# Underneath the wave function

What exists underneath the wave function?

Abstract

Nearly all tools that quantum physicists use are in some way based on the concept of the wave function. This means that such tools deliver a blurred view of the fine grain structures and fine grain behavior that these tools describe. This appears no handicap for applied physics. The tools fill the complete need of applied quantum physics. However, the blurred view hampers the search for the origins of features and phenomena, because they must be sought in the fine grain structure and the fine grain behavior.

By J.A.J. van Leunen

## Contents

# Tools

Many of the tools that quantum physicist use are directly or indirectly based on the information that is contained in the wave function. Also the equations that the corresponding quantum physics applies reflect what happens with this information. The wave function is a differentiable normalized continuous function and it owns a Fourier transformed version. It is commonly characterized as a probability amplitude distribution. Its squared modulus is a probability density distribution.

These characteristics make the wave function accessible to a large mathematical toolkit. Most of these tools base on Lie groups and Lie algebras.

# The wave function

What is the wave function?

Let us focus onto the wave function in configuration space.

It is a probability amplitude distribution.

Its squared modulus is a probability density distribution.

That probability density distribution is a normalized continuous location density distribution.

## Interpretation

Now interpret what this probability density distribution may stand for.

1. It is the probability of detecting the owner of the wave function at the location that is defined by the parameter of the wave function.
2. It is a continuous location density distribution
    a. That continuous location density distribution is the continuous description of a discrete location density distribution.
    b. This density distribution describes locations where the owner of the wave function can be.
    c. One of these locations is the currently actual location.

Both interpretations are possible and are mutually compatible. Interpretation 2b conforms to the Copenhagen interpretation.

The wave function not only offers a smoothed picture of reality. It also averages any fine grain dynamical behavior. This affects interpretation 2c.

Now see the second interpretation as a dynamic process. This dynamic process is supposed to act in steps.

At each subsequent instance the owner uses a new location. This conforms to an extended Copenhagen interpretation as is described in the next chapter. According to that extended interpretation the wave function collapses at every subsequent instance.

The locations form a coherent swarm and at the same time the locations form a stochastic path.

The owner hops along that micro-path.

If the owner is actually detected, then the hopping stops. The path and the swarm are no longer developed further. With other words, ***the wave function collapses*** more definitively. Usually the owner does not disappear. It is transformed into something else that also has a wave function. This means that at the instance of detection a new wave function is generated that characterizes the transformed object. It is also possible that the owner disintegrates into multiple objects. In any of these cases the wave function loses its original significance.

It is sensible to conclude that underneath the wave function some ***fine grain structure*** exists and that ***fine grain dynamics*** may occur.

Who has ever thought that a stochastic path may exist underneath the blurred description that the wave function represents?

The idea of the swarm and the stochastic micro-path can be exploited further. This opens a completely new and fresh view on the lowest levels of physics and what elementary particles could be. In the above sketched view they are ***point particles*** that have ***no internals***, but instead they have ***externals***. These externals are formed by the swarm that includes a micro-path. Most of the elements of the swarm are virtual locations that can be interpreted as past or future locations. Only one element represents the current location. However, the duration of that location is set by a very short progression step.

In a Hilbert space the elements of the swarm can be represented as eigenvalues of an operator. The eigenvalues of Hilbert space operators can be real numbers, complex numbers or quaternions. The corresponding eigenvectors span a subspace of the Hilbert space. With other words the swarm is represented by a subspace of the Hilbert space.

When a quaternionic Hilbert space is used, then these eigenvalues can cover progression and a 3D location. This enables the modelling of 3+1D dynamics.

The closed subspace that is spanned by the location eigenvectors is ***eigensubspace*** of another operator whose eigenvalues are retrieved from the full set of location eigenvalues that correspond to the swarm. For example the symmetry of the set and the characteristics of the micro-path lead to swarm wide properties. At any progression instant the state of the swarm is represented by the current location and by the extra properties that are delivered by the swarm wide operator.

***All discrete objects that own a wave function are represented by a subspace of the Hilbert space***. This does not confine to elementary particles. It also holds for composites, but in that case not only locations but also superposition coefficients contribute to the representing subspace.

Also in the case of composites the representing subspace is an eigensubspace of a suitable operator. A very important eigenvalue of the eigensubspaces is their dimension. It has a very intriguing physical interpretation. That eigenvalue has no equivalent in the set of characteristics of the wave function. The same holds for the eigenvalues that are related to the discrete symmetries of the sets of locations. Together with the current location the eigenvalue sets of the eigensubspace offer a ***far richer*** representation of the state of the owner of the wave function than the wave function offers.

## Gelfand triple

When we want to go back from the swarm to the wave function, then we must make use of the Gelfand triple. Every Hilbert space owns a Gelfand triple. The Gelfand triple features operators that have continuum eigenspaces. The Hilbert space can be considered to be embedded in the Gelfand triple.

In the Gelfand triple operators exists that corresponds to the swarm-element-location operator and the swarm-wide operator in the Hilbert space. Part of the continuum eigenspace of the swarm element-location operator will represent the wave function.

Something is missing here. That is the parameter space of the wave function. This is delivered by another operator that also resides in the Gelfand triple. Its eigenspace is flat and is spanned by the quaternions. An equivalent of this parameter operator exists in the Hilbert space. Its eigenspace is spanned by the rational quaternions. These two operators represent a precise fit between the Hilbert space and its Gelfand triple. For other operator pairs the fit might be imprecise.

## Functions as Hilbert space operators

By using bra-ket notation, operators that reside in the Hilbert space and correspond to continuous functions, can easily be defined starting from an orthogonal base of vectors. Let $\{q_i\}$ be the set of rational quaternions and $\{|q_i\rangle\}$ be the set of corresponding base vectors.

$|q_i\rangle q_i\langle q_i|$ is the configuration parameter space operator. Let $f(q)$ be a quaternionic function.

$|q_i\rangle f(q_i)\langle q_i|$ defines a new operator that is based on $f(q)$.

## Density operator

The wave function can be mapped back into Hilbert space, but this time the equivalent of the Gelfand triple parameter space operator is used as parameter space. The corresponding eigenvectors will now carry probability amplitude values. Thus the map of the wave function back into the Hilbert space delivers a probability amplitude operator.

The density operator that is derived from the squared modulus of the wave function still delivers a blurred view on the fine grain structure of the swarm and a blurred view of the fine grain dynamics of the elements of the swarm. For example the stochastic micro-path cannot be uncovered from the density operator.

## Complex number based presentations

In the modelling of a given situation, quaternionic representations are often not required and in that case they may better be replaced by complex number based representations. The complex wave function is an example. In such representations only the squared modulus of the wave function has direct physical significance. This kind of modelling can introduce confusion, because in that case the wave function is defined apart from a fixed normed complex number.

The potential confusion becomes clear when this is compared with a quaternionic wave function. A normalized quaternionic function can be considered as the product of a normed real function and a function that represents a normalized vector function. In case of the wave function the real function equals the square root of the location density distribution. The normalized vector function corresponds with a displacement density distribution. In the complex number based representation this reduces to a single displacement. With other words in this way the free selectable normed complex number has suddenly obtained physical significance. It stands for a small displacement.

## Tensor products

The probability amplitude operator is often used in combination with a tensor product of Hilbert spaces. This approach uses the fact that in complex number based representations, the wave function is fixed apart from a normed complex factor.

However massive elementary particles seem to couple symmetries and as a consequence they couple the corresponding spatial dimensions. For example the Dirac equation for the free electron couples a left handed representation to a right handed representation and the equation for the positron does the reverse. Other elementary particles such as quarks couple other symmetries. The results are noticeable by properties such as electric charges and color charges. This means that the representations must be 1+3D. This is accomplished by quaternionic Hilbert spaces.

The article “Division algebras and quantum theory” by John Baez. http://arxiv.org/abs/1101.5690 shows that for elementary particles the representation cannot use tensor products of two quaternionic Hilbert spaces, because this collapses into a real Hilbert space. Where a quaternionic Hilbert space can offer a dynamic 3D description can a real Hilbert space only offer a 1D static description.

Tensor products of complex Hilbert spaces do not pose these restrictions. They result in complex Hilbert spaces. Complex Hilbert spaces can represent the dynamics within one spatial dimension or with respect to one spatial parameter. Thus as long as dimensions are not coupled as they are for massive elementary particles, complex Hilbert spaces and Gelfand triples are suitable representation tools.

## Superposition coefficients

A similar objection against complex number based representations hold for all cases that couple different dimensions. Representing the spherical oscillations in the shell of atoms is another example where different dimensions are coupled. Normed superposition coefficients that are used to superpose the Fourier transformed wave functions in Fourier (read momentum) space can interpreted as the generators of displacements. In a paginated space progression model these displacements are small hops. This makes it possible to use sequences of such normed superposition coefficients in order to implement the spherical harmonic oscillations of the affected elementary particles.

These superposition coefficients correspond to eigenvectors that add to the dimension of the eigensubspace that characterizes the composite of elementary particles and corresponding sets of superposition coefficients. Each contributing elementary particle has its own set of superposition coefficients.

## Free elementary objects

Massive elementary particles can appear as free objects. This also holds for photons and gluons. Probably it also holds for the sets of normed superposition coefficients. Since protons are related to the oscillation modes of spherical harmonic oscillations it is sensible to suggest that photons correspond to sets of normed superposition coefficients. It might also be sensible to suggest that sets of normed superposition coefficients corresponds to a massive type of elementary particle. In that case neutrinos might form the candidates.

## Tools

The fact that tools blur fine grain structures and fine grain behavior and may cause mathematical inconsistencies is typical for most tools that physicists apply.

On the other hand the complex number based continuous descriptors can use the full toolkit that Lie groups and Lie algebras offer. This leads to the usual equations of motion that quantum physics applies.

The swarms require a 3+1D representation as is delivered by quaternionic Hilbert spaces. What are the equations for the fine grain behavior of the elements of the swarm?

The blurred tools fit the needs of applied quantum physics. They hide fine grain structure, but who cares? Only those that are interested in the origin of the phenomena and structure features might care. However, the blur easily leads to false interpretations of what really happens below the wave function. As long as these false interpretations do not harm applications, this defect of the methodology does not matter.

Only people with enough free time (like me) can invest the resources in order to find out what exists down there.

# Extended Copenhagen interpretation

In the traditional Copenhagen interpretation a measurement causes the collapse of the wave function. This Copenhagen interpretation can be taken one step further.

The extended Copenhagen interpretation can be understood as a recurrent process in which the "measurement" is the embedding of the concerned object into the surrounding continuum.

This means that at every embedding instant the wave function collapses on a new location.

The embedding process sends the corresponding information via a wave front into the embedding continuum. The averaged effects of these wave fronts form the gravitation potential.

The subsequent locations form a swarm. The symmetry properties and the statistical characteristics of this swarm are characteristic for the type of the object. Also this information is sent into the embedding continuum. The averaged effects of the corresponding wave fronts form the electromagnetic potential. This throws a different light on the notion of state.

The extended Copenhagen interpretation preserves the stochastic nature of the wave function. The next location is not known in advance. This new location must obey the probability that is defined by the squared modulus of the wave function.

This interpretation means that the wave function has a direct representation in Hilbert space. The stored values are eigenvalues of a location operator and they are sampled in a stochastic way. The corresponding eigenvectors span a closed subspace. The dimension of this subspace plays a special role. Apart from this dimension the subspace adds extra eigenvalues that hold for the complete subspace. These extra eigenvalues reflect the discrete symmetries of the set of locations and the statistical characteristics of the set. The micro-path may add dynamical characteristics. This offers a far richer notion of state than contemporary physics applies.

## Dynamical coherence

The control of dynamical coherence has to do with the fit between the Hilbert space and the Gelfand triple. A perfect fit kills all dynamics. No control causes dynamical chaos. Ruled control is detectable (and is not yet detected). Stochastic based control fits to the stochastic nature of the wave function.

Contemporary physics does not offer a description of a mechanism that ensures dynamical coherence. This mechanism must implement and schedule tasks, such that they stay in sync and do not cause dead locks or race conditions. It must implement a model wide clock. In this way it shows many aspects of a real time operating system.

It is odd to think that such complicated mechanism is housed inside the Hilbert space or its Gelfand triple.

## Generating the wave function

Take a particle

Embed it at a given location in a continuum.

At the next instance embed it at a slightly different location

This new location is NOT KNOWN IN ADVANCE. The selection of the location is governed by a predefined probability density distribution.

Keep selecting new locations.

After a while the set of locations looks like a swarm.

The stochastic characteristics of the process are constant.

Thus after a while the continuous location density distribution that describes the swarm no longer changes in a noticeable way.

The normalized version of this continuous function is a probability density distribution.

It is the squared modulus of the wave function.

It is not self-evident that the density function is a continuous function and it is also not self-evident that this function can be normalized and that it owns a Fourier transform. Some mechanism must ensure these non-self-evident facts.

It is also not self-evident that the controlling mechanism works in steps. However, the fact that the Hilbert space contains no means to control dynamic coherence means that the Hilbert space can only describe what happens and without dynamics it can only describe a static status quo.

The probability density distribution has a Fourier transform. (Because the wave function has a Fourier transform.)

As a consequence the swarm owns a displacement generator.

Thus at first approximation the swarm moves as one unit.

Further the probability density distribution is a wave package.

As a consequence, multiple versions of the same type of particle can together form detection patterns that look like interference patterns.

This can be interpreted as wave behavior.

# Preparation in advance

It looks as if the swarm is prepared in advance. It must not be that way, but it makes the interpretation of what happens a lot easier. It is also possible that the swarm generation is an on-going process. The interpretation does not influence the actual procedure.

If different types of swarms are generated, then these different types of swarms can be generated in seclusion at different sites.

These types may have different symmetries! Three dimensional swarms may exist in 2^3=8 different symmetries. Thus swarms may exist in at least 8 types.

Also continuous quaternionic functions exist in bundles that only vary in their symmetries.

Thus the quaternionic representation of the wave functions may exist in that many symmetry flavors.

## Cyclic preparation and usage

Here we describe a cyclic preparation.

At every progression instant only one of the elements of the prepared swarm is randomly selected in order to become the ACTUAL location of the particle.

This situation only lasts during a single progression step.

After a while the whole planned swarm is used. At that instance a new swarm is prepared.

## Embedding

The embedding continuum shows many aspects of a field and that field can be represented by a mostly continuous quaternionic function.

That function is not continuous at the location of the embedding of a discrete object.

However, due to the quick regeneration at a slightly different location, the singularities are effectively smoothened.

Thus in an averaged view the embedding continuum can be considered to be a continuous function. The swarms exist in 8 symmetry flavors and embedding continuums also exist in 8 symmetry flavors. As a consequence, embedding can offer 8x8 coupling versions.

# Eigensubspaces

The elements of the swarm are represented by eigenvectors. These eigenvectors span a closed subspace. The swarm has extra properties that are set by the discrete symmetries of the swarm, by the statistical characteristics of the swarm and by the characteristics of the micro-path. A very remarkable property is the dimension of the subspace. The wave function has no equivalent of this dimension. In this way the subspace and the extra properties form eigensubspaces of a corresponding operator. This operator has an equivalent in the Gelfand triple.

Since the eigenvalue sets exist in 8 symmetry flavors, will eigensubspaces exist in 8 varieties. Embedding continuums also occur in 8 symmetry flavors. The coupling between the eigensubspaces and the embedding continuums exist in 8×8=64 varieties. Electric charge, color charge and spin partly characterize these coupling varieties.

The dimension of the eigensubspace, the discrete symmetry characteristics of the set of locations and the characteristics of the micro-path are properties that do not occur in the wave function. They only occur in the discrete representation of the wave function. Deeper analysis of the discrete model tells that the dimension of the eigensubspace relates to the rest mass of the represented object.

See: http://vixra.org/abs/1405.0340 .

## Reference symmetry flavor

For continuous quaternionic functions it has sense to assign a reference symmetry flavor. It is the reference flavor of the parameter space. Coupling of a swarm to an embedding continuum that has the reference symmetry flavor produces a special category of particles. That category contains eight types. In contemporary physics this category contains the fermions.

## Stochastic grain

Why is the wave function a probability amplitude distribution?

The swarm that is introduced above may be generated by a combination of a Poisson process and a binomial process. The binomial process is implemented by a three dimensional spread function. The Poisson process delivers the parameter for the spread function. The result is something that is close to a Gaussian location distribution (a 3D normal distribution).

When seen as a charge distribution rather than as a location distribution, then the swarm corresponds to a rather smooth potential that at short distance looks as Erf(r)/r and at somewhat greater distance as 1/r. Thus it contains NO SINGULARITY!

## Movement

In a paginated space progression model movements occur in steps. They are initiated by displacement generators. The incremental displacements are induced by members of a set of superposition coefficients. In this way linear movements and oscillations that stay internal to a composite can be arranged. These superposition coefficients add to the dimension of the subspace that represents the moving or oscillating object.

A uniform movement does not change the representation. For a frame that moves with the swarm, the swarm is at rest. If the swarm moves with respect to a frame , then the swarm and the micro-path are stretched along the movement path. ***If the (average) hop size does not change***, then with a fast uniform movement in a flat embedding continuum the micro-path is unfolded into a chain that is parallel to a straight line. Under these conditions the swarm cannot go faster. Thus if hops already occur with maximum speed then a maximum speed for the swarm exists.

If all swarms have a fixed number of elements and the average hop size is a general constant then the maximum speed of swarms is a general constant.

## Summary

These deliberations show that it has sense to reason about what exists underneath the wave function.

This paper gives insight in what may exist underneath the wave function. Here an example is given and it need not be the correct view. That correct view is not the intention of the paper. The intention is to show that it is not smart to deny the existence of features and phenomena that might exist underneath the wave function. Quite probably these features and phenomena will never be directly observable. However, their traces in the form of their averaged or smoothed effects are noticeable. Contemporary physics uses these smoothed and averaged data in order to design applications.

If you want to understand the foundations of physics, then you must dive into the wonderland that exists underneath the wave function. The wave function does not explain these foundations. It only describes what happens to wave functions.