Exploration

Hidden Variables, Diffraction & Spacetime Topology

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Abstract

We explore the indeterminacy which arises when quantum mechanics is used to explain state changes of physical systems. According to the Copenhagen interpretation, the end state of a physical system generally has no determinable properties prior to being measured. Quantum mechanics can only predict probabilities of anticipated measurements results. The Copenhagen interpretation remains the most commonly taught interpretation of quantum mechanics. It holds that the act of measurement affects the system, causing the system to reduce to one of several probable states immediately upon measurement. This is known as wave function collapse. We discuss alternatives to the Copenhagen interpretation, including the de Broglie-Bohm pilot-wave interpretation, and we offer the spacetime topology interpretation.

Keywords: Hidden variables, spacetime voxels, TGD, double slit diffraction, photon dispersion.

Introduction

Hidden variable theorists argue that the state of a physical system, as formulated by quantum mechanics, does not give a complete description for the system and that quantum mechanics is ultimately incomplete. The indeterminacy of some quantum mechanics measurements is expressed quantitatively by the Heisenberg uncertainty principle.

Albert Einstein objected to the probabilistic nature of quantum mechanics. Although admitting that there is validity in the statistical approach of quantum mechanics formalism, Einstein refused to accept the hidden variable theory because it is irreconcilable with the idea that physics should represent a reality in time and space, free from quantum entanglement which involves superluminal action at a distance.

John Bell suggested that some types of local hidden variables are impossible, or that they evolve non-locally. His theory shows that if local hidden variables exist, certain experiments could be performed involving quantum entanglement where the result would satisfy a Bell inequality. If statistical correlations resulting from quantum entanglement could not be explained by local hidden variables, the Bell inequality would be violated. Physicists Alain Aspect and Paul Kwiat performed experiments which found violations of the inequality. Their results ruled out local hidden variable theories, but not non-local ones with superluminal action-at-a-distance. There are some experimental problems which may invalidate their finding.

Gerard't Hooft disputed the validity of Bell's theorem on the basis of the superdeterminism and proposed ideas of local deterministic models. In quantum mechanics, superdeterminism involves a hypothetical class of theories that evade Bell's theorem by being completely deterministic. Bell's

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theorem assumes that some types of measurements can be chosen and performed independently of each other and reveal the hidden variables involved. For Bell's inequality to follow, it is necessary to be able to predict what the deterministic results of the measurements would have been, had different choices been made.

It is conceivable that a local hidden variable theory can be constructed such that it is deterministic and always supports the predictions of statistical quantum mechanics. Superdeterminists do not admit the existence of chance or probability anywhere in the cosmos. This viewpoint is emphatically validated by the fact that double slit experiment, originally performed by Thomas Young, always produces the same bright and dark bands on a detector screen - implying that hidden variables are always present, local, and deterministic.

The double-slit diffraction pattern would not be expected if light consisted solely of classical quantum particles and this implies the possibility of hidden variables: pilot waves. Pilot wave theory, the first attempt at a hidden variable theory, was introduced by Louis de Broglie and developed by David Bohm. The de Broglie-Bohm theory reinterprets quantum mechanics as being deterministic and avoids the troublesome 'wave-particle duality' notion and wave function 'collapse' on the double-slit detector screen.

We argue that the spacetime topology interpretation also avoids wave-particle duality. However, it requires treating spacetime as a particulate medium consisting of four-dimensional spacetime 'voxels' which are conjectured to have Planck-scale wavelength and frequency. Spacetime 'parcels' may consist of microscopic and sub-macroscopic accumulations of coordinated voxels which constitute the granularity of the cosmic material discontinuum - which we term the physiostratum which in turn is a subset of the mesostratum continuum [1].

We adopt simple graphical topological representations of spacetime, rather than mathematical expressions, allowing visualizations of what would otherwise be represented by arcane and abstract formulas. The notion of spacetime was introduced by Hermann Minkowski and elaborated upon by Albert Einstein in his general theory of relativity. Topological geometrodynamics (TGD) is a modification of general relativity in an attempt to describe spacetime and associated phenomena completely in terms of abstract geometry and configuration spaces. TGD was originally promoted by John Wheeler and work on it continues [2].

Mesostratum Generated Spacetime Voxels

The mesostratum is conceived as an energetic substrate containing the zero-point-field (ZPF) from which the material world of our experience emerges bit by bit. The mesostratum continuum is perceptible in its effect on physiostratum phenomena that we can detect, observe, and measure. We argue further that physiostratum is a granular subset of the mesostratum and that it consists of oceanic array of tesselated interacting spacetime voxels. As indicated in Figure 1, the physiostratum is discontinuous with a spacetime voxel granularity on the scale of Planck length (10^{-33} centimeter) and Planck interval (10^{-43} second). We posit that spacetime consists of four-dimensional resonant parcels - dynamic cubical voxels of space that oscillate in time - and that spacetime is like a deformable substance consisting of tightly tesselated voxels. This corresponds to Einstein's concept of a deformable spacetime, that is, a substantive material-like spacetime.

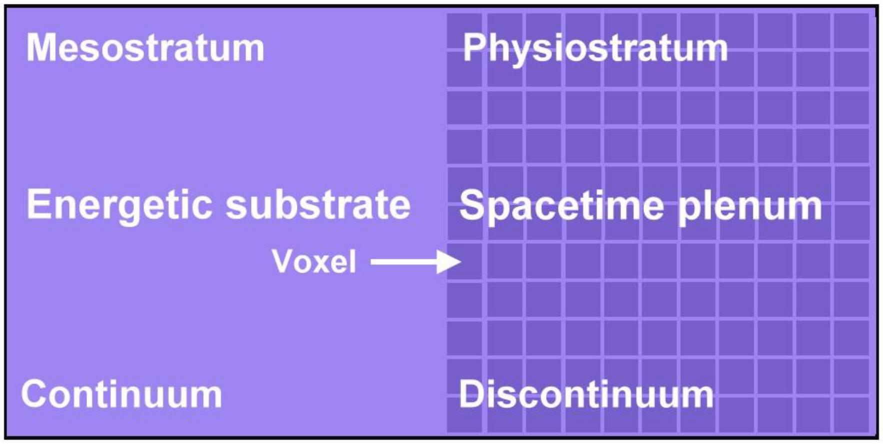

Figure 1 - Conceptual mesostratum and voxel array of the physiostratum.

We depict the motion of a quantum particle, say, a photon, during its transit through the physiostratum as jumping from one spacetime parcel to the next adjacent host parcel, while simultaneously retaining its mesostratum momentum and wavelike property. Let us perceive spacetime as the electron or photon sees it: as a bumpy granular environment and that they need to quantum jump from one spacetime parcel to another. We can accordingly deduce that universally consistent voxel oscillations (wavelength-frequency) set the speed of light, c, throughout the physiostratum.

The Quantum Wave Function

According to standard quantum mechanics, the information on the state of a quantum system is given by the wavefunction ψ which yields a probabilistic prediction regarding the result of an experiment performed upon that system. Roger Penrose points out that the wave function involves a functional freedom that is far greater than that which manifests itself in reality. Penrose asks, "are we to regard ψ as actually representing physical reality? Or is it to be viewed as being merely a calculation tool for working out probabilities of the results of experiments that *might* be performed?" The results of all such experiments are measurably real, but apparently not the wavefunction ψ itself. Indeed, the wavefunction representation does not anticipate the 'wave function collapse' which characterizes the actual the end state measurement.

Penrose points out that, "the conventional Copenhagen interpretation does not evade the issue of having to take ψ as an actual representation of *something* objectively 'real', out there in the world." One argument for some such reality springs from a principle suggested by Einstein, in which he argued for the "presence of an 'element of reality' in quantum mechanics formalism whenever it implies some measurable consequence with *certainty*." We will show that the wavefunction simply statistically mimics a deterministic reality that prevails due to a localized configuration of spacetime parcels (voxels) - which in the case of the double-slit experiment defines a Bohm-like ‘configuration space’ that guides quantum particles.

Adjacent Realities Concept

The wave function and associated spin, charge, and momentum specify the state of subatomic entities during transit within the mesostratum continuum while their mass and particulate nature specify their specific locations within physiostratum massive agglomerations, as for example on detector screens. This may be construed as wave-particle duality - a pairing of two separate sequential realities. Conversely, we propose adjacent realities, concurrent transcendent and material realities: wherein the wave function is a mesostratum continuum aspect while the quantum particle is a physiostratum discontinuum material aspect of a singular entity, for example, an electron or photon. These adjacent realities combine, form, and orchestrate our awareness and measurement of particulate objective reality (the physiostratum) which is coupled with an adjacent wave function signal transmission continuum (the mesostratum).

The momentum and location of a quantum particle are complementary variables in the adjacent realities of the mesostratum and the physiostratum, respectively. There is a limit to the precision with which certain pairs of properties of quantum particles, such as momentum p and position x, can be known concurrently. In quantum mechanics, this is the uncertainty principle, also known as Heisenberg's uncertainty principle. It follows from the fact that position x of a quantum particle must be referred to a gravitational agglomeration - a massive collection of quantum particles at rest in the physiostratum, e.g., a detector screen - while momentum p, the product of mass and velocity, a vector quantity, is a purely mathematical entity essentially defined in the mesostratum continuum. This illustrates that the reality of a quantum particle, or subatomic particle, depends on its appearance/interaction/detection in the physiostratum, otherwise the particle is but a conceptual entity in the mesostratum. Consequently, the instantiation of such particles depends on their interaction with or activation of physiostratum spacetime massive gravitational agglomerations.

The best support for the previous remark regarding instantiation, say of photons, is the total blackness of the cosmos except for pinpoints of starlight, faint gegenschein, or fuzzy nebulae as observed from deep space or as observed from the dark side of the moon. The night sky and cosmic space are ubiquitously flooded with multidirectional light rays, perhaps at the rate of tens of trillions of photons per square centimeter per second from countless stars and galaxies. Unless the photons impinge on a physiostratum object, a retina, photo emulsion, or CCD, their omnipresent light is imperceptible and their waveforms are only theoretically extant.

Indeed, waveforms and other mathematical representations of photons, electrons, and subatomic particles are ‘continuumthings’ that may be taken to exist in the mesostratum - like electromagnetic fields which also must interact with physiostratum objects to certify their reality.

Black Hole Voxel Reduction

It is instructive to examine the black hole effect on spacetime voxels near or at the event horizon where the gravitational pull becomes so great that photons cannot escape. Any light emitted from within the event horizon can never reach the outside observer. Photons approaching the event horizon from outside can never pass through the horizon but may form a photon sphere around the black hole. The photon sphere is a spherical region of space where gravity is strong enough to confine photons to orbit the black hole. The theoretical physiostratum radius of the photon sphere is 3/2 the Schwarzschild radius.

Dimensional analysis of the equation, $E = mc^2$ indicates a profound relation between the ratio (E/m) and the space/time ratio $[L/T]^2$. The explicit meaning of the equation is that nuclear binding energies and mass defects are related - that matter (mass) and energy are interchangeable and complementary. The implicit meaning of $E = mc^2$ is that energy and mass are essentially properties of spacetime, that is, space-displacement ΔL and time-interval ΔT. We define voxels as resonating cubes of spacetime with a wavelength and period of the Planck scale giving the ratio c, which is measured as the velocity of light $\sim 3\times 10^{10}$ cm/s.

Figure 2 shows the conceptual reduction of spacetime voxel wavelengths upon nearing a black hole event horizon. We argue that as voxel wavelengths approach zero, the velocity of physiostratum photons nearing the event horizon also approach zero. This implies that the corresponding mass approaches infinity in accordance with $m = E/c^2$, which is by definition a characteristic of the black hole mass compaction.

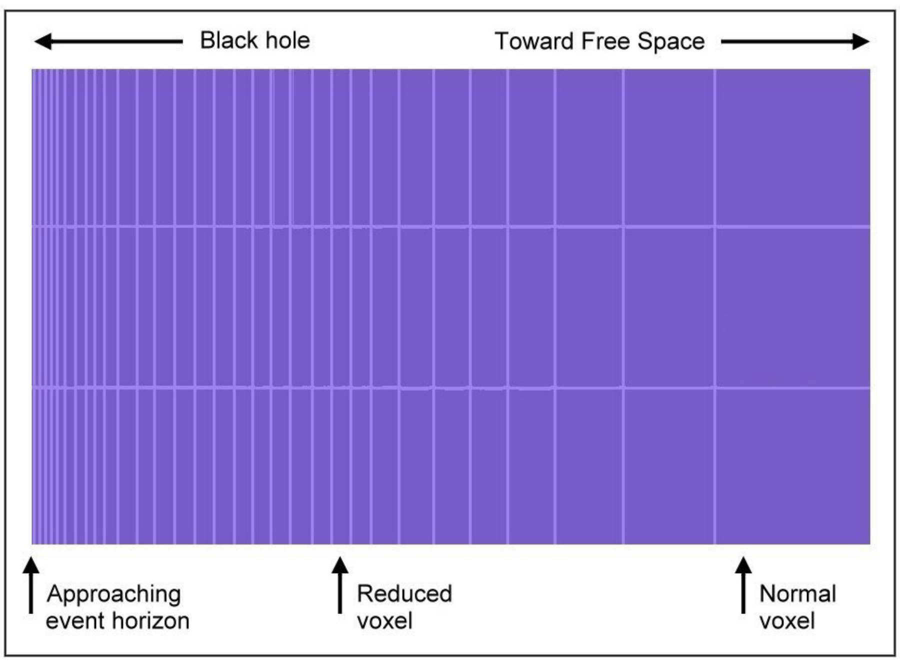

Figure 2 - Reduction of voxel wavelenght/frequency ratio approaching black hole.

Given the previous rationale, it follows that spacetime voxels in the vicinity of the surface of the Sun are also reduced, but significantly less than near a black hole event horizon. Accordingly, photons approaching the Sun at grazing incidence will deviate from a tangential line to a curved line, but will not orbit the Sun as in the case of a much more massive black hole. This corresponds to the deflection of light by the gravitational field of the Sun as predicted by Einstein's theory.

Dispersion of Light in Prisms

The black hole horizon is an extreme example of spacetime voxel reduction/modification by matter, which consists of gravitational agglomerations of large numbers of quantum particles. Such agglomerations may be a gas, liquid, solid, plasma, or a combination of these. Consider a solid which affects all contained and closely adjacent spacetime voxels: a triangular glass prism such as that used to study the dispersion of light. The process separates a beam of white light into its constituent spectrum of colors, as indicated in Figure 3.

As photons travel through a glass prism, each one is absorbed and re-transmitted by spacetime voxels and the atomic agglomeration comprising the prism. Upon impinging on an atom, each photon is instantaneously absorbed, causing the electrons in the atom to resonate. If the frequency of a photon does not match a resonance frequency of an orbital electron, it will be re-emitted at its original wavelength. The light wave then transits through the interatomic voxels until it impinges on the next atom and the process of absorption and re-emission is repeated. Violet light exiting the prism is separated from the red, as in Figure 3.

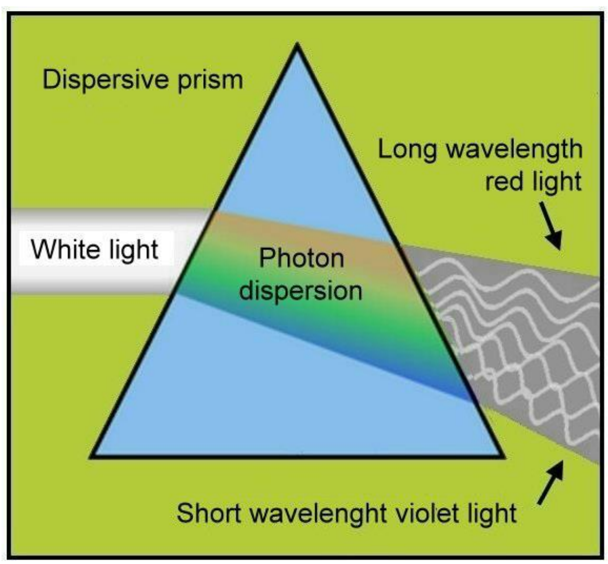

Figure 3 - Dispersion of white light in a prism.

We argue that the separation occurs because the violet light has traveled slower, having been deflected, absorbed, and re-transmitted by reduced spacetime voxels. This is based on the conjecture that spacetime voxels within a material are systematically reduced or distorted to various degrees by the surrounding and adjacent gravitational mass of the material.

The rainbow-colored photon dispersion depicted inside the prism illustrates that violet photons must follow one particular path through the prism while red photons must follow another. This suggests that there is a stepwise transition of spacetime voxel topology from the top to bottom of the prism which filters photons according to wavelength. As mentioned previously, a photon during its transit through the physiostratum jumps from one spacetime parcel to the next adjacent parcel while retaining its wavelike property.

Spacetime Topology Interpretation

In the double-slit experiment light passing through two precisely cut parallel slits in a thin opaque plate is collected on a photo-sensitive detector screen. After the photons pass through the slits, the image produced on the detector screen consists of a pattern of parallel light and dark regions corresponding to where more or fewer photons have impinged on the screen, Figure 4.

The pattern is taken as evidence of wave-particle duality inferred from a calculation which assumes that cylindrical wave fronts emanate from each slit and by constructive and destructive interference produce the pattern the develops on the screen. When it is examined, it is evident that the pattern was built piecemeal - quantum by quantum - not by continuous wave fronts but by a patterned accumulation of random spots hit by individual photons.

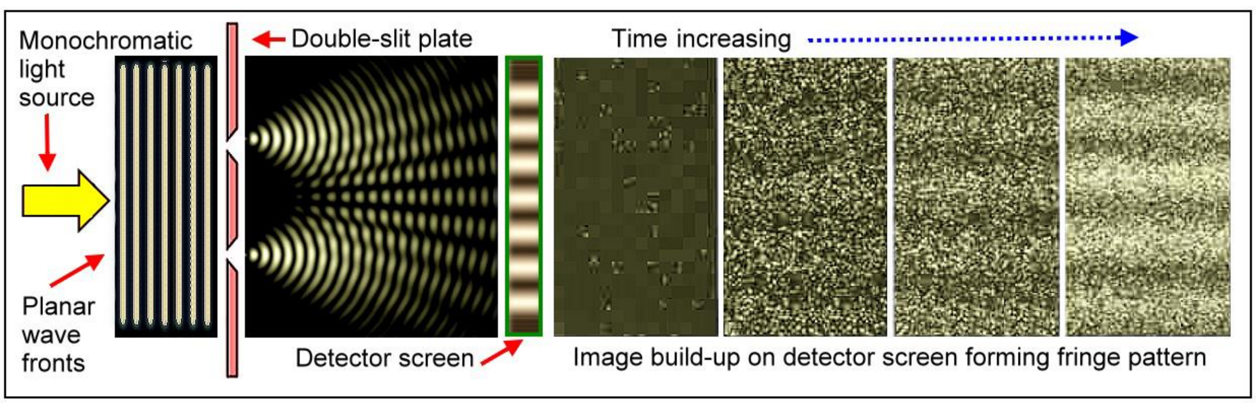

Figure 4 - Representation of double-slit photon dispersion pattern imaged on photon detector screen.

We propose that each individual photon passing through one or the other slit is deflected and guided by the modified/reduced spacetime topology - the voxel configuration space - within the bounds of each slit. This is based on the conjecture that spacetime voxels tend to assume a topological configuration in conformance with the topography of adjacent gravitational agglomerations, material objects, as depicted in Figure 5.

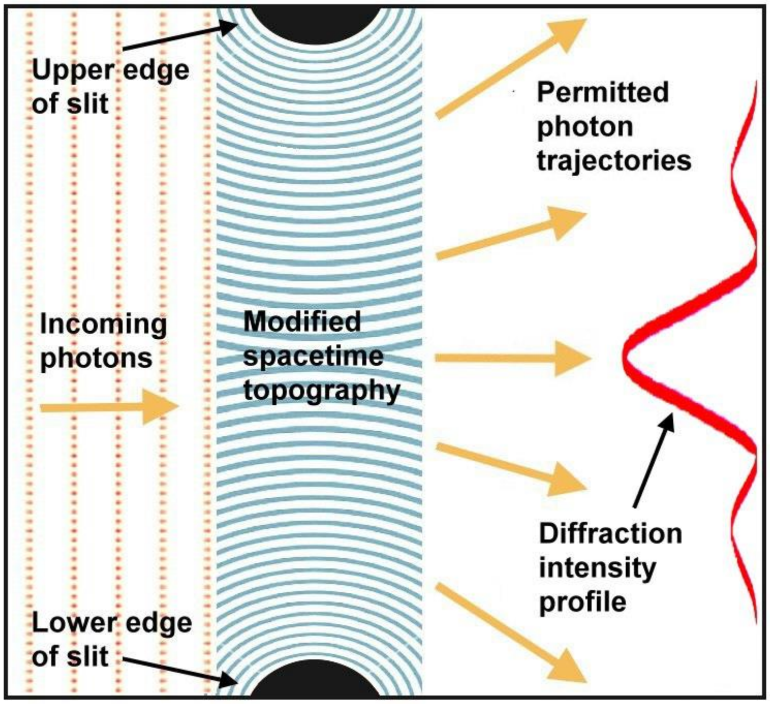

Figure 5 - Diffraction of photons by single slit voxel topography.

The double slit or multiple slit diffraction intensity profile will be produced by the voxel spacetime topology associated with the slit geometry used. Any multiple slit arrangement - or diffraction grating - is presumed to be constructed from a number of identical slits, each of which shares a combined diffraction topology environment similar but not necessarily identical to the single slit diffraction environment. For example, in the case of double slits it is likely that the proximity of the second slit will alter their shared voxel spacetime topology, which can configure adjacent to the intervening material surfaces between the slits.

Discussion

Space and time contemplated separately are intuitive and unremarkable, serving as convenient foundations for engineering and mathematical reference and coordinate systems. Combined as *spacetime* space and time assume a dynamic substantive nature with cosmological and quantum implications. This became evident after Minkowski introduced the radical concept of spacetime and Einstein implemented it in his general theory of relativity. Although space and time may be considered separate entities, the Lorentz geometry of special relativity can be most effectively represented in the context of a four-dimensional spacetime.

Topological geometrodynamics (TGD) is being developed to describe spacetime and associated phenomena completely in terms of abstract geometry and configuration spaces [2]. We posit four-dimensional spacetime voxels as elemental constituents of spacetime topology which demonstrably influences quantum phenomena and the diffraction and dispersion of subatomic particles. Indeed, in a previous article, we demonstrate the viability of the conjecture that spacetime voxels may be modified by mesostratum entities to produce cubic electrons and heavy electrons like the muon and tauon [3].

We propose that spacetime voxel topology variations may explain the Casimir effect. In studying the Casimir effect, typically two uncharged metallic plates in a vacuum are placed a few nanometers apart without any external electromagnetic field. In a classical description, the absence of an external field means that there is no force between them. From the quantum mechanics viewpoint, as the two plates are moved closer to each other, the total amount of zero point filed (ZPF) vacuum energy between the plates will be a bit less than the amount elsewhere in the vacuum, and the plates will attract each other. In quantum field theory, this Casimir effect arises due to virtual photons which comprise the vacuum field and which generate a net force depending on the nature and specific arrangement of the two plates. Our conjecture is that Casimir effect is due to voxel absorption or modulation between the plates.

Conclusion

It appears that the ultimate hidden variable which plagues quantum mechanics is spacetime. The state of a physical system is incompletely known unless topological variations of spacetime voxels and parcels are taken into account. These variations have prominent measurable effects within and adjacent to gravitational agglomerations, that is, physical objects. We demonstrated the effects of spacetime topology variations with examples, such as dispersion of photon fluxes in a prism, the diffraction of photon trajectories through slits and gratings. Quantum mechanics is incomplete unless it accounts for the detailed topology of the spacetime within which a physical system operates. Topological geometrodynamics (TGD) should ultimately provide the foundation and methodology for incorporating spacetime topology into quantum mechanics.

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