

# Can the wave function of an electron be divided and trapped?

*Electrons are elementary particles — indivisible, unbreakable. But new research suggests the electron's quantum state — the electron wave function — can be separated into many parts. That has some strange implications for the theory of quantum mechanics.*

*Experiments led by Humphrey Maris, professor of physics at Brown, suggest that the quantum state of an electron — the electron's wave function — can be shattered into pieces and those pieces can be trapped in tiny bubbles of liquid helium. To be clear, the researchers are not saying that the electron can be broken apart. Electrons are elementary particles, indivisible and unbreakable. But what the researchers are saying is in some ways more bizarre. [4]*

*The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the Wave-Particle Duality and the electron's spin also, building the Bridge between the Classical and Quantum Theories.*

*The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate and the Weak and Strong Interactions by the diffraction patterns. The Weak Interaction changes the diffraction patterns by moving the electric charge from one side to the other side of the diffraction pattern, which violates the CP and Time reversal symmetry.*

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## Preface

New research by physicists from Brown University puts the profound strangeness of quantum mechanics in a nutshell — or, more accurately, in a helium bubble. [4]

I think that we have a simple bridge between the classical and quantum mechanics by understanding the Heisenberg Uncertainty Relations. It makes clear that the particles are not point like but have a  $dx$  and  $dp$  uncertainty.

## The electron wave function

Electrons are elementary particles — indivisible, unbreakable. But new research suggests the electron's quantum state — the electron wave function — can be separated into many parts. That has some strange implications for the theory of quantum mechanics.



Experiments led by Humphrey Maris, professor of physics at Brown, suggest that the quantum state of an electron — the electron's wave function — can be shattered into pieces and those pieces can be trapped in tiny bubbles of liquid helium. To be clear, the researchers are not saying that the electron can be broken apart. Electrons are elementary particles, indivisible and unbreakable. But what the researchers are saying is in some ways more bizarre.

In quantum mechanics, particles do not have a distinct position in space. Instead, they exist as a wave function, a probability distribution that includes all the possible locations where a particle might be found. Maris and his colleagues are suggesting that parts of that distribution can be separated and cordoned off from each other.

"We are trapping the chance of finding the electron, not pieces of the electron," Maris said. "It's a little like a lottery. When lottery tickets are sold, everyone who buys a ticket gets a piece of paper. So all these people are holding a chance and you can consider that the chances are spread all over the place. But there is only one prize — one electron — and where that prize will go is determined later."

If Maris's interpretation of his experimental findings is correct, it raises profound questions about the measurement process in quantum mechanics. In the traditional formulation of quantum mechanics, when a particle is measured — meaning it is found to be in one particular location — the wave function is said to collapse.

"The experiments we have performed indicate that the mere interaction of an electron with some larger physical system, such as a bath of liquid helium, does not constitute a measurement," Maris said. "The question then is: What does?"

And the fact that the wave function can be split into two or more bubbles is strange as well. If a detector finds the electron in one bubble, what happens to the other bubble?

"It really raises all kinds of interesting questions," Maris said.

## Electron bubbles

Scientists have wondered for years about the strange behavior of electrons in liquid helium cooled to near absolute zero. When an electron enters the liquid, it repels surrounding helium atoms, forming a bubble in the liquid about 3.6 nanometers across. The size of the bubble is determined by the pressure of the electron pushing against the surface tension of the helium. The strangeness, however, arises in experiments dating back to the 1960s looking at how the bubbles move.

In the experiments, a pulse of electrons enters the top of a helium-filled tube, and a detector registers the electric charge delivered when electron bubbles reach the bottom of the tube. Because the bubbles have a well-defined size, they should all experience the same amount of drag as they move, and should therefore arrive at the detector at the same time. But that's not what happens. Experiments have detected unidentified objects that reach the detector before the normal electron bubbles. Over the years, scientists have cataloged 14 distinct objects of different sizes, all of which seem to move faster than an electron bubble would be expected to move.

"They've been a mystery ever since they were first detected," Maris said. "Nobody has a good explanation."

Several possibilities have been proposed. The unknown objects could be impurities in the helium—charged particles knocked free from the walls of the container.

Another possibility is that the objects could be helium ions — helium atoms that have picked up one or more extra electrons, which produce a negative charge at the detector.

But Maris and his colleagues, including Nobel laureate and Brown physicist Leon Cooper, believe a new set of experiments puts those explanations to rest.

## New experiments

The researchers performed a series of electron bubble mobility experiments with much greater sensitivity than previous efforts. They were able to detect all 14 of the objects from previous work, plus four additional objects that appeared frequently over the course of the experiments. But in addition to those 18 objects that showed up frequently, the study revealed countless additional objects that appeared more rarely.

In effect, Maris says, it appears there aren't just 18 objects, but an effectively infinite number of them, with a "continuous distribution of sizes" up to the size of the normal electron bubble.

“That puts a dagger in the idea that these are impurities or helium ions,” Maris said. “It would be hard to imagine that there would be that many impurities, or that many previously unknown helium ions.”

The only way the researchers can think of to explain the results is through “fission” of the wave function. In certain situations, the researchers surmise, electron wave functions break apart upon entering the liquid, and pieces of the wave function are caught in separate bubbles. Because the bubbles contain less than the full wave function, they’re smaller than normal electron bubbles and therefore move faster.

In their new paper, Maris and his team lay out a mechanism by which fission could happen that is supported by quantum theory and is in good agreement with the experimental results. The mechanism involves a concept in quantum mechanics known as reflection above the barrier.

In the case of electrons and helium, it works like this: When an electron hits the surface of the liquid helium, there’s some chance that it will cross into the liquid, and some chance that it will bounce off and carom away. In quantum mechanics, those possibilities are expressed as part of the wave function crossing the barrier, and part of it being reflected. Perhaps the small electron bubbles are formed by the portion of the wave function that goes through the surface. The size of the bubble depends on how much wave function goes through, which would explain the continuous distribution of small electron bubble sizes detected in the experiments.

The idea that part of the wave function is reflected at a barrier is standard quantum mechanics, Cooper said. “I don’t think anyone would argue with that,” he said. “The non-standard part is that the piece of the wave function that goes through can have a physical effect by influencing the size of the bubble. That is what is radically new here.”

Further, the researchers propose what happens after the wave function enters the liquid. It’s a bit like putting a droplet of oil in a puddle of water. “Sometime your drop of oil forms one bubble,” Maris said, “Sometimes it forms two, sometimes 100.”

There are elements within quantum theory that suggest a tendency for the wave function to break up into specific sizes. By Maris’s calculations, the specific sizes one might expect to see correspond roughly to the 18 frequently occurring electron bubble sizes.

“We think this offers the best explanation for what we see in the experiments,” Maris said. We’ve got this body of data that goes back 40 years. The experiments are not wrong; they’ve been done by multiple people. We have a tradition called Occam’s razor, where we try to come up with the simplest explanation. This, so far as we can tell, is it.”

But it does raise some interesting questions that sit on the border of science and philosophy. For example, it’s necessary to assume that the helium does not make a measurement of the actual position of the electron. If it did, any bubble found not to contain the electron would, in theory, simply disappear. And that, Maris says, points to one of the deepest mysteries of quantum theory.

“No one is sure what actually constitutes a measurement. Perhaps physicists can agree that someone with a Ph.D. wearing a white coat sitting in the lab of a famous university can make

measurements. But what about somebody who really isn't sure what they are doing? Is consciousness required? We don't really know."

Authors on the paper in addition to Maris were former Brown postdoctoral researcher Wanchun Wei, graduate student Zhuolin Xie, and George Seidel, professor emeritus of physics. [4]

## The Bridge

The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Quantum Theories. [1]

## Accelerating charges

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field. In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion. The same thing happens on the atomic scale giving a  $dp$  impulse difference and a  $dx$  way difference between the different part of the not point like particles.

## Relativistic effect

Another bridge between the classical and quantum mechanics in the realm of relativity is that the charge distribution is lowering in the reference frame of the accelerating charges linearly:  $ds/dt = at$  (time coordinate), but in the reference frame of the current it is parabolic:  $s = a/2 t^2$  (geometric coordinate).

## Heisenberg Uncertainty Relation

In the atomic scale the Heisenberg uncertainty relation gives the same result, since the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on  $\Delta x$  position difference and with a  $\Delta p$  momentum difference such a way that they product is about the half Planck reduced constant. For the proton this  $\Delta x$  much less in the nucleon, than in the orbit of the electron in the atom, the  $\Delta p$  is much higher because of the greater proton mass.

This means that the electron and proton are not point like particles, but has a real charge distribution.

## Wave - Particle Duality

The accelerating electrons explains the wave - particle duality of the electrons and photons, since the elementary charges are distributed on  $\Delta x$  position with  $\Delta p$  impulse and creating a wave packet of the electron. The photon gives the electromagnetic particle of the mediating force of the electrons electromagnetic field with the same distribution of wavelengths.

## Atomic model

The constantly accelerating electron in the Hydrogen atom is moving on the equipotential line of the proton and its kinetic and potential energy will be constant. Its energy will change only when it is changing its way to another equipotential line with another value of potential energy or getting free with enough kinetic energy. This means that the Rutherford-Bohr atomic model is right and only that changing acceleration of the electric charge causes radiation, not the steady acceleration. The steady acceleration of the charges only creates a centric parabolic steady electric field around the charge, the magnetic field. This gives the magnetic moment of the atoms, summing up the proton and electron magnetic moments caused by their circular motions and spins.

## The Relativistic Bridge

Commonly accepted idea that the relativistic effect on the particle physics is the fermions' spin - another unresolved problem in the classical concepts. If the electric charges can move only with accelerated motions in the self maintaining electromagnetic field, once upon a time they would reach the velocity of the electromagnetic field. The resolution of this problem is the spinning particle, constantly accelerating and not reaching the velocity of light because the acceleration is radial. One origin of the Quantum Physics is the Planck Distribution Law of the electromagnetic oscillators, giving equal intensity for 2 different wavelengths on any temperature. Any of these two wavelengths will give equal intensity diffraction patterns, building different asymmetric constructions, for example proton - electron structures (atoms), molecules, etc. Since the particles are centers of diffraction patterns they also have particle - wave duality as the electromagnetic waves have. [2]

## The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry. The Electroweak Interaction shows that the Weak Interaction is basically electromagnetic in nature. The arrow of time shows the entropy grows by changing the temperature dependent diffraction patterns of the electromagnetic oscillators.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2 spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with 1/2 spin. The weak interaction

changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the weak interaction, for example the Hydrogen fusion. Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T- symmetry breaking!!! This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.

Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman's interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with  $\frac{1}{2}$  spin creating; it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

## The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.

The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.

We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater then subatomic matter structures as an electric dipole change. There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.

The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction.



## Fermions and Bosons

The fermions are the diffraction patterns of the bosons such a way that they are both sides of the same thing.

## Van Der Waals force

Named after the Dutch scientist Johannes Diderik van der Waals – who first proposed it in 1873 to explain the behaviour of gases – it is a very weak force that only becomes relevant when atoms and molecules are very close together. Fluctuations in the electronic cloud of an atom mean that it will have an instantaneous dipole moment. This can induce a dipole moment in a nearby atom, the result being an attractive dipole–dipole interaction.

## Electromagnetic inertia and mass

### Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

### Relativistic change of mass

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

### The frequency dependence of mass

Since  $E = h\nu$  and  $E = mc^2$ ,  $m = h\nu / c^2$  that is the  $m$  depends only on the  $\nu$  frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the  $m_0$  inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

### Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force. [2]

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of

these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

## Gravity from the point of view of quantum physics

### The Gravitational force

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Big Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass ratio  $M_p = 1840 M_e$ . In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass.

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

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### The Higgs boson

By March 2013, the particle had been proven to behave, interact and decay in many of the expected ways predicted by the Standard Model, and was also tentatively confirmed to have + parity and zero spin, two fundamental criteria of a Higgs boson, making it also the first known scalar particle to be

discovered in nature, although a number of other properties were not fully proven and some partial results do not yet precisely match those expected; in some cases data is also still awaited or being analyzed.

Since the Higgs boson is necessary to the W and Z bosons, the dipole change of the Weak interaction and the change in the magnetic effect caused gravitation must be conducted. The Wien law is also important to explain the Weak interaction, since it describes the  $T_{\max}$  change and the diffraction patterns change. [2]

## Higgs mechanism and Quantum Gravity

The magnetic induction creates a negative electric field, causing an electromagnetic inertia. Probably it is the mysterious Higgs field giving mass to the charged particles? We can think about the photon as an electron-positron pair, they have mass. The neutral particles are built from negative and positive charges, for example the neutron, decaying to proton and electron. The wave – particle duality makes sure that the particles are oscillating and creating magnetic induction as an inertial mass, explaining also the relativistic mass change. Higher frequency creates stronger magnetic induction, smaller frequency results lesser magnetic induction. It seems to me that the magnetic induction is the secret of the Higgs field.

In particle physics, the Higgs mechanism is a kind of mass generation mechanism, a process that gives mass to elementary particles. According to this theory, particles gain mass by interacting with the Higgs field that permeates all space. More precisely, the Higgs mechanism endows gauge bosons in a gauge theory with mass through absorption of Nambu–Goldstone bosons arising in spontaneous symmetry breaking.

The simplest implementation of the mechanism adds an extra Higgs field to the gauge theory. The spontaneous symmetry breaking of the underlying local symmetry triggers conversion of components of this Higgs field to Goldstone bosons which interact with (at least some of) the other fields in the theory, so as to produce mass terms for (at least some of) the gauge bosons. This mechanism may also leave behind elementary scalar (spin-0) particles, known as Higgs bosons.

In the Standard Model, the phrase "Higgs mechanism" refers specifically to the generation of masses for the  $W^\pm$ , and Z weak gauge bosons through electroweak symmetry breaking. The Large Hadron Collider at CERN announced results consistent with the Higgs particle on July 4, 2012 but stressed that further testing is needed to confirm the Standard Model.

## What is the Spin?

So we know already that the new particle has spin zero or spin two and we could tell which one if we could detect the polarizations of the photons produced. Unfortunately this is difficult and neither ATLAS nor CMS are able to measure polarizations. The only direct and sure way to confirm that the particle is indeed a scalar is to plot the angular distribution of the photons in the rest frame of the centre of mass. A spin zero particles like the Higgs carries no directional information away from the original collision so the distribution will be even in all directions. This test will be possible when a much larger number of events have been observed. In the mean time we can settle for less certain indirect indicators.

## The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [3]

## Conclusions

Electrons are elementary particles — indivisible, unbreakable. But new research suggests the electron's quantum state — the electron wave function — can be separated into many parts. That has some strange implications for the theory of quantum mechanics. [4]

One of the most important conclusions is that the electric charges are moving in an accelerated way and even if their velocity is constant, they have an intrinsic acceleration anyway, the so called spin, since they need at least an intrinsic acceleration to make possible their movement .

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing. Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together. Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions.

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