# Existence of Majorana Fermions

*A low-temperature material made from the elements praseodymium, osmium, and antimony should be able to host subatomic particles known as Majorana fermions, MIT researchers have shown in a theoretical analysis. [28]*

*Princeton University scientists have observed an exotic particle that behaves simultaneously like matter and antimatter, a feat of math and engineering that could yield powerful computers based on quantum mechanics.*

*This paper explains the magnetic effect of the superconductive current from the observed effects of the accelerating electrons, causing naturally the experienced changes of the electric field potential along the electric wire. 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 changing acceleration of the electrons explains the created negative electric field of the magnetic induction, the Higgs Field, the changing Relativistic Mass and the Gravitational Force, giving a Unified Theory of the physical forces. Taking into account the Planck Distribution Law of the electromagnetic oscillators also, we can explain the electron/proton mass rate and the Weak and Strong Interactions.*

*Since the superconductivity is basically a quantum mechanical phenomenon and some entangled particles give this opportunity to specific matters, like Cooper Pairs or other entanglements, as strongly correlated materials and Exciton-mediated electron pairing, we can say that the secret of superconductivity is the quantum entanglement.*

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## Majorana Particles

Princeton University scientists have observed an exotic particle that behaves simultaneously like matter and antimatter, a feat of math and engineering that could yield powerful computers based on quantum mechanics.

The setup they created starts with an ultrapure crystal of lead, whose atoms naturally line up in alternating rows that leave atomically thin ridges on the crystal's surface. The researchers then deposited pure iron into one of these ridges to create a wire that is just one atom wide and about three atoms thick. Considering its narrow width, this wire is very long—if it were a pencil it would be five feet from tip to eraser. The researchers then placed the lead and the embedded iron wire under the scanning-tunneling microscope and cooled the system to -272 degrees Celsius, just a degree above absolute zero. After about two years of painstaking work, they confirmed that superconductivity in the iron wire matched the conditions required for Majorana fermion to be created in their material. Ultimately, the microscope was also able to detect an electrically neutral signal at the ends of the wires, similar to those seen in the Delft experiment. However, the setup also allowed the researchers to directly visualize how the signal changes along the wire, essentially mapping the quantum probability of finding the Majorana fermion along the wire and pinpointing that it appears at the ends of the wire.

By controlling these interactions, the researchers said, their Majoranas appeared "clean and removed from any spurious particles," which would be unavoidable in high-energy accelerator experiments. "This is more exciting and can actually be practically beneficial," Yazdani said, "because it allows scientists to manipulate exotic particles for potential applications, such as quantum computing."

In addition to their potential practical uses, the pursuit of Majoranas has broad implications for other areas of physics. Scientists believe, for example, that another sub-atomic particle called neutrinos, which also interact very weakly and are very hard to detect, could be a type of Majorana—a neutrino and anti-neutrino being the same particle. In addition, scientists regard Majoranas as possible candidates for dark matter, the mysterious substance that is thought to account for most matter in the universe, but which has not been directly observed because it also does not directly interact with other particles.

In previous proposals, the appearance of Majoranas would only happen under a narrow range of conditions. Typically, it is hard to have superconductivity and magnetism in the same material—magnetic fields usually kill superconductivity. But in the Princeton team's method, the magnetic field is present only where it is needed, on the wire, so superconductivity creeps in from the underlying lead unimpeded. [27]

## Researchers propose a new method for verifying the existence of Majorana fermions

A low-temperature material made from the elements praseodymium, osmium, and antimony should be able to host subatomic particles known as Majorana fermions, MIT researchers have shown in a theoretical analysis.

Majorana fermions, first predicted by physicists in 1937, can be thought of as electrons split into two parts, each of which behaves as independent particles. These fermions do not exist as elementary particles in nature but can emerge in certain superconducting materials near absolute zero temperature. In superconducting materials, electrons flow without resistance generating little or no heat.

The new analysis by graduate student Vladyslav Kozii, postdoc Jörn Venderbos, and Lawrence C. (1944) and Sarah W. Biedenharn Career Development Assistant Professor Liang Fu predicts this special state should occur in a praseodymium, osmium and antimony compound, PrOs4Sb12, and similar materials made of heavy metals.

Physicists describe electrons by their energy, momentum, and spin. An electron can occupy a possible energy level, and an unoccupied level is called a hole. In the new analysis, Majorana fermions emerge as a quantum superposition of an electron and a hole that move freely, with each having the same direction, or spin. This Majorana fermion spin can interact with the spin of atomic nuclei in the material, so it ought to be seen using nuclear magnetic resonance techniques, they predict.

"We address a certain class of superconductors, show that they have Majorana fermions as freely propagating quasiparticles in the bulk, and then look at how they can be detected and what other

properties these materials have that one could use in the future for interesting functionality," says Venderbos. "I think it very nicely bridges the gap between experiment and theory and it can be used by experimentalists right now." Their paper was published this month in the journal Science Advances.

A key physics concept in this work is that of time-reversal symmetry. Such symmetry means that equations of motions governing an object or particle stay the same if one could reverse the direction of time—with time flowing backward rather forward. If the equation of motion of electrons in a material is different when time flows backwards—as is true in magnets, for instance—then time-reversal symmetry is said to be broken. This gives physicists an important way to distinguish different materials. In the proposed antimony-compound based superconductor, analysis shows that the Majorana fermions can only exist when time reversal symmetry is broken. Upon reversing the motion in time, the spin of the Majorana fermions is reversed—for example, from clockwise to counterclockwise—and this implies a different equation of motion for Majorana fermions going backward in time. "Regarding the material that we proposed, actually there is one recent experiment that confirms that time-reversal symmetry is broken in the superconducting state of this material. This reinforces our conclusion that it is indeed a very promising candidate for our theory to apply," Kozii explains.

Majorana fermions were first proposed by Italian physicist Ettore Majorana as a special mathematical solution for quantum behavior of electrons. Princeton University researchers reported detection of a zero-dimensional realization of these particles at the end of an atom chain in October 2014. The MIT theorists now show that the three-dimensional propagating Majorana fermions they predict are governed by Majorana's original equation. "The extensive study we have performed shows that this peculiar particle may now find its realization in solid state physics in a real material," Venderbos says.

Electrons in materials such as metals and semiconductors can fill only certain energy levels, or bands, with excluded, or forbidden, energy levels referred to as a bandgap. In a superconductor, this is also called the superconducting gap. Ordinarily, it takes outside energy in order to lift a lower energy electron to a higher energy level, especially when it has to cross a bandgap. The Fu groups' analysis of praseodymium, osmium, and antimony reveals that there are some special points in its electronic excitation spectrum where the bandgap vanishes in its superconducting state, which means that low energy excitations are possible. "However low energy you take, there will be always excitation at this energy. These excitations are exactly these Majorana fermions we were talking about," Kozii explains. Venderbos adds, "There are some excitations for which you don't have to put in any energy or just an infinitesimally tiny amount and you can still create the excitation."

Noting that Fu has made "some fantastic predictions in the past," Princeton University professor of chemistry Robert J. Cava, who was not involved in this research, suggests: "Experimentalists should listen to what he has to say. ... I am very happy to see that he and his coworkers have presented an analysis of real materials in which their ideas might be embodied."

Kozii, Venderbos, and Fu analyzed these unconventional superconductors for a year. For Kozii, the work will become part of his doctoral thesis.

The researchers hope their work will inspire experimentalists to look again at some previously studied materials to identify ones that host superconducting states with Majorana fermions. "I think the first step would be just to find a material in which everyone can agree that it has these Majorana fermions. That would be really exciting and constitute the discovery of a new type of superconductor in experiment," Venderbos says. "The next step would be to think about functionalization of these materials, what could be the specific applications." Trying to make quantum devices out of these materials is one possible direction. "We hope this research ultimately brings closer efforts from the quantum material and quantum device community in finding out the many facets of Majorana fermions," Fu adds. [28]

## The Quest of Superconductivity

Superconductivity seems to contradict the theory of accelerating charges in the static electric current, caused by the electric force as a result of the electric potential difference, since a closed circle wire no potential difference at all. [1]

On the other hand the electron in the atom also moving in a circle around the proton with a constant velocity and constant impulse momentum with a constant magnetic field. This gives the idea of the centripetal acceleration of the moving charge in the closed circle wire as this is the case in the atomic electron attracted by the proton. Because of this we can think about superconductivity as a quantum phenomenon. [2]

## Experiences and Theories

### Conventional superconductivity

Conventional superconductivity can be explained by a theory developed by Bardeen, Cooper and Schrieffer (BCS) in 1957. In BCS theory, electrons in a superconductor combine to form pairs, called Cooper pairs, which are able to move through the crystal lattice without resistance when an electric voltage is applied. Even when the voltage is removed, the current continues to flow indefinitely, the most remarkable property of superconductivity, and one that explains the keen interest in their technological potential. [3]

### High-temperature superconductivity

In 1986, high-temperature superconductivity was discovered (i.e. superconductivity at temperatures considerably above the previous limit of about 30 K; up to about 130 K). It is believed that BCS theory alone cannot explain this phenomenon and that other effects are at play. These effects are still not yet fully understood; it is possible that they even control superconductivity at low temperatures for some materials. [8]

### Superconductivity and magnetic fields

Superconductivity and magnetic fields are normally seen as rivals – very strong magnetic fields normally destroy the superconducting state. Physicists at the Paul Scherer Institute have now demonstrated that a novel superconducting state is only created in the material $CeCoIn_5$ when there are strong external magnetic fields. This state can then be manipulated by modifying the field

direction. The material is already superconducting in weaker fields, too. In strong fields, however, an additional second superconducting state is created which means that there are two different superconducting states at the same time in the same material. The new state is coupled with an anti-ferromagnetic order that appears simultaneously with the field. The anti-ferromagnetic order from whose properties the researchers have deduced the existence of the superconducting state was detected with neutrons at PSI and at the Institute Laue-Langevin in Grenoble. [6]

## Room-temperature superconductivity

After more than twenty years of intensive research the origin of high-temperature superconductivity is still not clear, but it seems that instead of *electron-phonon* attraction mechanisms, as in conventional superconductivity, one is dealing with genuine *electronic* mechanisms (e.g. by antiferromagnetic correlations), and instead of s-wave pairing, d-waves are substantial. One goal of all this research is room-temperature superconductivity. [9]

## Exciton-mediated electron pairing

Theoretical work by Neil Ashcroft predicted that solid metallic hydrogen at extremely high pressure (~500 GPa) should become superconducting at approximately room-temperature because of its extremely high speed of sound and expected strong coupling between the conduction electrons and the lattice vibrations (phonons). This prediction is yet to be experimentally verified, as yet the pressure to achieve metallic hydrogen is not known but may be of the order of 500 GPa. In 1964, William A. Little proposed the possibility of high temperature superconductivity in organic polymers. This proposal is based on the exciton-mediated electron pairing, as opposed to phonon-mediated pairing in BCS theory. [9]

## Resonating valence bond theory

In condensed matter physics, the resonating valence bond theory (RVB) is a theoretical model that attempts to describe high temperature superconductivity, and in particular the superconductivity in cuprate compounds. It was first proposed by American physicist P. W. Anderson and the Indian theoretical physicist Ganapathy Baskaran in 1987. The theory states that in copper oxide lattices, electrons from neighboring copper atoms interact to form a valence bond, which locks them in place. However, with doping, these electrons can act as mobile Cooper pairs and are able to superconduct. Anderson observed in his 1987 paper that the origins of superconductivity in doped cuprates was in the Mott insulator nature of crystalline copper oxide. RVB builds on the Hubbard and t-J models used in the study of strongly correlated materials. [10]

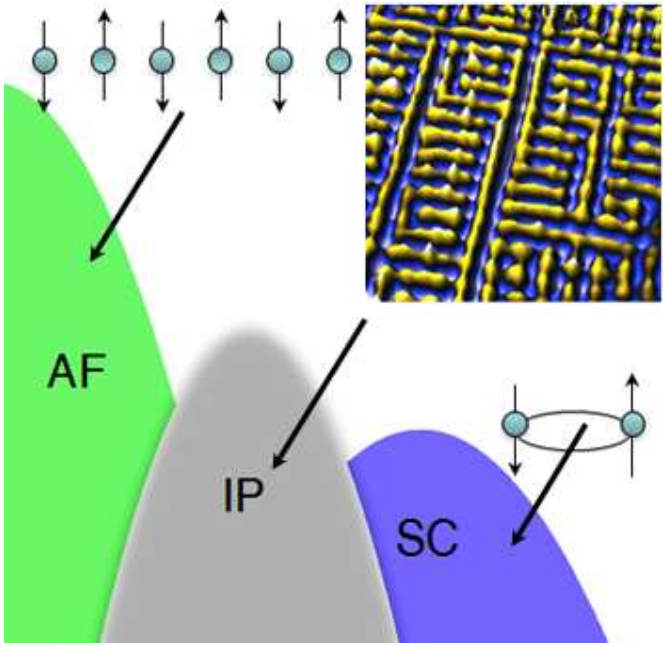
## Strongly correlated materials

Strongly correlated materials are a wide class of electronic materials that show unusual (often technologically useful) electronic and magnetic properties, such as metal-insulator transitions or half-metallicity. The essential feature that defines these materials is that the behavior of their electrons cannot be described effectively in terms of non-interacting entities. Theoretical models of the electronic structure of strongly correlated materials must include electronic correlation to be accurate. Many transition metal oxides belong into this class which may be subdivided according to their behavior, *e.g.* high-$T_c$, spintronic materials, Mott insulators, spin Peierls materials, heavy fermion materials, quasi-low-dimensional materials, etc. The single most intensively studied effect is probably high-temperature superconductivity in doped cuprates, e.g. $La_{2-x}Sr_xCuO_4$. Other ordering or

magnetic phenomena and temperature-induced phase transitions in many transition-metal oxides are also gathered under the term "strongly correlated materials." Typically, strongly correlated materials have incompletely filled *d*- or *f*-electron shells with narrow energy bands. One can no longer consider any electron in the material as being in a "sea" of the averaged motion of the others (also known as mean field theory). Each single electron has a complex influence on its neighbors. [11]

## New superconductor theory may revolutionize electrical engineering

High-temperature superconductors exhibit a frustratingly varied catalog of odd behavior, such as electrons that arrange themselves into stripes or refuse to arrange themselves symmetrically around atoms. Now two physicists propose that such behaviors – and superconductivity itself – can all be traced to a single starting point, and they explain why there are so many variations.




An "antiferromagnetic" state, where the magnetic moments of electrons are opposed, can lead to a variety of unexpected arrangements of electrons in a high-temperature superconductor, then finally to the formation of "Cooper pairs" that conduct without resistance, according to a new theory. [22]

## Unconventional superconductivity in $Ba^{0.6}K^{0.4}Fe^{2}As^{2}$ from inelastic neutron scattering

In BCS superconductors, the energy gap between the superconducting and normal electronic states is constant, but in unconventional superconductors the gap varies with the direction the electrons are moving. In some directions, the gap may be zero. The puzzle is that the gap does not seem to vary with direction in the iron arsenides. Theorists have argued that, while the size of the gap shows

no directional dependence in these new compounds, the sign of the gap is opposite for different electronic states. The standard techniques to measure the gap, such as photoemission, are not sensitive to this change in sign.

But inelastic neutron scattering is sensitive. Osborn, along with Argonne physicist Stephan Rosenkranz, led an international collaboration to perform neutron experiments using samples of the new compounds made in Argonne's Materials Science Division, and discovered a magnetic excitation in the superconducting state that can only exist if the energy gap changes sign from one electron orbital to another.

"Our results suggest that the mechanism that makes electrons pair together could be provided by antiferromagnetic fluctuations rather than lattice vibrations," Rosenkranz said. "It certainly gives direct evidence that the superconductivity is unconventional."

Inelastic neutron scattering continues to be an important tool in identifying unconventional superconductivity, not only in the iron arsenides, but also in new families of superconductors that may be discovered in the future. [23]

## A grand unified theory of exotic superconductivity?

### The role of magnetism

In all known types of high-Tc superconductors—copper-based (cuprate), iron-based, and so-called heavy fermion compounds—superconductivity emerges from the "extinction" of antiferromagnetism, the ordered arrangement of electrons on adjacent atoms having anti-aligned spin directions. Electrons arrayed like tiny magnets in this alternating spin pattern are at their lowest energy state, but this antiferromagnetic order is not beneficial to superconductivity.

However if the interactions between electrons that cause antiferromagnetic order can be maintained while the actual order itself is prevented, then superconductivity can appear. "In this situation, whenever one electron approaches another electron, it tries to anti-align its magnetic state," Davis said. Even if the electrons never achieve antiferromagnetic order, these antiferromagnetic interactions exert the dominant influence on the behavior of the material. "This antiferromagnetic influence is universal across all these types of materials," Davis said.

Many scientists have proposed that these antiferromagnetic interactions play a role in the ability of electrons to eventually pair up with anti-aligned spins—a condition necessary for them to carry current with no resistance. The complicating factor has been the existence of many different types of "intertwined" electronic phases that also emerge in the different types of high-Tc superconductors—sometimes appearing to compete with superconductivity and sometimes coexisting with it. [24]

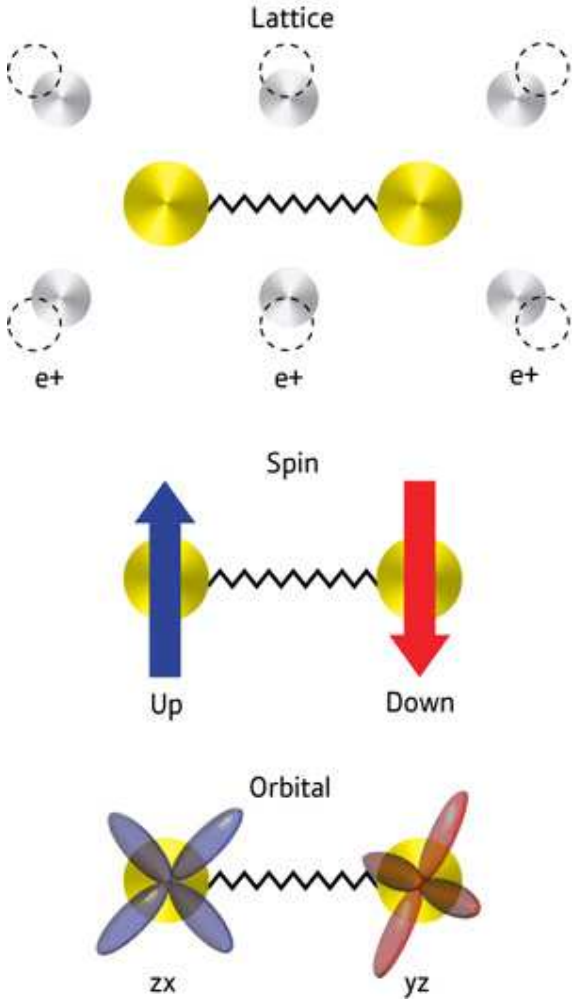
## Concepts relating magnetic interactions, intertwined electronic orders, and strongly correlated superconductivity

Unconventional superconductivity (SC) is said to occur when Cooper pair formation is dominated by repulsive electron–electron interactions, so that the symmetry of the pair wave function is other than an isotropic s-wave. The strong, on-site, repulsive electron–electron interactions that are the proximate cause of such SC are more typically drivers of commensurate magnetism. Indeed, it is the suppression of commensurate antiferromagnetism (AF) that usually allows this type of unconventional superconductivity to emerge. Importantly, however, intervening between these AF and SC phases, intertwined electronic ordered phases (IP) of an unexpected nature are frequently discovered. For this reason, it has been extremely difficult to distinguish the microscopic essence of the correlated superconductivity from the often spectacular phenomenology of the IPs. Here we introduce a model conceptual framework within which to understand the relationship between AF electron–electron interactions, IPs, and correlated SC. We demonstrate its effectiveness in simultaneously explaining the consequences of AF interactions for the copper-based, iron-based, and heavy-fermion superconductors, as well as for their quite distinct IPs.

### Significance

This study describes a unified theory explaining the rich ordering phenomena, each associated with a different symmetry breaking, that often accompany high-temperature superconductivity. The essence of this theory is an ”antiferromagnetic interaction,” the interaction that favors the development of magnetic order where the magnetic moments reverse direction from one crystal unit cell to the next. We apply this theory to explain the superconductivity, as well as all observed accompanying ordering phenomena in the copper-oxide superconductors, the iron-based superconductors, and the heavy fermion superconductors. [25]

## Superconductivity's third side unmasked




Shimojima and colleagues were surprised to discover that interactions between electron spins do not cause the electrons to form Cooper pairs in the pnictides. Instead, the coupling is mediated by the electron clouds surrounding the atomic cores. Some of these so-called orbitals have the same energy, which causes interactions and electron fluctuations that are sufficiently strong to mediate superconductivity.

This could spur the discovery of new superconductors based on this mechanism. “Our work establishes the electron orbitals as a third kind of pairing glue for electron pairs in superconductors, next to lattice vibrations and electron spins,” explains Shimojima. “We believe that this finding is a step towards the dream of achieving room-temperature superconductivity,” he concludes. [17]

## Strongly correlated materials

Strongly correlated materials give us the idea of diffraction patterns explaining the electron-proton mass rate. [13]

This explains the theories relating the superconductivity with the strong interaction. [14]

## Fermions and Bosons

The fermions are the diffraction patterns of the bosons such a way that they are both sides of the same thing. We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too.

### 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. 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. [18] One of these new matter formulas is the superconducting matter.

## Higgs Field and Superconductivity

The simplest implementation of the mechanism adds an extra Higgs field to the gauge theory. The specific spontaneous symmetry breaking of the underlying local symmetry, which is similar to that one appearing in the theory of superconductivity, triggers conversion of the longitudinal field component to the Higgs boson, which interacts with itself and (at least of part of) the other fields in the theory, so as to produce mass terms for the above-mentioned three gauge bosons, and also to the above-mentioned fermions (see below). [16]

The Higgs mechanism occurs whenever a charged field has a vacuum expectation value. In the nonrelativistic context, this is the Landau model of a charged Bose–Einstein condensate, also known as a superconductor. In the relativistic condensate, the condensate is a scalar field, and is relativistically invariant.

The Higgs mechanism is a type of superconductivity which occurs in the vacuum. It occurs when all of space is filled with a sea of particles which are charged, or, in field language, when a charged field has a nonzero vacuum expectation value. Interaction with the quantum fluid filling the space prevents certain forces from propagating over long distances (as it does in a superconducting medium; e.g., in the Ginzburg–Landau theory).

A superconductor expels all magnetic fields from its interior, a phenomenon known as the Meissner effect. This was mysterious for a long time, because it implies that electromagnetic forces somehow become short-range inside the superconductor. Contrast this with the behavior of an ordinary metal. In a metal, the conductivity shields electric fields by rearranging charges on the surface until the total field cancels in the interior. But magnetic fields can penetrate to any distance, and if a magnetic monopole (an isolated magnetic pole) is surrounded by a metal the field can escape without collimating into a string. In a superconductor, however, electric charges move with no dissipation, and this allows for permanent surface currents, not just surface charges. When magnetic fields are introduced at the boundary of a superconductor, they produce surface currents which exactly

neutralize them. The Meissner effect is due to currents in a thin surface layer, whose thickness, the London penetration depth, can be calculated from a simple model (the Ginzburg–Landau theory).

This simple model treats superconductivity as a charged Bose–Einstein condensate. Suppose that a superconductor contains bosons with charge *q*. The wavefunction of the bosons can be described by introducing a quantum field, ψ, which obeys the Schrödinger equation as a field equation (in units where the reduced Planck constant, *ħ*, is set to 1):

$$i\frac{\partial}{\partial t}\psi = \frac{(\nabla - iqA)^2}{2m}\psi.$$

The operator ψ(*x*) annihilates a boson at the point *x*, while its adjoint $\psi^\dagger$ creates a new boson at the same point. The wavefunction of the Bose–Einstein condensate is then the expectation value ψ of ψ(*x*), which is a classical function that obeys the same equation. The interpretation of the expectation value is that it is the phase that one should give to a newly created boson so that it will coherently superpose with all the other bosons already in the condensate.

When there is a charged condensate, the electromagnetic interactions are screened. To see this, consider the effect of a gauge transformation on the field. A gauge transformation rotates the phase of the condensate by an amount which changes from point to point, and shifts the vector potential by a gradient:

$$\psi \to e^{iq\phi(x)}\psi$$
$$A \to A + \nabla\phi.$$

When there is no condensate, this transformation only changes the definition of the phase of ψ at every point. But when there is a condensate, the phase of the condensate defines a preferred choice of phase.

The condensate wave function can be written as

$$\psi(x) = \rho(x)\, e^{i\theta(x)},$$

where ρ is real amplitude, which determines the local density of the condensate. If the condensate were neutral, the flow would be along the gradients of θ, the direction in which the phase of the Schrödinger field changes. If the phase θ changes slowly, the flow is slow and has very little energy. But now θ can be made equal to zero just by making a gauge transformation to rotate the phase of the field.

The energy of slow changes of phase can be calculated from the Schrödinger kinetic energy,

$$H = \frac{1}{2m}|(qA + \nabla)\psi|^2,$$

and taking the density of the condensate ρ to be constant,

$$H \approx \frac{\rho^2}{2m}(qA + \nabla\theta)^2.$$

Fixing the choice of gauge so that the condensate has the same phase everywhere, the electromagnetic field energy has an extra term,

$$\frac{q^2\rho^2}{2m}A^2.$$

When this term is present, electromagnetic interactions become short-ranged. Every field mode, no matter how long the wavelength, oscillates with a nonzero frequency. The lowest frequency can be read off from the energy of a long wavelength A mode,

$$E \approx \frac{\dot{A}^2}{2} + \frac{q^2\rho^2}{2m}A^2.$$

This is a harmonic oscillator with frequency

$$\sqrt{\frac{1}{m}q^2\rho^2}.$$

The quantity $|\psi|^2$ ($=\rho^2$) is the density of the condensate of superconducting particles.

In an actual superconductor, the charged particles are electrons, which are fermions not bosons. So in order to have superconductivity, the electrons need to somehow bind into Cooper pairs. [12]

The charge of the condensate *q* is therefore twice the electron charge *e*. The pairing in a normal superconductor is due to lattice vibrations, and is in fact very weak; this means that the pairs are very loosely bound. The description of a Bose–Einstein condensate of loosely bound pairs is actually more difficult than the description of a condensate of elementary particles, and was only worked out in 1957 by Bardeen, Cooper and Schrieffer in the famous BCS theory. [3]

## Superconductivity and Quantum Entanglement

We have seen that the superconductivity is basically a quantum mechanical phenomenon and some entangled particles give this opportunity to specific matters, like Cooper Pairs or other entanglements, as strongly correlated materials and Exciton-mediated electron pairing. [26]

## Conclusions

Princeton University scientists have observed an exotic particle that behaves simultaneously like matter and antimatter, a feat of math and engineering that could yield powerful computers based on quantum mechanics.

Probably in the superconductivity there is no electric current at all, but a permanent magnetic field as the result of the electron's spin in the same direction in the case of the circular wire on a low temperature. [6]

We think that there is an electric current since we measure a magnetic field. Because of this saying that the superconductivity is a quantum mechanical phenomenon.

Since the acceleration of the electrons is centripetal in a circular wire, in the atom or in the spin, there is a steady current and no electromagnetic induction. This way there is no changing in the Higgs field, since it needs a changing acceleration. [18]

The superconductivity is temperature dependent; it means that the General Weak Interaction is very relevant to create this quantum state of the matter. [19]

We have seen that the superconductivity is basically a quantum mechanical phenomenon and some entangled particles give this opportunity to specific matters, like Cooper Pairs or other entanglements. [26]

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