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ESSAY: QUANTUM MATERIALS, QUANTUM GEOMETRY AND NON-TRIVIAL TOPOLOGY OF THE ATOM.

1. Geometry is the basis of the quantum world and quantum materials.

The quantum world conceals a geometry whose foundation is essentially universal. This geometry governs and synchronizes all processes in the quantum world. Based on this geometry, Nature further constructs itself, creating stable blocks – atoms – from which the observable material world is constructed. The observable world, like a fractal, reflects the processes occurring in the quantum world. Based on this logic, the geometry of the quantum world can be comprehended both theoretically and through experiment and mathematical formalism, opening the door to an understanding of the original geometric foundation and, subsequently, the deepest secrets of Nature. This resolves the difficulties of physics itself and provides new impetus for technological development by exploring what Nature shares with us.

Quantum materials, whose electronic, magnetic, and optical properties are determined not only by the structure of the crystal lattice but also by the quantum mechanical effects that arise within them, help us understand the geometry of the quantum world. The term "quantum material" refers to any material that exhibits not only physical properties but also quantum mechanical properties when exposed to extremely low or high temperatures, as well as strong magnetic fields. Quantum materials exhibit quantum interference, spin-orbit interactions, quantum trapped bands, and topological effects.

A distinctive feature of quantum materials (superconductors and quantum Hall effect systems) is that quantum mechanical effects manifest themselves on a macroscopic scale as the collective action of elements in the crystal lattice of the matter at low and high temperatures, in strong magnetic fields, or on small scales. The result of such collective actions is unusual magnetism, superconductivity [151], the quantum fractional Hall effect [144], topological insulating behavior, quantum criticality, and many others.

The behavior of these collective effects is analogous to the behavior of a single quantum element and can be described by the laws of quantum mechanics. While quantum mechanics establishes the microscopic laws of nature, quantum materials bring these invisible subatomic laws to the surface. This allows these collective effects to be observed, exploited in everyday life and at scales characteristic of humans. In this regard, the diverse class of quantum materials opens up opportunities for both fundamental research and technological innovation in a variety of fields. [153][154][155][156][157][158][159][160]

The key characteristics of quantum materials are:

Quantum coherence, the ability of electron waves to maintain phase coupling over long wavelengths, is critical for observing phenomena such as superconductivity and the quantum Hall effect.

Strong electron correlations, where their interactions become dominant, leading to the formation of exotic states such as spin liquids or Mott insulators.

Topological properties, where the structure of electron states in momentum space can possess topological invariants that provide protection against local perturbations.

The study of quantum materials requires the integration of solid-state physics, quantum field theory, chemistry, materials science, and the application of other disciplines, as quantum

materials create a bridge between fundamental quantum mechanics and practical applications in microelectronics, nanoelectronics, optoelectronics, and energy, opening up fundamentally new possibilities for the creation of technologies and the development of physics as a science.

In examining the topics covered in this article, related to quantum materials, their effects, classifications, and experiments, I consider it necessary and logical to emphasize aspects directly related to atomic structure, as the structure of the atom and its geometry determine the shape and geometry of the crystal lattice. This is quite well illustrated by the example of graphene [150], whose atomic structure allows for exfoliation to a thickness equal to one atom. Therefore, the purpose of this essay is to focus more specifically on subatomic structure and its relationships with issues of quantum materials and quantum geometry.

2. **Quantum Geometry.**

The collective motions of electrons in quantum materials are generally characterized and described by complex wave functions. As already explored, the possible quantum states of a crystal carve out a curved shape. A new scientific field, Quantum Geometry, studies these questions.

Quantum geometry is a theory in physics that studies the intrinsic geometric properties of quantum systems and determines the electronic properties of quantum materials through the shape and curvature of the wave functions of electrons in a crystal lattice.

Nobel Prize-winning theoretical physicist F. Haldane once proposed a new quantum-geometric explanation for the fractional quantum Hall effect, proposing the existence of a quantum metric describing the shape of the circulating trajectories of composite fermions. The existence of this metric was long ignored.

In 2024, a research team from Nanjing University experimentally observed collective quantum excitations in a fractional quantum Hall liquid – chiral modes, where electrons in a material's crystal lattice rotate together and in only one specific direction as a manifestation of a collective effect. This observation provided experimental evidence for a new geometric theory for studying quantum-geometric effects in topologically correlated states of matter.

Following a research team from Shenzhen University in 2025 that proposed a unified theoretical framework for spin quantum geometry, predicting new effects, a subsequent research team from Zhejiang University systematically constructed the theory of quantum geometry for the first time, revealing its key role in optical response and the senetoelectric transition. Subsequently, a research team (Southern University of Science and Technology) proposed a new mechanism in which magnetic geometry directly induces quantum geometry, generating intrinsic nonlinear transport effects, which violates the traditional notion that this effect depends on spin-orbit coupling.

These experiments and theoretical proposals have led to quantum geometry becoming a key theoretical foundation in condensed matter physics for understanding the behavior of electrons, new states of matter, and optical responses.

According to traditional theory, the emergence of quantum geometry effects depends on strong spin-orbit coupling. However, research shows that in magnetic materials, the symmetry of the magnetic geometry in the crystal lattice space can suppress or resolve quantum geometric effects such as the Berry curvature dipole and the quantum metric dipole, directly inducing intrinsic nonlinear transport effects without the need for strong spin-orbit coupling. This establishes a profound connection between magnetic geometry and quantum geometry.

In the quantum world of quantum materials, quantum geometry defines the difference in phase and amplitude between two quantum states, where the phase difference is described by the Berry curvature, and the amplitude difference by the quantum metric. The Berry phase and the quantum metric are components of the **Quantum Geometric Tensor (QGT**). By definition, the QGT is a mathematical framework and a set of mathematical rules used to describe how a quantum material's quantum system changes when subjected to a stimulus.

«The Berry curvature is part of the quantum geometry of a material. The QHE is the archetypical demonstration that quantum geometry is one of the key quantities that make a material a quantum material. As we will discuss in the remainder of the review, the Berry curvature turns out to be the anti-symmetric part of a tensor Q, the quantum geometric tensor (QGT) [2]. In recent years it has become apparent that the symmetric part of this tensor, the quantum metric, g, also plays a key role in making a material, quantum. In a loose sense, the quantum metric appears to be the key quantity to understand the properties of materials in which both interactions and quantum geometry lead to macroscopic manifestations of quantum mechanics». [5]

Quantum geometry plays a key role in various physical phenomena in quantum materials, particularly optical responses, Landau levels, and fractional Chern insulators. Its influence on superfluid weight, spin stiffness, exciton condensates and electron-phonon coupling is also studied and discussed. Taking these aspects into account, quantum geometry has a pervasive significance for understanding the emergent behavior of quantum material structures, which explains its rapid development in the current period. [5]

As a branch of mathematics and theoretical physics, Quantum Geometry serves as the basis for the theory of Quantum Gravity in its quest to unite Quantum Mechanics and General Relativity into a unified Theory of Everything.

Until recently quantum geometric tensor (QGT) of wavefunctions were derived only theoretically. In November 2025, under the leadership of the Massachusetts Institute of Technology (MIT), the first direct measurement of the QGT of electron motion in a solid was conducted using ARPES photoelectron spectroscopy, opening new horizons in the study of quantum states. [1] [2] [10]

In the QGT measurement technique the quantum state can be represented as a landscape. The map of this landscape is the quantum geometric tensor (QGT), which shows how the landscape changes when various factors act on the substance, reveals the behavior of the material and allows insight into the structural essence of matter and what shapes its properties.

Understanding the geometry of quantum states is a key to the creation of new technologies and, at the same time, fundamental knowledge. This new method opens up promising opportunities for materials research and makes it possible to link theoretical calculations with real experimental data. It is planned to use this method to study a wide range of materials, especially those with nontrivial topology.

According to study leader Riccardo Comin, the participants have developed a plan to obtain completely new information that was previously inaccessible. This opens up new avenues not only for understanding the quantum properties of materials, but, more importantly, for controlling these properties. If the quantum behavior of solids can be controlled, this could have significant practical implications for manipulating the properties of semiconductors, creating new superconductors, and quantum computers.

The new ARPES method used is also expected to become ubiquitous. This new opportunity to measure the quantum geometry of materials arose thanks to close collaboration between theoreticians and experimentalists.

In the news [2] Elizabeth Thomson introduces the details of the experiment [1] and provides a number of quotes, in particular from the project leader Riccardo Comin, an associate professor of physics at the Massachusetts Institute of Technology (MIT).

The work done is based on the description of the wave hypostasis of the electron."You can think of it like a surface in a three-dimensional space, - says Comin. - There are different types of wave functions, ranging from the simple to the complex. Think of a ball. That is analogous to a simple, or trivial wave function. Now picture a Mobius strip. That's analogous to a complex, or non-trivial wave function. And the quantum world is filled with materials composed of the latter". [2]

"Until now, the quantum geometry of wave functions could only be inferred theoretically, or sometimes not at all. And the property is becoming more and more important as physicists find more and more quantum materials with potential applications in everything from quantum computers to advanced electronic and magnetic devices". [2]

The results of the previous experiment by the same group are published in [3][4]. Other detailed information about this experiment [1] can also be found in the publication Shalma Wegsman in Quanta Magazine. [10]

"Topological materials are no longer so mysterious: Physicists commonly use them to discover new phases of matter and are exploring their potential for quantum computing. But only recently have they come to appreciate the fuller picture of quantum geometry that includes not only the Berry curvature but also the quantum metric – the shape of the rugged landscape that can exist on top of a torus-shaped map. A couple of years ago, the quantum metric helped researchers understand what was going on in a 2D crystal that hosted an exotic new form of superconductivity – the flow of electricity with no resistance.

The physicist Riccardo Comin and collaborators recently mapped the full quantum geometry of a crystal for the first time. Päivi Törmä helped show how quantum geometry can explain exotic material behaviors such as superconductivity". [10]

In a recent essay, "**Where Can Quantum Geometry Lead Us?**" [9], Päivi Törmä, a professor of physics at Aalto University, Finland, notes many important aspects of quantum geometry and also identifies current issues in this new science:

"**It has been theoretically predicted that quantum geometry governs a variety of physical phenomena.**

Once a few smoking-gun experiments on quantum geometry effects have been achieved, the focus should swiftly shift from showing that "quantum geometry is there" to **how can we utilize this concept to better understand nature and, eventually, to create new technologies**.

To proceed on the quantum geometry road, we should implement the extraction – and smart visualization – of quantum geometric concepts as a standard functionality of these tools.

Despite challenges, our goal should be that the most powerful numerical methods of condensed matter physics will provide the essentials of the quantum geometry of the bands, properly visualized, as easily as they give the energies. Once this becomes a routine, we will start seeing things from the perspective of quantum geometry, like we now do from the band structure's, and this will be a source of understanding and discovery.

A whole new theory framework is needed to capture the physics-relevant quantum geometry aspects even in cases where the standard concepts cannot be used. Inspiration for this

search can be found from the effective mass tensor of a two-body bound state in a system of multiple nonisolated bands where the quantum geometric contributions and band dispersions intertwine [30].

Finally, widening means also that we condensed-matter–quantum-geometry enthusiasts should make friends with the communities that have been studying quantum geometry for a long time—high energy physics, cosmology, and quantum information—and dive into their literature [31]. The danger of drowning there is of course considerable, but the embarrassment of reinventing too many wheels is an even more daunting prospect.

It remains to be seen whether quantum geometry, including both quantum metric and the Berry curvature and thus **topological physics**, will play an equally large role in our world. What is clear is that the world needs out-of-the-box discoveries: world energy production and consumption are literally burning questions, as are scarcity of materials and several other gut-wrenching problems. Innovations as big as the transistor are much more urgently needed now than at the time transistor was invented. Therefore, we should try all possibilities.

Perhaps the most notable prospect from quantum geometry is to guide the way to room temperature superconductivity. The interplay of light, electronic transport, and quantum geometry intrigues me as well, because photovoltaics is another area where major technological advances can have world-changing impact. There may be other equally important goals for which quantum geometry can provide guidance, but my imagination stops here.

I give the floor to the reader who probably has a different background and can thus come up with different ideas". [9]

Well, if the floor is given to a reader with a different background and the potential to offer new ideas, then perhaps it's simply impossible not to take advantage of it. In this essay, I'd like to outline how my new ideas relate to questions of quantum geometry, which studies the manifestation of quantum-mechanical effects on a macroscopic scale in quantum materials, and how these ideas converge with questions of the geometrization of physics.

The center of my ideas and research results is atomic structure and the universal method Nature uses to generate matter through the process of symmetry-doubling bifurcation [89][92][93][96].

Atomic structure is directly related to the structure of the crystal lattice of matter and the processes that occur within it under changing temperature conditions or under various types of influences, which are directly within the scope of quantum geometry and are studied by it. I consider an approach to questions of atomic structure based on the properties of topology, and in particular its very first object of study – the Möbius strip.

As noted in [9], it turns out that "topological physics was perhaps only one aspect of a wider and possibly even more influential concept, namely, quantum geometric physics".

If so, then considering atomic structure based on topological properties has a direct connection with questions of quantum geometry and may help to better understand and explain the effects observed in experiments.

Conducting experiments raises new questions for explaining the effects, and perhaps "a whole new theory framework is needed to capture the physics-relevant quantum geometry aspects even in cases where the standard concepts cannot be used." [9]

Historically, standard concepts in physics have been built on the assumption that the atom is composed of particles, and this underlies current concepts and established theories. However, recent experimental advances in quantum geometry support the idea that the structure of matter is determined by a nontrivial topology.

Based on theoretical propositions, experimental observations, and the conclusions drawn from them in the framework of quantum geometry, one can already assume and even assert that the structure of the atom is geometrically determined by bounded, nontrivial surfaces that are closed and represent integrally interconnected systemic entities. The presence of quantum activity is confirmed by the emergence of quantum-mechanical macro-effects observed in the crystal lattices of quantum materials and measured using quantum thermodynamics.

In light of this logical assertion, I would like to introduce readers to my conceptual proposal regarding questions of atomic structure. What I propose is an explanation of the structure of the atom based on the geometric transformations of monopole and dipole spatial geodesic lines of magnetism, which are determined by the essence of the all-encompassing and fundamental principle of complementarity. [161][172] [31][38][88]-[97][111]

In a closed atomic space, bounded by the nontrivial geometry of spatial geodesic lines of magnetism, an act of energy generation occurs, and magnetic geometry induces quantum geometry.

3. **A Better Understanding of Nature. The Ontological Principle.**

The proposal of an atomic model based on a nontrivial topology is an integral part of a self-consistent monistic concept [89]-[93], in which my conceptual reasoning begins with the structure of the cosmic medium and the dual structure of its matrix magnetic unit (cell) as a physical point in space.

The geometry of such a unit (cell) is determined by the ontological essence of the **fundamental principle of complementarity**, the physical embodiment of which is **magnetism**. Consequently, the essence of magnetism is a complementary duality, which has an initial monopole state without an external magnetic field. During the bifurcation of magnetic loops, the monopole state of magnetism transitions to a dipole state, which is inherent in baryonic matter. In this transition, the gravitational interrelationship is actualized along with the manifestation of an external magnetic field, opposite charges, and mass. The magnetic dipole, formed by the bifurcation of a magnetic monopole, is the basic element of Nature's construction of atoms. [31][90][92]

The **ontological essence** of the fundamental complementary principle is the dual interrelationship of two mirror-asymmetric opposites of a single whole in their mutual cyclical motion, traditionally illustrated by the ancient Yin-Yang symbol, in which the mirror-asymmetric relationship of interconnected components is achieved through a 180-degree rotation. Magnetism is the physical embodiment of the principle of complementarity, and the original magnetic loop must be represented by incorporating the designated complementary duality into its representation, which is geometrically achieved using a Möbius strip with one 180-degree rotation initially.

The complementary principle of combining the geometric image of the cyclical closed movement of energy with its mirror-asymmetric image, which underlies the creation of the one-sided Möbius strip, allows us to consider it as an analogy to the Yin-Yang symbol, which reflects the principle of complementarity in two dimensions, and the Möbius strip in three dimensions.

Thus, this approach allows us to geometrically represent the initial magnetic monopole loop with the nontrivial topology of a Möbius strip with one inversion. This is followed by the geometry of quanta, then the dipole intra-atomic nontrivial topology that determines the structure of the atom, then the structure of the crystal lattice, and finally the properties of matter. In

accordance with this, logic moves toward questions of energy extraction, as well as fundamental theoretical generalizations for creating a Theory of Everything. It is worth discussing how all of this is conceptually connected and what logical basis it provides for the current stage of the geometrization of physics. [172]

Wave geometries are mediated by the structure of the cosmic medium and are determined by the processes occurring within it. If we take into account the work of our predecessors regarding the structure of the cosmic medium, as well as the achievements of our contemporaries [17][18][19][20][21][22][23][24][25][26][79][80][83][84][85], then the cosmic medium can be called the **Quantum Medium** with all its contents, the basis of which is a matrix of dynamic spinning units [19-21][22][23-25]. The nature of these units is magnetic and represents a living cosmic plasma according to how Nobel laureate H. Alfvén defined it [12][13][14][15], and Nobel laureate F. Wilczek also expressed related thoughts about the magnetic ingredients of the cosmic medium. [16]

In my proposed self-consistent concept [89][90][91][92][93], such a living plasma is called **magneto-plasma**, the magnetic units of which perform continuous and unceasing oscillations (spinning), caused by the geometry of their complementary structure and its properties. [90][31]

According to my new ideas presented in the proposed concept based on the ontology of the **principle of complementarity**, these magnetic units are magnetic loops that include inversion, in other words, a 180-degree reversal. Such a geometric representation of the original magnetic loop in the format of the nontrivial topology of the Möbius strip as a starting point for an entire conceptual framework has not yet been proposed by any scientist.

In the concept I propose, the ontology of the complementarity principle and magnetism as its physical embodiment are the **starting point** from which all subsequent conceptual reasoning proceeds, while the Möbius strip and its topological properties provide the necessary visualization of all transformations of a dynamic physical unit (cell) of space, bounded by a nontrivial topology.

These geometric transformations, based on the topological properties of the Möbius strip, include: bifurcation (fibration) of the magnetic loop-monopole and its geometric transformation into a wave magnetic dipole (the basic element of baryonic matter) with doubling of the initial parameters of the magnetic monopole; two states of the magnetic dipole, geometrically transformable into each other based on a topological property and visualizing the physics of the "proton-electron" and "neutron"; the actualization of the bipolar gravitational interrelationship in the magnetic dipole together with an external magnetic field, opposite charges, and mass; actualization of the interlinked relationship of magnetic dipoles (quantum entanglement) in subsequent bifurcation/fibration phases and the formation of a universal scheme of topological dipole nodes "Center-Periphery," which is the basis of the atomic structure in proposed new planetary model of the atom based on wave magnetic dipoles; based on the bifurcation/fibration phases, an explanation of the process of charge quantization and the formation of the periodic table of chemical elements with visualization of their models of the first two periods, including fluorine [92][111], as well as other issues that are consequences of the spatial geometric transformations that take place in the Quantum Medium and its vital functions.

With regard to all of the above, which constitutes the conceptual framework of the new proposal as a fundamental study, there are already theoretical proposals and experimental studies in the scientific field that examine related issues: magnetic monopole [94 [2]][79][80][147][148]

[90 [94]-[116]], monopole bifurcations [143][149], charge quantization with the involvement of a monopole [94 [1]]] [143], hydromagnetic dynamo models [64][65] and others.

In relation to this, I would like to emphasize that the questions listed above are considered by me in the proposed monistic concept in that interconnection which represents that type of self-consistency when the logic of reasoning, starting from any of them, leads to all the others without additional postulates and conditions. [89]-[93]

4. **Geodesic Lines.**

For this essay, I have briefly outlined the basic chain of geometric spatial transformations of a magnetic monopole loop based on the nontrivial topology and properties of the original Möbius strip. These fundamental geometric transformations are equally extrapolated into the micro-world of quantum phenomena and the atom, and into the macro-world of stellar-planetary system formations, and demonstrate a fractal-like structure of scaling levels, which forms the basis for generalizations and the creation of a Theory of Everything.

Based on the fact that magnetism is the physical embodiment of the principle of complementarity, and the geometry of the Möbius strip is a reflection of the complementary superposition of the cyclical closed movement of energy with its mirror-asymmetric image, then in such a magnetoelectric Möbius circuit, two opposing mirror-asymmetric flows, as they move in opposite directions, create a reconnection effect with the release of quanta. As a result, such a magnetic loop with an inverse reversal is an oscillator and a quantum generator. [90[45][46]]

During the bifurcation (fibration) of such a magnetic monopole loop along the Möbius curvature line, its inversion and length double. This doubling of the magnetic monopole loop's framework parameters leads to the formation of a new dual symmetry and the transformation of the closed loop from a "magnetic monopole" state to a "magnetic dipole" state.

Furthermore, at subsequent stages of bifurcations/fibrations, but now of magnetic dipoles, topological dipole nodes form. These nodes form the basis of the atom's structure, existing in two mutually inverse states due to the properties of the magnetic dipole. Based on the topological property caused by inversion (a 180-degree reversal), in all phases of fibrations, as new symmetries form during the generation and growth of matter from within, the framework parameters and properties of the magnetic monopole are transferred to all generated objects. Hence the well-known fact that all objects in space, from atoms to galaxies, undergo magnetoelectric oscillations with the emission and absorption of quanta.

This is a very important aspect in understanding the nature of magnetism, opening up a new perspective on the physics of the atom and its structure, which determines the structure of the crystal lattice of matter and the motion that occurs within it both regularly and under the influence of external factors: temperature, strong fields, laser radiation, mechanical stress (impact, friction), electromagnetic radiation, and others.

Now I would like to demonstrate the connection between this dipole basis for the atomic structure, formed by the bifurcation/fibration of a magnetic monopole loop on the nontrivial topology of the original Möbius strip, and the concepts of **General Relativity and Quantum Mechanics.**

General Relativity (GR) examines not the forces acting on it, but the curvature of space itself. Motion in such a space occurs along its **curved geodesic lines**.

The Möbius strip is the **initial geodesic line** of the shortest distance over which a magnetic monopole loop (magnetic flux) completes a two-cycle rotation, creating a dynamic

interaction of complementary opposites in space that results in the release of portions of energy – the **emission of quanta**.

In other words, a geodesic line in Möbius strip geometry is the minimum distance that must be traveled in the vortex motion of magnetism to release an energy quantum (electricity), whose shape follows the curvature and bends of the moving magnetic flux that generated it.

It is this interrelationship between the magnetic and electrical components that is reflected by the "Clifford parallels," indicating that **magnetic geometry induces quantum geometry** and, as a consequence, the **spatial geometry of emitted quanta replicates the shape of their emitter.** This is directly related to Quantum Mechanics, which describes the behavior of matter and energy at the atomic and subatomic levels using mathematical formalism, in particular the wave function.

The space bounded by a geodesic line in the form of the original Möbius strip, due to the presence of constant magnetoelectric reconnections, is a dynamic vortex cell of the Quantum Medium matrix and defines the discrete-continuous structure of space-time. Such a closed magnetic circuit is an elementary geometric form of space-time motion, based on the complementary essence of magnetism and underlies all movement and the structure of the manifested world.

This closed dynamic magnetoelectric circuit is also the sought-after relativistic "particle" conditioned by the bounded nontrivial surface of the Möbius strip, the geometric structure of which was sought and attempted to be depicted in the works of K. Schwarzschild [95[7]], and then A. Einstein together with N. Rosen [47], and which remained in the history of science as the well-known "**ER bridge**", with the help of whose geometry the authors at that time were unable to fully solve the posed problem of visually depicting the original spatial cell (elemental) and its geodesic curvature, which must be closed as energy generation occurs only in a closed space. This is universal at any level: quantum, atomic, biological, cosmic.

Thus, the geometric approach based on the topology of the Möbius strip provides GTR with the initial geometry of space-time curvature and the visualization of a closed elemental as a matrix cell of space-time, and Quantum Mechanics with the initial form of a quantum phenomenon conditioned by the geometric structure and magnetoelectric properties of such a matrix magnetic unit (cell), inducing quanta in its vortex motion. And in this regard, on one physical cell of space in the original form of the non-trivial topology of the Möbius strip, it is possible to combine the formats of two fundamental theories at the very starting point of reasoning, carrying out the process of geometrization. [172]

If we look at the graphic representation of the ancient Yin-Yang symbol from the discussed perspective, it geometrically visualizes a closed circuit of two complementary opposites and the release of a quantum of energy at the points of their junction (the wave function in the middle of the circle). When the sinusoidal front of an emitted discrete wave quantum closes, a Möbius pattern is always obtained. To visualize this closure, it is necessary to display the sinusoid as a strip, not a line. [90][161]

Therefore, an important conclusion is that the **geometry of the Möbius strip is the geodesic line of the spatial structure** that extremizes the movement of magnetic flux in the form of two mirror-asymmetric opposites in a closed magnetoelectric circuit. [161] As a full circular revolution is completed, simultaneously creating a 180-degree inversion, the end result of the interaction of the two resulting opposite magnetic fluxes of this circuit is the release of quanta. The magnetic geometry of such a circuit induces a quantum geometry.

In [90], using a simple "***origami-twist***" method for a Möbius strip with a minimal aspect ratio, the formation of a Möbius vortex is geometrically demonstrated.

5. **The Role of Topological Physics in the Structure of the Atom.**

That the nontrivial topology and geometry of the Möbius strip are directly related to the structure of the quantum world is already a well-known scientific fact. These are the questions of Quantum Mechanics. Regarding the structure of the spatial fabric and its curvature, which underpin General Relativity, it is essentially necessary to return to the ideas of William Clifford which lay at the origins of questions about the geometrization of physics. It was he who proposed considering the spatial fabric as curvatures, which he represented in the form of parallels, known as "***Clifford parallels***." [27]-[30]

But the closed "Clifford parallels" represent nothing more than the topology of the Möbius strip, and it turns out that, even from the Clifford parallels, the formats of QM and GTR began to converge at a single point on the original geodesic line of magnetism in the form of the Möbius strip and its quantum activity.

Based on such ideas, W. Clifford claimed that this "explains the laws of electric and magnetic attraction/repulsion, the action of electric currents on magnets and on each other, the laws of induction, the derivation of the velocity of charges and the polarization of light, the rotation of the plane of polarization by a magnetic field. All these things must be deduced from knowledge of the geometric forms of atoms and their relationships with the ether." [27][30] Speaking in the language of the monistic concept I proposed, "these things must be deduced from knowledge of the geometric forms of the structure of atoms and their quantum exchange with the Quantum Medium." [30][90]

Based on the shape of the initial geodesic line, which is analogous to “Clifford parallels”, and from its applications to aspects of GTR and QM, as well as on the bifurcation property of a magnetic monopole loop, inherent to magneto-plasma as a hydrodynamic fluid, logic leads to the formation of atoms as a result of a process of stepwise bifurcations with doubling of symmetries. In the monistic concept I proposed this process of bifurcations with doubling of the parameters of the initial magnetic monopole loop is connected with the phenomenon of a hydromagnetic dynamo [64][65], in which a doubling of magnetic loop (flux) occurs. And by establishing interdisciplinary bridges, I have proposed a new model of the process of magnetic flux doubling, which, in essence, is a method for the formation of atoms. [93][96][111]

According to the proposed logic, let us approach the nontrivial topology of atomic structure. [92][94]

In the first phase of bifurcation/fibration the magnetic monopole loop is geometrically transformed into a two-arm magnetic dipole with a doubling of the original monopole loop parameters: the loop length is doubled and the inversion is doubled. In this case, the nontrivial topology of the original Möbius strip with one inversion is transformed into a nontrivial topology of a Möbius strip with two inversions. This doubling determines a new geometric shape of the magnetic loop (flux) in the form of a figure-eight, in which the two arms of the magnetic dipole are connected through the crossing of the Möbius curvature line.

A **magnetic dipole** is a change in the geometric structure of space-time caused by a new redistribution of energy and momentum due to the doubling of the framework parameters and associated with the manifestation of an external magnetic field, the actualization of the gravitational interrelationship between charges and mass.

Having a mirror-asymmetric chirality, the arms of a magnetic dipole act as opposite charges, and the crossing point is the point where the charge undergoes a topological reversal, becoming its opposite. Based on this interrelationship in a magnetic dipole, two oppositely charged components can exist in a state of magnetoelectric equilibrium. This explains why, being oppositely charged and in such a geometric interrelationship, the atomic components ("proton-electron") do not stick together, but are held together by magnetoelectric gravitational equilibrium (balancing). The gravitational interrelationship between the dipole arms embodies the nature of magnetism and, through the crossing point, functions as an automatic regulator, similar to a balance beam with a movable axis. This provides feedback for each change that occurs, thereby ensuring the dynamic stability of the magnetic dipole.

The bipolar structure of the magnetic dipole is universal, and gravity performs the same balancing role between the dipole components of the planet-star in the stellar-planetary system of the macrocosm, just as the "proton-electron" does in the microcosm of the atom. The crossing point of the Möbius curvature line of the magnetic dipole in the proposed monistic concept is called the **gravitational tensor**. I believe that the Langrangian point (libration point) has the same relationship to the dipole structure at a different scale.

As this becomes clear, gravity, as a dual interrelationship between the dipole components, finds its explanation in the macrocosm of cosmic systems and the microcosm of the atom. The nontrivial topology of the Möbius strip elegantly manifests itself in many universal properties and elegantly "squeezes" gravity into the micro-world.

The magnetic dipole is the next **closed geodesic line** of space-time which represents the shortest or optimal distance that magnetic flux must travel to ensure the continuous and uninterrupted operation of a two-arm oscillator, which operates in a mode of uninterrupted and continuous oscillations with the emission and absorption of quanta and is the **basic element** for the formation of baryonic matter.

The emitted quantum formations (portions of electricity or magneto-plasma) are the result of the quantum activity of the wave magnetic dipole, but are not its constituent components. That is, they have no direct relation to the structure of the dipole, in which one arm of the "figure eight" is destined to play the role of the center "proton," and the other arm – the role of the peripheral "electron." These roles are distributed between the dipole arms when the symmetry between them is broken and the center of equilibrium (gravitational tensor) shifts toward the arm with the increased mass. This shift occurs in accordance with the principle of a balance beam with a moving axis. [92][161]

A two-arm dipole oscillator determines the quantum activity of an atom within the crystal lattice of a matter and saturates the atomic space with quantum formations, which in current physics concepts are given various names: quasi-electrons, photoelectrons and others. This does not change their essence, which is that these emissions have a discrete wave character. They are not constituent parts of the atom, but rather a product of atomic magnetic rhythm-dynamics which induces electrical fluctuations. It is these emissions that can exhibit active collective effects, which are determined by the nature and intensity of external influences.

In the atomic structure, a magnetic dipole can exist in two mutually inverse states, geometrically transformable into each other based on their nontrivial topological properties. One state is the "figure eight" state which forms the basis of a unified physics for the "proton-electron" together, and the second state is when the dipole arms are coaxially nested to each other forming a double Möbius pseudo-ring. In this state the magnetic dipole acquires neutrality

and forms the basis of the physics of the "neutron." Based on their topological properties, the "proton-electron" and "neutron" represent modifications of the same dipole entity ("particle"), as hypothetically proposed by E. Rutherford and discribed by W. Heisenberg. [121] [161]

The magnetic dipole is the basic element of Nature for the creating the atom. When the symmetry of the arms is broken, the magnetic dipole becomes the first element of the periodic table of chemical elements – protium (hydrogen).

Further creation of atomic elements occurs through subsequent doublings of magnetic dipoles in fibrational phases. The process of bifurcations/fibrations causes **charge quantization** [31][92][94][97][111][161] and the charges of atoms are always multiples of the minimum charge calculated value potentially hidden in the magnetic monopole before its bifurcation. The bifurcation of a magnetic monopole geometrically redistributes the framework parameters and actualizes the external magnetic field along with the charges in their opposite phases. Mass is also actualized along with the gravitational interrelationship that links the arms of the resulting magnetic dipole through the intersection of the Möbius curvature line. The similarity in the forms of Coulomb's and Newton's laws, which R. Feynman sought to explain, is due to the universal dipole scheme. [161]

With further doublings during bifurcations, beginning with the second phase of fibration, with the doubling of magnetic dipoles, the link topological interrelationship (quantum entanglement) is actualized. [91][92] In this case, some arms of all the formed magnetic dipoles remain connected into a single topological node, which acts as the atomic core (center), while the opposite arms act as the peripheral membrane. Due to the polarization orientation of the topologically connected magnetic dipoles in the radial direction, a "Center-Periphery" scheme is formed, which establishes the fact that the new model of the atom remains planetary, but the representation of the atomic components is fundamentally changed. These components form a seamlessly connected, stable structure due to topological properties and actualized interconnections (gravity and quantum entanglement) ensuring the stability of matter. Model diagrams of atoms of the first two periods of the Periodic Table of Chemical Elements, including the element fluorine, are presented in [92][111].

Through the peripheral vibrational membrane, the atom carries out its external quantum activity, emitting and absorbing quanta. The vibrational membrane also forms the crystal lattice and enables chemical bonding. Due to the quantum activity of magnetic atomic dipoles, the crystal lattice of matter is always saturated with quantum formations, which are the carriers of electrical conductivity in materials under certain conditions. These quantum formations can be controlled by applying various types of stimulation to them, as well as by shaping flat and other zones of materials at different angles.

It's worth noting a very important property mediated by the nontrivial topology of the Möbius strip. When dipole nodes and systems form based on the topological interconnection of dipoles into a single node, the entire system is automatically and instantly synchronized. This instantaneous nature is due to the scientifically established property of quantum entanglement. All dipole formations, prior to their manifestation, were part of a single system – a closed magnetic monopole cell or a macro-cell of monopoles. Due to bifurcation, all generated components of the system formation remain quantum entangled and, accordingly, instantly synchronized. [161]

It can be noted that the dipole and "Center-Periphery" schemes are universal and have the same application not only in the atom, but also in stellar-planetary systems, as well as in systems of biological organisms, societies, and social groups.

The proposed atomic structure based on a nontrivial topology of magnetic dipoles lays out a logical path that defines the important role of topological physics within quantum geometry for understanding issues related to quantum materials, as well as for geometric engineering and aspects related to the structure of any matter.

Atoms are a product of the Quantum Medium and the result of the collective action of its topological magnetic matrix cells in a universal bifurcation process with doubling of the initial parameters. In other words, the formation of atoms is a manifestation of the macro-effect of the collective bifurcation of the initial magnetic loops, which represent unmanifested matter in a monopole state of magnetism on a nontrivial Möbius strip topology with one inversion, which has the ability to transmit the framework properties into all generated matter.

The formation of matter, determined by spatial monopole and dipole geodesic lines based on the nontrivial topology of the Möbius strip, could create a new basis for explaining the quantum-mechanical macro-effects observed in quantum materials experimentally and proposed theoretically in quantum geometry and condensed matter physics. The new atomic model could give quantum geometry a new impetus, as it allows for the integration of the proposed innovation with what has already been theoretically and experimentally developed and achieved.

The proposed atomic model introduces a new understanding: the atomic structure itself is integral, and intracrystalline motions are determined by the activity of quantum radiation from atomic dipoles and are based on the displacements of arrays of these quantum formations in collective effects, which acquire different properties in different crystal lattices and under different types of influence. But the most important thing is that they represent intracrystalline quantum fluctuations that can be controlled, and their current flow can also be geometrically directed.

An approach to understanding atomic structure based on nontrivial topology could significantly impact our understanding of the nature of things, the effectiveness of finding not only "magic angles" but also the selection of combinations of atomic compounds for various purposes according to the required properties, and, consequently, the future development of physics and new technologies.

As the results of experiments in quantum geometry and quantum materials show, the wave function of a material moves along a curved trajectory, which may indicate that its curved trajectory is determined by the nontrivial shape of the aforementioned geodesic lines of magnetism that create the structure of the atom. If, when the conditions of action on a material change and the material subsequently returns to its original state, the material becomes topological – that is, the direction of the imaginary arrow of movement across the landscape changes – then the manifestation of this property has its hidden cause, underlying the structural form, namely, the topological properties of the atom itself and the crystal lattice based on it. Other examples also support the proposed new atomic model.

In the physics of wave processes (quantum mechanics, optics, magnetism), the Möbius strip serves as the physical embodiment of a nontrivial fibering, in which, upon completing a full revolution, a wave or state vector acquires an additional geometric shift – the Berry phase. The relationship of the Berry phase to the geometry of the Möbius strip is a classic example of how abstract mathematical topology directly corresponds to the physical properties of a system. The Berry phase generated in a compact optical Möbius system is particularly promising for geometric quantum mechanics and its applications, such as modeling, metrology, sensorics, and computing. [124][130][35]

"The nontrivial topological properties of Möbius strip entirely determine the emergences of the monopole magnetic field and the quantum spin Hall effect. In other words, the complex geometries and topologies of two-dimensional systems can provide a new perspective to investigate new phenomena of Hall physics implied in a high-dimensional space." [144]

The presence of the Hall effect and the Berry phase in quantum materials indicates the presence of Möbius curvature in their crystal structures.

The state vector of a quantum particle or the polarization vector of light behaves on a Möbius strip exactly like an arrow moved along its surface by parallel translation: [110][162]-[171][90 [76]]

6. **A New Theoretical Framework for Describing Aspects of Quantum Geometry.**

To what extent is a new theoretical framework necessary for describing aspects of quantum geometry? This is a highly relevant question, which touches on the very foundation of the structure of matter, that is, the structure of the atom, and our current level of understanding of this structure. To some extent, this is a very subtle scientific question, as science is at a crossroads of paradigm shift.

I believe it is necessary to consider the opinion of Nobel laureate and J. Milner Prize winner G. Hooft, that “Quantum mechanics is based on a mathematical method used to describe very ordinary physical effects. I think the physical world itself is a very ordinary one that is completely classical. But in this completely classical world, there are still too many things that we don’t know today; there are steps we’re basically missing on our path to deeper understanding”. [69]

“I’m talking about steps that would exploit the fact that the whole world is very simple and straightforward. The trouble is, the world still appears complicated to us now, which is why we’re in this situation”. [69]

In a recent paper, "How quantum is quantum geometry?", the authors conclude: “To summarize, our analysis shows that most phenomena associated with quantum geometry are in fact of a classical origin, and originate from the interplay between slow and fast degrees of freedom of a dynamical system.” [152]

This topic can be developed further, but I offer a constructive conceptual approach to the issues of the theoretical foundation and my new reasoning within the framework of my proposed self-consistent concept, the center of which is the atom and its structure.

Therefore, in this essay, I attempt to outline my proposed new atomic model, which originates from the initial magnetic cell of spacetime in the nontrivial topology of the Möbius strip. This cell possesses quantum mechanical activity and is a magnetic monopole nucleus, the existence of which was hypothetically proposed by P. Dirac in Quantum Mechanics. This cell can also be considered the initial relativistic "particle" that several authors have attempted to represent in General Relativity. Represented in the nontrivial Möbius strip topology for the general relativity framework, this relativistic particle, bounded by a nontrivial surface, simultaneously serves as the initial geodesic line representing the shortest distance traveled by magnetic flux to create its opposite and emit a quantum.

It is precisely this conceptual fusion of two fundamental theories, at the very outset of discussions on a single physical cell of spacetime, which has a distinct form and quantum activity, that is capable of generating a new theoretical foundation for questions of the geometrization of physics and, accordingly, for quantum geometry.

The process of stepwise bifurcations of such a spatial magnetic cell gives rise to the phenomenon of a hydromagnetic dynamo, in which, through **geometric spatial transformations of a monopole geodesic line into a dipole geodesic line,** the formation of baryonic matter occurs with the actualization of an external magnetic field, gravity, charges and mass, as well as quantum entanglement to maintain the integrity of the system formation. It is the topology of the Möbius strip in its dipole variant of development that reveals the **essence of the gravitational interrelationship.**

This conceptual fusion of two fundamental theories, at the very beginning of reasoning on a single physical cell of space-time, which has a distinct form and quantum activity, is capable of generating a **new theoretical foundation from a single starting point** for questions of the geometrization of physics and, accordingly, for quantum geometry. [172]

"The true answers must undoubtedly come from the incorporation of the gravitational force. At first sight it may seem difficult to believe that such an extremely weak force could cause so much havoc in a theoretical construction such as the Standard Model. The point is, however, that if gravity really corresponds to the curvature of space and time, as we must conclude from the successes of Einstein's theory of General Relativity, then Quantum Mechanics predicts quantum fluctuations in this curvature that, at the tiniest distance scales, grow out of control. This means that either gravity theory, or Quantum Mechanics, or both, must be replaced by some superior paradigm when we wish to describe physics at distance scales smaller than 10^{-33} CM. Whatever paradigm this would be, it is likely to entirely reform our understanding of the fundamental interactions, answering all our present questions at one stroke". [87]

"…you have to start from the beginning, like I said about quantum mechanics. … we need to step backward first, and that's always my message in science in general: before you understand something, just take a few steps back. Maybe you have to make a big march back, all the way back to the beginning". [69]

I have made a kind of forced march to the origins of quantum science. In this return to the very beginning, I have reexamined the interpretations of the experiments of J. Thomson and E. Rutherford (Geiger-Marsden) and provided new explanations for them based on a proposed new wave model of the atom, which separates the essence of the electron as a component of atomic structure from the essence of the electron as a quantum formation. [31][88][92]

The overlap of these essences in the understanding of electrons as intra-atomic "particles" and electrons as quantum formations occurred at the time of the birth of quantum mechanics and those interpretations of these experiments that were based on the concepts of that time regarding the structure of the atom as consisting of individual particles. Now, experimental work has greatly advanced and possesses more powerful tools that allow us to reconsider previous views and draw new conclusions. I also offered a new interpretation of a recent experiment (2013) involving laser radiation on a hydrogen atom, based on a new atomic model proposal. [63]

In this experiment, the results are explained using the Copenhagen Interpretation and are aimed at confirming it. However, the proposed new approach to atomic structure allows us to view the results [63] from a different perspective, based on the nontrivial topology of the wave-dipole model of the atom. [92] [38]

If we consider the atom outside of this experiment, the sub-micro-quantum flash is constantly present around the atom [(Fig. 15) [156]], but not as a random or probabilistic phenomenon, but as a result of the atom's precisely synchronized and stable wave rhythmodynamics, reflected by its line emission-absorption spectrum. [38] In experiment [63], the intensity of the flash depended on the degree and duration of exposure to laser radiation,

which induced a more intense response of atomic dipole radiation in the form of a flash of emitted quantum, which in the experiment was called a photoelectron. And the result of the experiment [63] confirms the fact that the atom produces more intense radiation of photoelectrons under external influence and this radiation can be controlled using laser (or other) influence.

In view of the above, it can be said that the nontrivial topology of the Möbius strip reveals the secret of Nature both in the construction of the atom and in its internal structure, which remains planetary and is in fractal similarity with the structure of the stellar-planetary system, which was and is the correct line of thought. However, within the particle paradigm and with the introduction of additional postulates, further development of the planetary model representation on particles is not justified.

An atom is not the result of the fusion of particles through abstract forces acting between particles. As a stable structure, an atom is a unified construct and the result of spatial transformations in the act of generating matter from within through fibration, similar to how a cellular biological organism is generated through the fibration of DNA strands. This universal process is precisely where the natural actualization of system-forming interrelationships – gravity and quantum entanglement – occurs, as well as the manifestation of magnetic forces based on them, which preserve this structure as a holistic system-forming entity.

No abstract forces, with their attempts to explain them, can create an atom or a stellar-planetary system as a unified whole, just as it is impossible to create a biological object by compressing cells into organs, or organs into a single organism. These structures are created through the process of generation from within through bifurcation with doubling, which is universal and occurs initially in the quantum world, then in the biological world, and finally in the macrocosm.

An atom is a stable quantum-mechanical system with a wave-based rhythm-dynamics of life activity, conducting quantum exchange with the Quantum Medium and maintaining the stability of matter, as well as entering into chemical interactions with other atoms based on frequency-vibrational characteristics. During their life activity, atomic dipoles undergo continuous and unceasing oscillations with the release and absorption of quanta through the atomic membrane; in other words, they carry out the process of quantum respiration, quantum metabolism, and quantum symbiosis with the Quantum Medium.

Unlike the previous Bohr-Rutherford particle model, the proposed planetary model of the atom based on the nontrivial topology of wave magnetic dipoles requires no additional postulations or adjustments, is consistent with line spectra, can point to new pathways for energy production, and offers many other explanations of the structure of matter.

The new atomic model could be of great significance for a better understanding of natural phenomena, for the creation of new technologies, opening up prospects for the design of new electronic devices through geometric engineering, and for describing aspects of quantum geometry, a tool used to create a kind of topographic map of the wave function's motion in a material under varying magnetic field influences.

"Nontrivial topology always implies nontrivial quantum geometry, since topology is also related to the properties of the wave function." [102]

Based on the logic of all of the above, if we take into account the fact that standard existing concepts do not answer all the questions posed by experimenters in the current context of research and practical achievements in quantum geometry, then why not try to look at these

questions from the perspective of new conceptual approaches, if these approaches prove successful in finding clearer answers. [30][31][88]-[97][111][112]][161][172]

In the current period of scientific development, the non-trivial topology of the Möbius strip reveals the secrets of nature on a larger scale, both in the structure of matter itself and in the production of new materials using this geometry.[100][110][122]-[142]

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