described by Rovelli are real (as in Selleri's interpretation) but they are two and divided only in the visible plane of reality while they retain their unitary nature or at least a correlation in an underlying plane, the nature of which we will try to illustrate at least a little below, by means of a recent redefinition of imaginary numbers [4]. In this context, entanglement can also find an explanation.

II. SOME INTERPRETATIONS OF THE RESULTS OF THE DOUBLE-SLIT EXPERIMENT

Experiments such as the one described in the Introduction are now numerous and have involved not only photons but also particles with mass. Seemingly completely counterintuitive interference outcomes also involve-

-d emissions of single photons or single particles with mass.

When a single particle, such as an electron, crosses a double slit, according to Selleri [2], who follows the approach of Einstein and De Broglie (similar in some ways to Bohm's more recent interpretation [5] [6]), the wave (which is a physical wave) splits into two waves, one with the corpuscle (driven by the wave), the other empty (without the corpuscle).

However, even if one of them is empty, the two waves show an interference phenomenon after crossing the double slit, affecting the trajectory of the corpuscle.

In the still dominant Copenhagen interpretation, on the contrary, the wave is a wave of probabilities, and Schrodinger's function ψ describes the probability of finding the electron at different points on the detection screen.

However, in every case the ψ wave function ($\psi_{12}(x)$, where x is the coordinate for which the probability of finding the particle is calculated) is a superposition of two partial waves, $\psi_1(x) + \psi_2(x)$, each corresponding to one of two possible paths through the slits. The resulting ψ wave function ($\psi_{12}(x)$) shows an interference pattern, with regions of high and low probability of detecting the electron.

It is claimed that when the electron is revealed on the screen, the wave function ψ collapses (the so-called "wave function collapse") to the specific point where the electron is revealed. It is necessary to bear in mind, for the purposes of the following discussion, that ψ functions are complex functions. In fact: $\psi(x) = a(x) + i b(x)$. Of course, the one presented is a compact form of the Schrödinger function, where $a(x)$ and $b(x)$ indicate the real and imaginary part of the wave function, respectively).

Furthermore, the functions relating to the interference and entanglement phenomena of massless particles such as photons are also complex functions.

III. BEYOND SPATIAL DIMENSIONS

Before presenting our interpretation of the results of the double-slit experiments, mention must be made of a recent study on the nature of reality.

Faggin [7] [8] (with D'Ariano [7]) advances the hypothesis that there is a reality more basic than that perceivable with the senses, a kind of dimension that would underlie quantum phenomena and, in his opinion, consciousness (the thesis of Faggin, who says that "All is One" [8], seems to recall the "Undivided Wholeness" of Bohm ("We must learn to view everything as part of Undivided Wholeness" [9])).

Following Faggin, one would say that the universe appears (space, matter and time) is not the substratum from which consciousness emerges, but rather the opposite: there would exist a kind of universal, quantum consciousness with free will, from which the classical, apparently predictable world would originate. Both Faggin's thesis of consciousness seen as irreducible and the thesis that relegates consciousness to epiphenomenon, call to mind the processes of generation of mathematical objects expressed by Paolilli [10]. The scholar notes that a geometric object with n dimensions is generated by a geometric object with more than n dimensions and not vice versa, but at the same time states that the opposite is true for sets and power sets, which are a human construction. Following Faggin, this second scenario would seem more realistic, because consciousness, according to his opinion, is an irreducible element, as it pre-exists the material world. Faggin [11] also argues

that minus derives from plus (where plus is indeterminism, and with it free will, that classical physics can not explain), so consciousness would be the plus from which minus derives).

As we shall see, whatever the generative process of the universe, random or teleological, this dimension most likely exists and is necessary for the existence of the universe as we know it. In fact, it is linked to imaginary numbers, which are not imaginary at all, but descriptive of this dimension. Imaginary numbers, as we will see in next section, are not the result of an assumption of convenience, but are just as real as real numbers, although they can be referred to a different plane of reality (of lower dimensionality [4]).

Imaginary numbers, in fact, now appear to be inextricably linked to quantum physics, and not only for a factor of convenience in calculation and/or elegance. It could be argued that although the most common version of quantum theory is indeed based on complex numbers, there is nevertheless a version of it, the “real quantum theory” [12], in which only real numbers are used. However, as shown by J.S. Bell [13] in 1964, “some quantum effects can not be modeled by any classical theory” [12]. The role of imaginary numbers in Quantum Physics therefore appears increasingly irreplaceable [12] and, above all, they are indispensable for describing phenomena such as entanglement and superposition [14].

IV. THE LINK BETWEEN IMAGINARY NUMBERS AND THE ROOT OF REALITY

Imaginary numbers, introduced by Bombelli [15] who defined the imaginary unit “numero sofisticato” (sophistic number), were defined as “lateral numbers” by Gauss (quoted by E.T. Bell [16]) due to their representation at the sides of the axis of real numbers in the complex plane. In recent times [4] it has been pointed out that imaginary numbers differ from real numbers only for their “dimensionality”, which is lower than the dimensionality of real numbers. In this frame, the reality of imaginary numbers is the same as that of real numbers, even if less evident for us who live in a universe characterised by elements (space, successions of events, i.e. time) which can be measured using real numbers.

Following this approach, it has been proposed that imaginary numbers could be defined as *infranumbers* and the imaginary unit as an *infranumeric unit*, while retaining the letter *i* to denote this unit. To prove this thesis, a simple artifice was used: representing, only for a first step, the real numbers by means of a strip instead of a straight line (see Figure 1) [4].

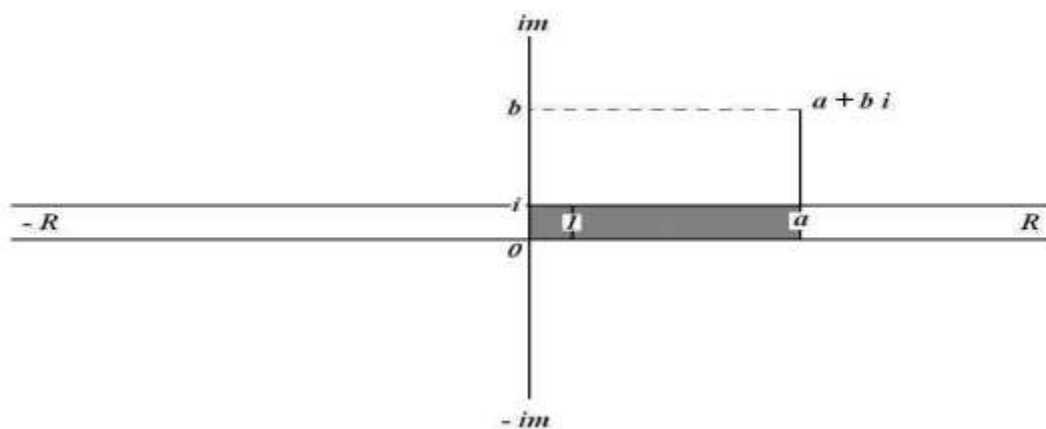


Fig. 1. Real numbers are measured on the strip as surfaces; imaginary ones are represented by vertical segments. The imaginary (infranumeric) unit is a segment. An example of a complex number is shown in the first (NE) quadrant. As in the complex plane, the coefficient *b* is measured on the vertical axis.

In the cited paper, recalling the teachings of Brahmagupta [17], it is emphasised that two negative numbers multiplied by each other give a positive result because it is assumed that the multiplier does not alter the nature of the product with respect to the multiplicand, i.e. if the role of the multiplier is only to indicate how many times the multiplicand must be subtracted from zero. Conversely, if the multiplier has the same nature as the multiplicand, the result has a different nature (e.g. multiplying linear metres by linear metres the result is in square metres, whose nature is different from that of linear meters). However, it must be emphasised that while the square root of a positive number is always positive and therefore, in the absence of other data, nothing can be said about the nature of the result, it is not the same for the root of a negative number. In this case we can be sure that the nature of the result is not the same as the radical and is therefore indicated by an imaginary number. Therefore the unit i could be defined, when referring to the physical world, as the unit of measurement of a dimension lower than the spatial ones. As can be seen in Figure 1, in fact, the root of a negative number refers to a segment, i.e. a one-dimensional object, whereas real numbers, in Figure 1, refer to surfaces, i.e. two-dimensional objects. The dimensionality of real numbers in this representation is thus twice that of imaginary numbers. However, as it is suggested by Paolilli [4], “it is more practical, and especially more in line with the current use of mathematics, to consider real numbers and imaginary numbers as one-dimensional and half-dimensional (that is elevated at 0.5) objects respectively” and therefore to represent them on the complex plane. The relationship between the two types of numbers is therefore basically the same as in Figure 1. Note that on the x-axis of the complex (Argand-Gauss) plane, real numbers, which are necessary to measure space, are represented by segments, whereas imaginary numbers with respect to the real axis always occupy a dimensionless point (i.e. they project a dimensionless point onto it), as if to indicate their non-spatial nature. Therefore, imaginary numbers could be associated with a non-spatial plane of reality underlying space, a plane we might call *root-reality*.

Indeed, the semi-dimensional nature of imaginary numbers compared to that of real numbers is confirmed by the well-known fact “that in the complex plane multiplying a real number by i is equivalent to making a rotation of 90 degrees (counterclockwise), that is exactly half the rotation determined by the multiplication of two real numbers, the second of which (multiplier) is negative” [4].

To conclude this section, it is therefore possible to hypothesise that the lower dimensionality of imaginary numbers, or infranumbers, compared to real numbers, is indicative of the existence of a plane of reality that is internal to reality and, above all, has no spatial dimensions, thus casting a light on non-local phenomena.

V. WAVES, PARTICLES AND PLANES OF REALITY

Rovelli [1] writes that only particles and never waves are detected in experiments, thus in fact corroborating the thesis of probability waves. In fact, looking at the sky, we never see the light except when it interacts with something, be it a planet or the air (and our eyes). However, following this thesis, many results of experiments such as the double-slit appear paradoxical and somewhat inexplicable. Entanglement also seems decidedly mysterious (“spooky action at a distance”, in Einstein's words [18]).

If, on the other hand, we admit that there is a plane of reality that we apparently can not perceive, phenomena like entanglement or interference of matter waves appear much less paradoxical.

As already mentioned, experiments only detect particles and never waves. In our opinion this is due to the fa-

-ct that electromagnetic and matter waves do not “inhabit” only a single plane (or level) of reality. Photons and other particles are waves traversing space but their “essence” lies in the plane described by imaginary numbers, i.e. the above-mentioned root-reality. More precisely, while they are waves, although they traverse space, they retain their “individuality” in the non-spatial plane, manifesting themselves as particles when they interact with elements in the spatial plane (in other words we see their effects).

We can consider, for the sake of simplicity, the complex plane, in which only one space dimension is shown. It is important to reiterate what was observed in the previous section: an imaginary quantity, having a vertical development in the complex plane, with respect to the axis of real numbers is always a dimensionless object.

As we have seen in Section II, with respect to the double-slit experiment with electrons, the wave $\psi_{12}(x)$ is a superposition of two partial waves $\psi_1(x) + \psi_2(x)$. However, when the electron is detected on the photographic plate, its energy is the same whether the two waves arrive together and interfere, or whether one of the two paths is obstructed. In our opinion, this means that although divided on the spatial plane, the wave retains its unity, at least in the sense that the two waves remain perfectly related, on the non-spatial plane, and when the wave is actually detected, at a single point, does it exert its full energy. As already mentioned, this plane, described by imaginary numbers, has no spatial dimension, which may explain how the long-distance interactions of entangled particles occur instantaneously: in reality, they maintain their unity in the root-reality. The root-reality, compared to space, as we have seen, is dimensionless.

As we know, light and "matter waves" (such as electron waves), as long as they propagate in space, can be described by both real and complex functions. However, in interference and entanglement phenomena, as seen above, a function is required, a part of which must contain imaginary numbers, numbers that disappear when calculating the probability that the particle will be detected at a specific point in space. This shows how the wave phenomenon affects not only space, but also what we have called root-reality. As a complex diagram shows, the reality described by imaginary numbers has no extension into physical space, although it could be a generator of it. Therefore the root-reality is the realm of synchronicity: waves that split in space or entangled particles but distant in space remain united in that dimension, with no need for time to relate (0 distance in space = 0 time to relate).

Finally, a note: Faggin's thesis, that “All is One” [8], in the light of the constation that the root-reality has not a spatial extension, calls to mind a mathematical observation [19] [20] according to which $\infty \cdot 0 = 1$. This relationship, for the physical world, can be interpreted in the sense that the infinite possibilities and configurations of the universe (or universes) can be connected to a single dimensionless point with respect to space, realising the totality (the “One” of Faggin).

VI. CONCLUSION

Quantum Physics has had great successes although there has never been total consensus on its foundations. This paper has tried to address this problem. To this end, inspiration has been drawn mainly from D'Ariano and Faggin's observations on the nature of the universe on the side of Physics [7], and from Paolilli's reinterpretation of imaginary numbers on the side of Mathematics [4]. Regarding the nature of the dimension (or plane) underlying visible reality, no new hypotheses have been put forward that differ from those put forward by Faggin (and D'Ariano) [7] [8]. However, by grasping the relationship between this dimension and imaginary

numbers (redefined as infranumbers), it has been deduced that it has no spatial extension. It seems to be somehow the seat of individuality and, since it has no physical spatial extension, it is the realm of synchronicity: a wave that splits in space or entangled particles that move apart in space remain united in that dimension, with no need for time to relate.

As we have seen, light and "matter waves" (such as electron waves) can be described by both real and complex functions, but in the case of interference and entanglement phenomena, imaginary numbers become necessary, thus revealing the existence of what we have called root-reality.

REFERENCES

- [1] C. Rovelli, Helgoland, Milan, Adelphi, 2020.
- [2] Selleri, *Fisica senza dogma. La conoscenza scientifica tra sviluppo e regressione* (Physics without dogma. Scientific knowledge between development and regression), Bari, Dedalo, 1989.
- [3] L. De Broglie, "Recherches sur la théorie des Quanta" (Research on Quantum Theory), in *Annales de Physique* (Annals of Physics), 10 (3), 1925, 22-128.
- [4] A.L. Paolilli, "The Nature of Imaginary Numbers from the Perspective of their Dimensionality", in *International Journal of Innovation in Science and Mathematics*, 12 (1), 2024, 1-4.
- [5] D. Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables. I", in *Physical Review Journals Archive*, 85, 1952, 166-179.
- [6] D. Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables. II", in *Physical Review Journals Archive*, 85, 1952, 180-193.
- [7] G.M. D'Ariano, F. Faggin, "Hard Problem and Free Will: An Information-Theoretical Approach", 2020, <https://arxiv.org/abs/2012.06580>.
- [8] F. Faggin, *Irriducibile. La coscienza, la vita, i computer e la nostra natura* (Irreducible. Consciousness, life, computers and our nature), Milan, Mondadori, 2022.
- [9] D. Bohm, *Wholeness and the Implicate Order*, Routledge, 1980.
- [10] A.L. Paolilli, "On the Nature of N-Dimensional Mathematical Objects, with $N > 0$ ", in *International Journal of Innovation in Science and Mathematics*, 7 (3), 2019, 143-147.
- [11] F. Faggin, et al., *Resurrezione. Fisica Quantistica, Teologia e Mistica a Confronto* (Resurrection. Quantum Physics, Theology and Mysticism Compared), San Pietro in Cariano, Gabrielli Editori, 2024.
- [12] M. Renou, A. Acín, M. Navascués, "Quantum Physics Falls Apart without Imaginary Numbers", in *Scientific American*, April, 2023.
- [13] J.S. Bell, "On the Einstein Podolsky Rosen Paradox", in *Physics*, 2 (3), 1964, 195-200.
- [14] KD Wu et al., "Operational Resource Theory of Imaginarity", in *Physical Review Letters*, 2021, 126.
- [15] R. Bombelli, *L'algebra* (Algebra), Giovanni Rossi, 1572 (manuscript circa 1550).
- [16] E.T. Bell, *The development of mathematics*, New York, 1945.
- [17] Brahmagupta, *Brāhmasphuṭa Siddhanta* (Correctly Established Doctrine of Brahma), 628.
- [18] A. Einstein, "Letter to Max Born", 1947, in Max Born Ed., *Born-Einstein Letters, 1916-1955*, New York, Walker & Company and MacMillan, 1971.
- [19] S. Khuraijam, "Defining the Undefined", in *International Journal of Current Research*, 11 (6), 2019, 4574-4575.
- [20] A.L. Paolilli, "Division by Zero: the Link Between Numbers and Infinity", in *International Journal of Innovation in Science and Mathematics*, 7 (5), 2019, 212-214.

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