An unorthodox view on the foundations of physical reality.

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Abstract

This paper is telling essentials of the story of the Hilbert Book Test Model without applying the mathematical formulas. The paper cannot avoid the usage of mathematical terms, but these terms will be elucidated such that mathematical novices can still understand most of the story. The Hilbert Book Test Model is a way to investigate the part of the foundation of physical reality that cannot be observed. This foundation is necessarily simple and it can easily be comprehended by skilled scientists. However, this paper is targeted to readers that are not skilled in math.

1 Introduction

This paper relies on the content of "The Hilbert Book Test Model". That paper contains all the formulas that are filtered from this paper. In fact the formulas are no more than a very compact piece of language. Thus this paper is intended to tell in essence the same story as "The Hilbert Book Test Model" paper does. The reader is expected to be interested in the subject. Nobody claimed that this is easy reading.

1.1 The author's predestination

The interest of the author in the foundation of physical reality awakened during his physics study at the TUE when he was for the first time confronted with quantum physics. I was astonished by the fact that quantum mechanics was done in a completely different way than classical mechanics was done. I asked my very wise lecturer why this difference exists. His answer was that in quantum physics the superposition principle plays a major role. This principle states that linear combinations of solutions of an equation that describes the movement of a quantum mechanical system are again solutions of that same equation. I was not very happy with that answer because the superposition principle plays indeed an important role in quantum physics, but for me it was difficult to comprehend why this was the reason of the huge differences between the two approaches. I told him about my concern, but he answered that this was the best answer that he could give.

I decided to perform my own research and dived into literature. After a while I encountered an at that time recent booklet of Peter Mittelsteadt with the title " Philosophische Probleme der Modernen Physik" (1963). That booklet contained a chapter about "quantum logic". After reading this chapter I concluded that quantum logic formed a more appropriate answer to my dilemma. Nature appeared to obey a logic that differs from classical logic, which is the logic system that we humans use in order to reason about our environment. This fact raised my interest in quantum logic and I studied everything what was available on this structure at that time. In 1936 quantum logic was discovered by Garret Birkhoff and John von Neumann. In mathematics this structure is now known as an orthomodular lattice. Lattices are relational structures. They prescribe what kind of relations can exist within that structure. The duo called their discovery "quantum logic" because its relational structure is quite similar to the relational structure of classical logic. Much later I discovered that attaching this name to the orthomodular lattice was not a lucky decision.

Another curious aspect of quantum physicists also intrigued me. Quantum physicists use Hilbert spaces as a storage medium for dynamic geometric data. Hilbert spaces are mathematical constructs whose elements are vectors and each pair of vectors is related by an inner product. The inner product is a number. The Hilbert space can only cope with numbers that are member of a division ring. In a division ring all non-zero numbers own a unique inverse. Only three suitable division rings exist. This significantly limits the possible choices. The choices consist of the real numbers, the complex numbers and the quaternions. Thus more exotic number systems such as octonions and bi-quaternions are excluded.

My lecturer taught me that all observable quantum physical quantities are eigenvalues of Hermitian operators. Operators map Hilbert vectors onto other vectors or onto themselves. If the operator maps a vector onto itself, then this vector is called eigenvector. In that case the operator attaches an eigenvalue to this eigenvector. Hermitian operators combine Hilbert eigenvectors with real number valued eigenvalues. Such numbers are scalars. When I looked around I saw a world that had a structure that was configured from a three dimensional spatial domain and a one dimensional time domain. In the quantum physics of that time, no operator represented the time domain and no operator was used to deliver the spatial domain in a compact fashion. After some research I discovered a four dimensional number system that could provide an appropriate normal operator with an eigenspace that represented the full four dimensional representation of my living environment. At that moment I had not yet heard from quaternions, but an assistant professor told me about the discovery of Rowan Hamilton that happened more than a century earlier in 1854. Hamilton's quaternions appeared to be the numbers that I had rediscovered. I was astonished that quantum physics did not apply these numbers. Instead quantum physics extensively used complex numbers. Quite probably the reason was that complex function theory was far more mature than quaternionic function theory.

My university, the TUE, targeted applied physics and there was not much time nor support for diving deep into the fundamentals of quantum physics. After my study I started a career in high-tech industry where I joined the development of image intensifying devices. There followed my confrontation with optics and with the actual behavior of elementary particles. See: What image intensifiers reveal. I took part in the specification of two standards that concern the quality of the imaging process in which photons and elementary particles play the role of information transporters. One standard concerned the Optical Transfer Function (OTF) and its modulus, the Modulation Transfer Function (MTF). The OTF is the Fourier transform of the Point Spread Function (PSF). This Fourier transform is the spatial spectrum of the image of a point-like object. The other standard concerned the Detective Quantum Efficiency (DQE). This qualifier treats the generator of the image as a stochastic Poisson process. Combined with the Point Spread Function as a binomial attenuation process it creates a Poisson process that spreads its efficiency over a spatial region.

In 1987 my career switched from physical research to scientific software generation. In that period another incident strongly influenced my current insight in quantum physics. In 1995 I got the request to advise my employer about an improved way of software generation. The costs of the generation of complicated embedded software was growing in an uncontrollable way and would soon pass the costs of development and construction of the hardware that must use this software. The hardware was constructed in a modular way and that construction method was supported by a vivid and healthy component market. This construction method was far more efficient and delivered far more robust results than the existing software generation process. Thus, I decided to advice my employer that software should be constructed in a similar modular way. The next few years I designed a demonstration of the methodology and the tools that must enable this way of modular software generation. The estimate was that in this way the efficiency of the software generation process could be improved by several orders of magnitude. The modular construction methodology is a champion in the reduction of the number of relevant relations that the designers and system configurators must handle. Reducing the relational complexity appears to be the most influential and therefore the most important issue.

This indicates that relational structures must be qualified by the measure at which their relational complexity can be reduced. Thus quantum logic was important because its relational structure appeared to be such that compared to a monolithic structure its relational complexity can be reduced with several orders of magnitude. This insight stimulated me to interpret the orthomodular lattice as part of a recipe for modular construction and not as a logical system as its discoverers did. Above is shown that initially I made the same mistake as the discoverers did. Thus, the elements of the orthomodular lattice are modules or modular systems and not logical propositions.

In 2001, during the dot-com bell, the modular software generation research project was stopped because my employer did not want to invest any longer in a long term project. Instead he decided to transport the software generation process to low wage countries. There the software generation landed in the same exponentially growing cost condition. Currently software is still generated in a non-modular way. The cost is a little bit reduced by applying open source software. This choice does not reach the targeted efficiency and robustness of the modular system generation process.

Through this experience, I learned to see the universe as one big collection of modular systems. Contrary to the software generation industry, physical reality appears to apply the modular design and construction methodology. For me this leads to the most influential and most basic law of physics. It cannot be stated in terms of a formula, because formulas tend to use numbers and the orthomodular lattice does not support numbers. Instead the law can be stated in the form of a commandment: “Thou shalt construct in a modular way”.

Only after my retirement I got sufficient time to dive deep into the foundations of physical reality. In 2009 I started my personal research project that in 2011 got its current name “The Hilbert Book Model”.

1.2 The paper

This document will offer the interested reader a scientifically justified view on the foundation and the lower level structure of physical reality. The lower levels of the structure of physical reality are not accessible for observation by human senses or by advanced measuring equipment. The only way that is left for investigating this subject is the application of mathematical test models. The foundation and the lower levels of the structure are necessarily simple and for that reason they are easily comprehensible for skilled scientists. However, this paper is addressed to an audience that is not skilled in advanced mathematics. In fact, this paper will not contain mathematical formulas. Still, a pure mathematical model will underlay this presentation. It is impossible to completely avoid the usage of mathematical terminology. These terms will be elucidated as much as is possible. Dutch and not English is the native language of the author. As a consequence the descriptions may not be optimal. Where the author fails, the reader may call the online services such as Google and Wikipedia to the rescue.

The paper will be based on the content of “The Hilbert Book Test Model”. Aside from its foundation, this test model will only cover a few extension levels. The model will be called “test model” because it is principally impossible to prove the validity or invalidity of the applied model as a correct description of the lower levels of the structure of physical reality. What is described in the test model is not accessible for observation. Thus experimental verification is impossible. Still the reader will recognize many structures and phenomena that were discovered via experiments.

2 The foundation

The model will be based on a structure that does not yet contain numbers. Concepts such as space and time need numbers in order to specify their value and in order to describe the way that these values change. Thus in this lowest level of the model notions such as time and space do not yet exist.

The structure at the lowest level is a relational structure. Only a certain kind of relations are tolerated to exist in this structure and a set of about 25 axiomatic rules precisely define which relations and which combinations of relations are acceptable. Many kinds of relational structures exist and the selected foundation is only one kind of these relational structures. For that reason we give the selected relational structure a name. We call it an "orthomodular lattice". This is the name that mathematicians use for this structure. In 1936 this structure was discovered by Garret Birkhoff and John von Neumann. Garret Birkhoff was an expert in lattice theory and John von Neumann was a very broadly oriented scientist that was highly interested in the structure of quantum physics. The relational structure of the orthomodular lattice happens to be very similar to the relational structure of classical logic and for that reason the duo named their discovery "quantum logic". This was an unlucky decision, because the orthomodular lattice has little in common with a system of logical propositions. Still several scientists keep investigating the suitability of logical systems as foundations of physical theories.

3 Hilbert space

The duo that discovered “quantum logic” could have known that this structure does not represent a logical system, because in their introductory paper they showed that a substructure of a more complicated structure showed exactly the structure of an orthomodular lattice. This more extended structure was discovered a few decades earlier by David Hilbert and others. For that reason it was named “Hilbert space”. The Hilbert space is a multidimensional collection of objects that are related by what is called an inner product and it is certainly not a collection of logical propositions. Instead the Hilbert space can be used as a storage medium for dynamic geometric data. For that reason the Hilbert space can cope with objects that consist of a scalar and a three dimensional vector that points to the geometric location. The scalar represents the corresponding progression instant. The elements of the Hilbert space are called Hilbert vectors. The Hilbert vectors must be distinguished from the dynamic geometric data that can be stored in the Hilbert space. These dynamic geometric data objects are quaternions and together these quaternions form a number system. The inner products that interrelate the Hilbert vectors have a value that is taken from that same number system. The Hilbert space can only cope with number systems that are division rings. In a division ring every non-zero element has a unique inverse. Only three suitable division rings exist. These are the real numbers, the complex numbers and the quaternions. In the test model we select the most elaborate version of these number systems. Depending on their dimension the number systems exist in multiple versions that differ in the way that they are ordered.

Thus, from the selected relational structure follows in a straightforward way the next level of the model as a storage medium for dynamic geometric data. As a consequence, quite early in the development of the model notions of time and location already enter the model in a well-defined way. In this way, mathematics stringently restricts the manner in which the selected foundation can be extended to a higher level of the model. Mathematics prevents the generation of a fantasy.

3.1 Atoms

Now let us go back to the lowest level, which was defined as an orthomodular lattice. That lattice is an atomic lattice. Atoms are elements that are not constituted from other elements. In their representation in the Hilbert space, the atoms are constituted from single elements that cannot be subdivided. These elements are called Hilbert vectors and each Hilbert vector spans a one-dimensional subspace. Attached to this Hilbert vector belongs a single stored dynamic geometric data element. A thing that we will call “operator” administers the combination of the Hilbert vector and the corresponding eigenvalue. The Hilbert vector will be called the eigenvector that belongs to the eigenvalue and the operator can combine many different eigenvalues with their own eigenvectors. The Hilbert vectors that belong to different eigenvalues will be mutually independent. Mutually independent means that these vectors are directed perpendicular to each other. Their inner product equals zero. Thus N different eigenvalues correspond to an N dimensional subspace of the Hilbert space.

4 Modules

Again we go back to the foundation. We already claimed that the foundation is not a logic system. This raises the question were the foundation then stands for. The author suggests that the foundation is part of a recipe for modular construction. In fact this suggests that the most fundamental law that governs the model is the instruction to construct all discrete items in a modular way. Modular construction is known to use its resources in a very economical fashion and this way of system generation can significantly reduce the relational complexity of complicated systems. It enables reuse and eases system configuration. Thus this suggestion is not an arbitrary choice.

The atoms of the lattice represent elementary modules and these elementary modules are represented by a single Hilbert vector and a single dynamic geometric value. However, this choice reduces the validity of the representation to a single progression instant and a single geometric location. Thus, in order to achieve a more persistent elementary module, we must somewhat widen the concept of the elementary module. On another progression instant the same elementary module is represented by another Hilbert vector and another spatial location. After ordering of the progression instants the elementary object appears to hop along a path and the landing locations will form a swarm. The hopping path as well as the location swarm will now represent the point-like elementary module. Here we assume that at the same instant an elementary module cannot correspond to two different landing locations.

5 Coherence

In the described way a set of elementary modules will easily represent a quite chaotic model. In contrast to this primitive model, our experience with physical reality shows a far more coherent picture. In order to fix this, ***we postulate the existence of mechanisms that control the coherence of the generated location swarms***. The effect of the mechanism is that after a huge number of hops the location swarm can be characterized by a ***continuous location density distribution*** and that in addition ***this function owns a Fourier transform***. This is a very stringent requirement and it is far from straightforward, but let us see what these requirements mean. The first requirement can be met by a stochastic process that generates the locations where the hops will land. After a while the statistical properties of the swarm will mature such that the form of the location density distribution will stabilize. The existence of the Fourier transform means that the swarm owns a displacement generator such that ***at first approximation the swarm appears to move as one unit***. Thus the swarm follows its own path, which has its own kinematics. With other words the point-like elementary object is now represented by a more feature-rich swarm that is generated by the dynamic hopping dance. This dance is performed under the control of a dedicated stochastic mechanism. The fact that having a Fourier transform corresponds to owning a displacement generator is a mathematical fact that goes beyond the scope of this paper. It is an essential ingredient of the reasoning that is exploited here. A stochastic Poisson process that is combined with a binomial process, which is implemented by a spatial spread function can generate the suggested coherence conditions. If the process produces a normal distribution that approaches a Gaussian distribution, then a typical swarm is generated. The location density distribution of this test swarm forms a smooth test function, which equals an error function that is divided by its argument. Reality need not be exactly like this example, but it also will not be far off.

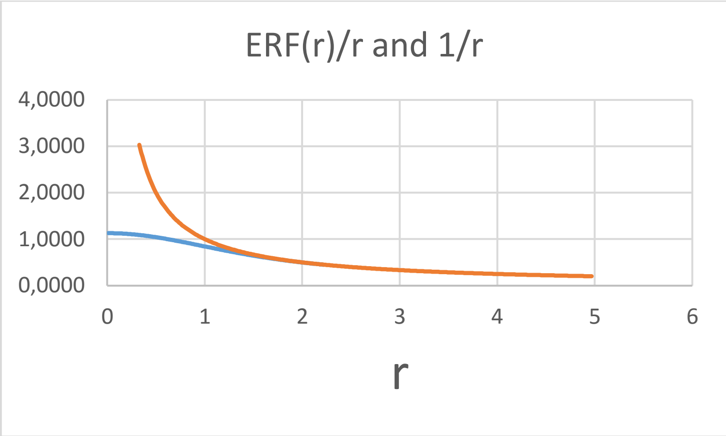

Figure 1. Close to the geometric center the singularities are converted in a smooth function. Further from the center the form of the Green's function (1/r) is retained.

6 Continuums

The current state of the model does not support a storage medium for continuums. In fact we already met a continuum in the form of the description of the swarm by a location density distribution, which is required to be a continuous function. The function describes a dynamic set of discrete locations. Thus, these locations influence the form of the function. In some sense they deform an originally flat continuum in a curved continuum that describes the location density distribution. The flat continuum plays the role of the parameter space of the function. This view can also be reversed. The continuum which is represented by the function follows the raw location density distribution, which on its turn is generated by the elements of the swarm. If many of such swarms are present, then the continuum forms a kind of smooth "landscape" that represents the description of a large series of swarms.

The infinite dimensional separable Hilbert space can store all elements of all swarms, but it has no means to store the smooth description of these swarms. However, every infinite dimensional separable Hilbert space owns a companion in the form of a non-separable Hilbert space, which is capable of storing these smooth descriptions in the continuum eigenspaces of corresponding operators.

Paul Dirac introduced a nice method for the notation of Hilbert vectors, which is known as the bra-ket notation. This notation gives every Hilbert vector a name and places this between a | bar and a ⟩sign. Thus the Hilbert vector with name John is indicated as $|John\rangle$. The inner product that relates vector $|John\rangle$ and vector $|Will\rangle$ is indicated by $\langle John|Will\rangle$. We will not go into further details, but this notation can be applied to create relations between functions and operators and the same continuous function can relate an operator in the separable Hilbert space to a corresponding operator in the non-separable Hilbert space. Thus it can relate the swarms that are stored in the separable Hilbert space with the continuous descriptors of that swarm that are stored in the non-separable Hilbert space.

This means that this methodology is capable of relating the elementary modules that represent the atoms of the orthomodular lattice with fields that offer a smooth description of their presence.

7 Parameter spaces

Number systems can also be interpreted as flat continuums and their rational values can be interpreted as evenly spread swarms. However, these objects are better interpreted as a kind of functions of which the target values equal their parameter values. With other words, these objects are parameter spaces. In the Hilbert spaces these continuums and sets are eigenspaces of so called reference operators. The Hilbert spaces can house several of such reference operators and corresponding parameter spaces in parallel. It is possible that a kind of such parameter spaces float over another kind of parameter space. Different parameter spaces can differ in the way that they are ordered. A parameter space can be ordered by selecting a particular Cartesian coordinate system. In fact it is possible to select on a given center, one of eight mutually independent Cartesian coordinate systems. Thus the corresponding parameter spaces exist in eight symmetry flavors. A polar coordinate system is usually specified relative to a Cartesian coordinate system. The polar coordinates may start with the polar angle or the polar coordinate system can start with the azimuth and each of these angles can increase or decrease. The floating polar coordinate systems will be called ***symmetry centers***. The symmetry flavors of symmetry centers influence the contributions that the inhabitants of the symmetry center deliver to an integral that collects the properties of the inhabitants. This fact attaches a charge property to the symmetry center.

8 Elementary modules

Elementary modules typically live on top of a selected symmetry center. The description of the raw swarm and the description of the hopping path use the corresponding polar coordinate system. The elementary modules perform their hopping dance within the realm of their private symmetry center. This categorises the elementary modules with respect to their symmetry flavor. Thus elementary modules exists in a set of categories that differ in their symmetry flavor. In addition they can float over a background coordinate system. With respect to the smooth description of their location swarm these elementary modules act as artifacts that deform the fields that act as the smooth description of these elementary modules.

The point-like elementary object can be caught by a detection process or another kind of conversion process. The location density distribution describes the probability of detecting the concerned module at the location that is represented by the local parameter value.

The mechanism that controls the coherence of the behavior of the elementary module ensures that the location density distribution, which describes the swarm of landing locations, owns a Fourier transform. Aside from providing a displacement generator, this fact also allows the swarm to be represented by a wave package. Usually a moving wave package disperses. That is not the case for this representation because the location density distribution is continuously regenerated. However, the consequence of having a Fourier transform is that the swarm can form detection patterns in the form of interference patterns. These interference patterns may suggest that the swarm is constituted from a set of waves.

A single hop represents a small displacement in configuration space and it represent a factor which is close to unity in Fourier space. This fact is exploited by a methodology which is called “path integral”. This method puts all multiplication factors in a sequence and since these factors are close to unity, the multiplications can be replaced by summations of the logarithms of these factors. The result describes the displacement of the swarm as a whole unit. The multiplication factors are more closely representing the more stable displacement generator of the swarm and do not represent the vigorous hops that determine the elements of the swarm. The result forms a proper qualification of the coherence that is installed by the governing mechanism.

8.1 Symmetry flavors

Elementary modules live on top of symmetry centers. The symmetry centers act as spatial parameter spaces that are ordered by a selected polar coordinate system. The center of the coordinate system floats over a background parameter space, which is ordered by a selected Cartesian coordinate system. Both types of parameter spaces are eigenspaces of corresponding reference operators. Apart from their relative movement with respect to the background parameter space the symmetry centers are static items. This part of their properties can be characterized by an anti-Hermitian operator. The polar coordinate system is defined relative to a Cartesian coordinate system, which specifies the Cartesian ordering of the symmetry center. This Cartesian ordering specifies the symmetry flavor of the symmetry center. It is possible to distinguish eight independent versions of Cartesian coordinate systems. This corresponds with the fact that due to its four dimensions, the quaternionic number system exist in sixteen different versions. If the real part is kept fixed then still eight different versions result. An important fact is that with respect to multiplication the quaternions exist in left handed and right handed versions. Thus, the ordering influences the arithmetic properties of quaternions. But the ordering has more influences. The ordering of the parameter space influences the contribution that the symmetry center delivers to an overall integral that covers the whole background parameter space. This influence can be estimated by encapsulating the symmetry center by a cubic boundary that follows the directions of the applied coordinate systems. The influences can be expressed by factors that are determined by the number of discrepant directions. This factor must include the sign of the direction. This results in a short list of factors: -3,-2-1,0,1,2,3. This list corresponds to a set of symmetry related charges. The directions can be indicated with colors. The isotropic cases -3,0,3 get neutral colors. The other values get corresponding R,G,B values. This characterization corresponds with the charges that are attached to the elementary particles, which are contained in the Standard Model.

The charges are artifacts that influence a corresponding field that we will give the name of “symmetry related field”. The model locates the charges at the center of the corresponding symmetry centers. The elementary module that lives on top of the symmetry center inherits the symmetry related charges of the symmetry center.

Two views are possible. One view interprets the deformation of the field as an influence that is caused by the symmetry related charge of the symmetry center. The other view interprets the action that the field exerts onto the elementary module, which resides on top of the symmetry center. If multiple symmetry centers are present, then this second view can be used to explain the mutual influences that the elementary modules pose onto each other.

8.2 Quaternionic rotations and symmetry flavor switches

In multiplications quaternions do not generally commute. This is due to the arithmetic behavior of the imaginary part. The multiplication of two imaginary quaternions results in a quaternion that has a real part and an imaginary part. Any of the two parts may be zero and the imaginary part is directed perpendicular to both multiplication factors. The sign of the result depends on the handedness of the participating quaternions. This has a particular effect when the result is subsequently multiplied with the reverse of the second quaternion. In that case the piece of the imaginary part of the first quaternion that is perpendicular to the first quaternion gets rotated over an angle that is twice the angle that the real and the imaginary part of the first quaternion form.

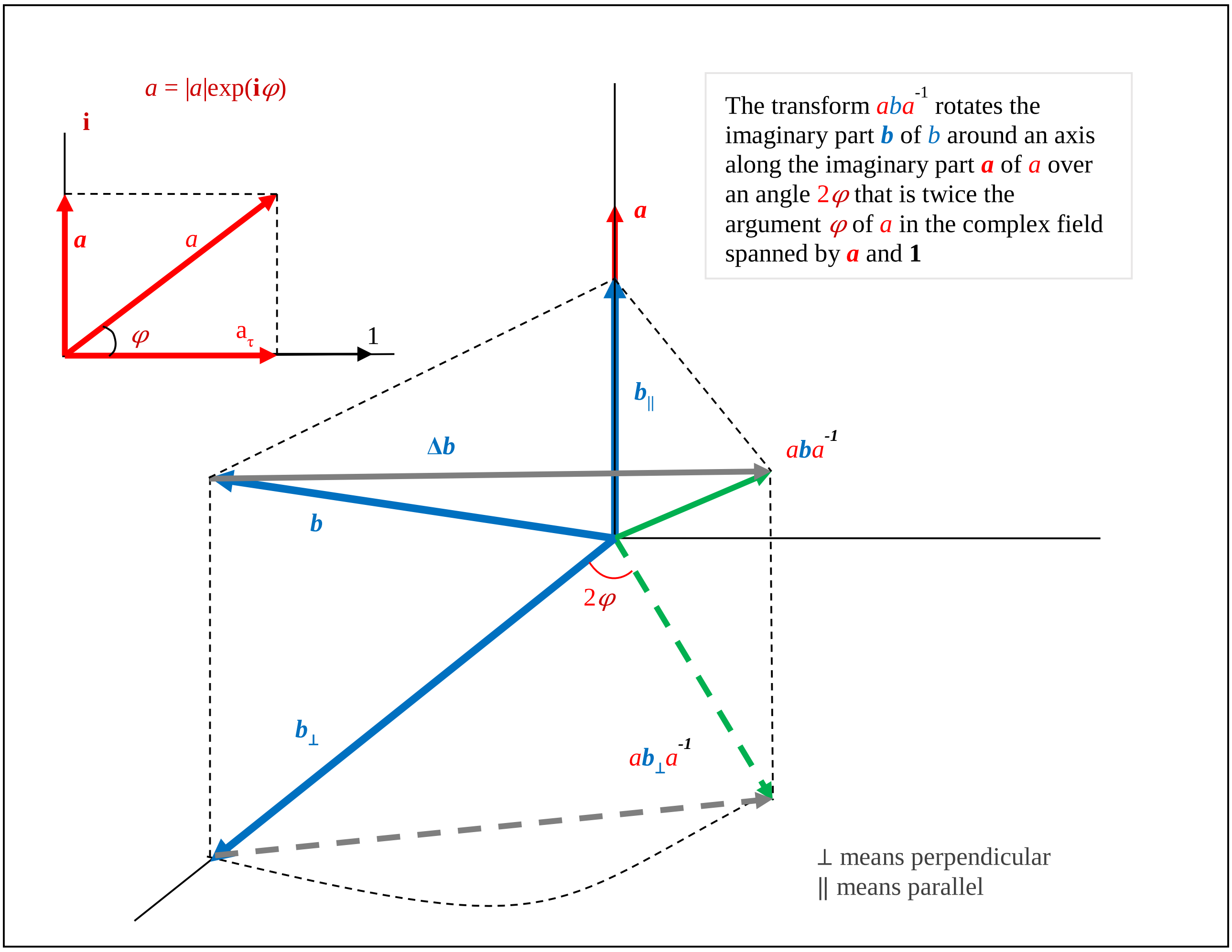

Figure 2: Quaternionic rotation

A special kind of quaternions have real parts that have the same size as the size of their imaginary part. These quaternions shift the rotated part of the subject to another dimension. Thus these kind of quaternions can shift the symmetry flavor of anisotropic elementary modules.

9 The dynamic model

The base model is formed by an infinite dimensional separable quaternionic Hilbert space and its non-separable companion. It is possible to construct a category of operators that use the elements of the quaternionic number system as its eigenvalues. In the separable Hilbert space the eigenspace of the operators must be countable. This means that the eigenvalues that constitute these eigenspaces must be rational quaternions. If all rational quaternions of a quaternionic number system are used, then the corresponding eigenvectors form an orthonormal base that spans the complete separable Hilbert space. A similar procedure can be followed in the non-separable companion Hilbert space, but there the eigenspaces of the corresponding operators are continuums. This procedure shows that it is possible to embed or map the complete separable Hilbert space inside its non-separable companion. The operators that are constructed in this way are ***reference operators***. The symmetry centers that are mentioned above are eigenspaces of a special kind of reference operators. They float over a selected background reference operator.

The swarms of the elementary modules are stored in eigenspaces of operators that reside in the separable Hilbert space. The elementary modules live on the symmetry centers. These symmetry centers are carriers of symmetry related charges and with their elementary module they float over a background parameter space. The smoothed location density distributions that describe the swarm form part of a more extended continuum for which the background parameter space acts as a covering parameter space. The extended continuum can be interpreted as an embedding field, but it can as well be interpreted as a describing field. The charges are the artifacts of a second continuum that we will indicate as the symmetry related field.

Now construct a boundary that splits the continuum eigenspace of a selected background reference operator such that it divides the real part of the quaternionic eigenspace into two parts. The boundary is characterized by a progression value. Let this value increase such that the boundary moves as a function of progression. The subspace that is spanned by the corresponding Hilbert eigenvectors moves as a vane through both Hilbert spaces.

The vane scans over both fields and this boundary can be interpreted as the present static status quo that splits past from future.

This view introduces the concept of creation. It is possible to view the Hilbert spaces as unchangeable items that are already completely filled with data. In this view both past and future are completely determined. However, it is also possible to take the view that the information about the current static status quo is created at the progression instant that is attached to the scanning vane. This second view is used by current physical theories. From a mathematical point of view the first interpretation is as valid. Both interpretations describe the same mathematical model. However, the selected interpretation significantly affects the description of the mechanism that control the coherence of the swarm, which characterizes an elementary module. Previously this description is given in terms of a dynamic stochastic process that generates the landing locations of the hops that constitute the swarm.

10 Fields

Fields are continuum eigenspaces of operators that reside in the non-separable Hilbert space. The model distinguishes two basic fields.

One is the embedding field. This field describes the hopping behavior of the elementary modules. As a consequence this field plays a role in the interaction between the location swarms that represent the hopping elementary particles. The embedding field describes both the rational values that constitute the background parameter space and it treats the landing locations of the hopping elementary modules as artifacts that are taken from a discrepant parameter space, which is formed by the symmetry center on which the elementary particle resides. In this way the embedding field covers all of universe and this occurs always and everywhere. In this way the field acts as an ideal transporter for information that travels in the form of vibrations of this field. Information messengers are solutions of the differential equations, which describe the dynamic behavior of this field.

The second basic field is the symmetry related field. It describes the influences of the symmetry related charges that characterize the symmetry centers on which the elementary modules reside. This field relies on the nearby presence of symmetry centers that carry the charges that keep the field in existence. This does not make this field a proper carrier of messengers that transport information over long ranges.

The discrete players and the fields interact in a complicated way. The behavior of the fields is governed by differential equations. Partial differential equations indicate in which direction the changes of the fields take place. The influence of point-like artifacts is covered by first and second order partial differential equations. In quaternionic differential calculus two different inhomogeneous second order partial differential equations exist. One of these equations can be split into two first order partial differential equations and the other cannot be split. It is based upon a differential operator, which is known as d'Alembert's operator. Both second order partial equations also exist as homogeneous equations. These versions hold in the absence of artifacts that disturb the continuity of the corresponding field.

Both basic fields obey the same homogeneous second order partial differential equations. This fact indicates that the difference between the two basic fields is located in the artifacts that disturb their continuity.

The homogeneous second order partial differential equations have many different solutions that can exist in parallel. The d'Alembert's equation supports waves as part of its set of solutions and for that reason this equation is called "wave equation". In an odd number of participating spatial dimensions, both second order partial differential equations offer solutions that keep their shape when they travel through space. The one dimensional solutions also keep their amplitude. They can travel huge distances and still keep their integrity. The three dimensional solutions diminish their amplitude with increasing distance from the source. The shape keeping solutions can be interpreted as information carriers. These solutions are not waves. If these solutions occur in strings, then they get many characteristics in common with waves. One of them is the frequency of the sequence.

This part of field behavior concerns point-like artifacts, such as elementary modules and the centers of symmetry centers. Other, more extensive artifacts are also possible. For example it is possible that for certain regions of the background parameter space the embedding field does not exist. The field cannot exchange information with these regions. At the border of these regions the field can still show a coherent behavior. The inside of the region is "black".