Relativistic Longitudinal Spin Wave[*]

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Abstract

In a study of magnetic losses in iron and steel a relativistic longitudinal spin wave was found. The exceedingly small mass and large scale of the spin wave requires an accurate relativistic description for a boson. Because of these characteristics it forms a state that is decoupled from property variations of the substrate on a small scale and is only weakly dissipated. In the effort to explain the behavior of this spin wave an elementary quantum representation of a particle was found to be provided by a differential equation which produces two solutions: one for boson family and one for fermion family of elementary particles. This derivation of a local statistical quantum state equation from the massless dispersion relation provides a general mechanism for obtaining a statistical description required for quantum mechanics and produces a definition of a quantum particle. The new analysis allowed confirmation of the mass value of the longitudinal spin wave from the original experimental measurements. The analysis required the introduction of a reference frame located with the particle which resulted in a quantum description that is consistent with the principles of relativity.

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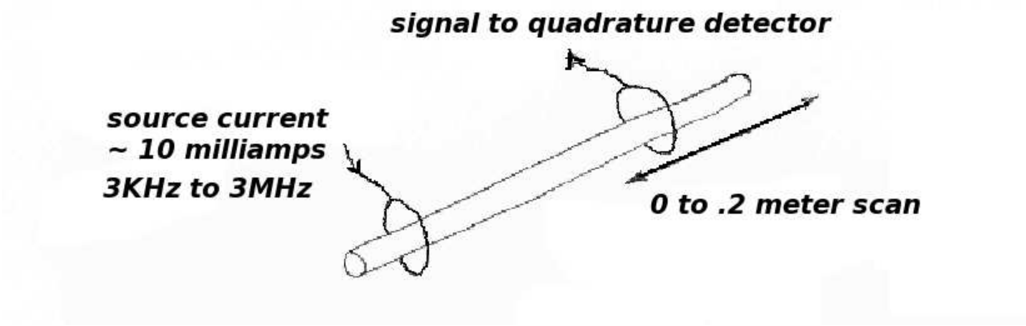
I. THE PROBLEM

In a 1932 paper P.A.M. Dirac proposed a form of relativistic quantum mechanics that operates without the explicit representation of a potential, with a local definition of time, and it also contained a longitudinal interacting particle [1]. Some of these ideas are very useful in order to integrate relativity into quantum mechanics. The use of the laboratory frame of reference alone is not sufficient for this relativistic description of a quantum particle. A concrete physical example with data of a longitudinal exciton is used to make a connection. The example that will be used is from solid state physics of ferromagnetism. The scales being discussed are immaterial as the basic quantum activity is define at all scales and is not isolated to the atomic regime. The resulting derivation supports the conjecture that a particle can be realized out of the actions on a massless field that concurrently supplies the statistical foundation for a quantum particle while being consistent with relativity.

With Maxwell's mathematical theory of electromagnetism and the introduction of the toroidal transformer core, Henry Rowland started reporting in 1873 dynamic permeability measurements [2] [3]. Transformers were an important new technology and had to be characterized. Unfortunately the dynamic measurements on annealed iron behaved in a manner that could not be explained when compared to the static properties. This was a study of loss mechanisms and at times there were no losses but the signals appeared to be amplified. The effort to figure out the basics of the problem was dropped for almost a century. A recent non Ohmic loss problem encountered in superconducting niobium [4] used in large linear particle accelerator cavities had enough similarities that brought our attention back to the ferromagnetic loss problem in Rowland's transformer called the anomalous eddy current loss because they are both macroscopic quantum processes [5] on a large scale. Our initial eddy current measurements on a steel bar actually produced more questions than answers [6]. The fundamental problem for the annealed low carbon steel or pure iron can be stated quite simply. In a coupled transformer with a primary and a secondary separated on a linear inductor, photons at the driven frequency are injected by the primary and then retrieved at the secondary coil. When the injected photons are traveling in the inductor from the measurements they appear to acquire a mass, a very small mass $1.3 \times 10^{-9}\ m_e$, where m_e is the electron mass. The value of the mass and the distribution of the signal in the bar are significant features and not accurately described either by standard electrodynamics or a simple non-relativistic quantum analysis of the field alone.

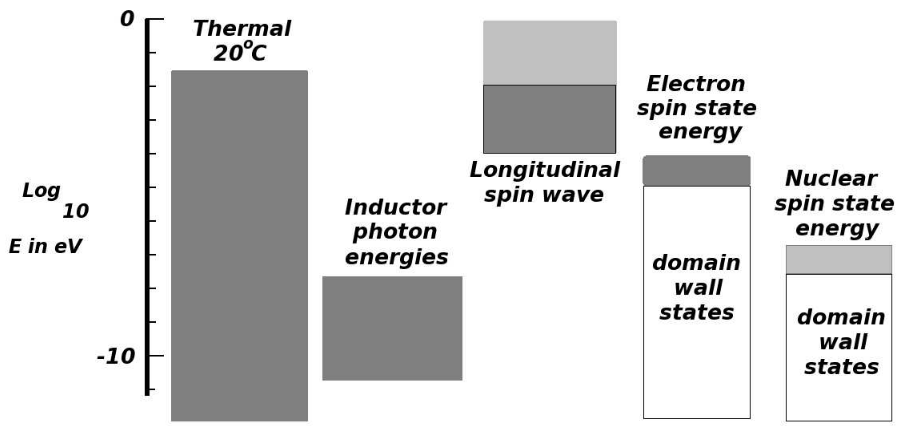
FIG. 1: ***Source and detector arrangement for generating and detecting the fields and exciton in a soft ferromagnetic iron alloy. reference [6].***



Using a simple inductor in making measurements on steel has some hidden advantages. The first is that for a linear Ohms law conducting materials there is a complete closed form analysis of the eddy current response and the fields [7] that has been well tested [8]. This analysis is accurate for any linear magnetic material that can be described by $B = \mu H$. Even if a power series representation of the magnetic field in the materials is applied the results found in well annealed iron or low carbon steel are still inconsistent with those solutions. The standard calculated responses from electromagnetic theory for the field will fail when collective coherent quantum transitions are driven by the applied field, since these transitions are not captured by the field equations. In a non-magnetic material currents induced by the inductor remain local to the source and opposed to the source field. Because of that property they limit the extent of the field beyond the source inductor much like a damped dipole field. In a ferromagnetic conductor the spin system competes against this loss mechanisms and drives an in phase signal in the material. Finding a synchronous field many material diameters away from the source inductor is an indication that the source fields are being transformed into modes that are only weakly dissipative and easily propagate long distances. Historically this effect is called the anomalous eddy current loss.

A demagnetizing and annealed ferrous bar has a refined magnetic domain size distribution and that limits significant leakage of the high static internal magnetic field by the domains geometrical arrangement. The high concentration of magnetic moments associated with the two electronic bands, spin parallel/anti-parallel to the local field, formed from the valance electrons can interact with the dynamic magnetic moment of the source inductor. Those spin states that lie within the thermal band at the Fermi surface can be affected by this weak external moment. The array of orientation of the domain moments which is at a scale much smaller than the material diameter along with a weak induced dynamic moment insures that there will be a significant population of moments to interact with the time dependent source field. Magnetic transitions driven by the source field differs from the conduction Ohmic losses in that this energy stored in a magnetic transition and can be reversibly accessed and is not lost into the thermal energy of the solid. So when the field energy is absorbed into these magnetic transitions it can be dynamically stored. The situation is complicated because there are a range of allowed spin transition energies because of the existence of the magnetic domain boundaries where the local internal **B** field changes sign through the magnetic domain boundary. These lower concentration domain wall moments with their state separation extending from zero to maximum values found within the domains, see figure 2. This continuum of states along with the thermal reservoir allows a strong connection to be made from the low energy applied induction field to the much higher energy time dependent longitudinal propagating magnetization that is generated.

FIG. 2: ***Energy diagram for a low carbon steel***



The result is a large scale internal magnetic excitation that is driven by a weak time dependent field which builds to a steady state value with an oscillating longitudinal magnetization. This response is strongly temperature dependent an becomes increasingly large until quenched at the Curie temperature. The dispersion curve for this longitudinal magnetic oscillation was measured for the propagating mode and found to have a mass of $1.3 \times 10^{-9} m_e$ where m_e is the electron rest mass, see reference [6]. This low mass and longitudinal oscillating magnetization identified the exciton as a longitudinal spin wave because the spin was not coupled to the electronic mass via a transverse torque of the Lorentz force. The transverse spin wave has an effective mass close to that of the electronic mass and is observed on a micron scale not the meter scale [11].

These spin waves are very insensitive to the materials dimensional variation, surface finish variations, surface oxides, local decarburization (variation in chemistry), local induced magnetization, local heat treatment history and variations in local applied static magnetic fields. The reason these spin waves can be easily detected over large distances is once they are created they only interact very weakly with material variations. Their utility for materials inspection is practically nil because of this decoupling from structural and material variations on a small scale. Small in this case is on the order of a few centimeters. A good demonstration of this behavior is the response when with a few centimeters of a bar on which a transition measurement is being made is raised from room temperature through the Curie point, 770 C. There are affects but such a drastic change only produces relatively modest changes, see reference [6]. This results in a stable quantum systems whose wave functions are not destroyed by decoherence at room temperature on a large scale. This makes it almost an ideal system to study the quantum properties of a bosons in a simply laboratory experiment.

The time dependent magnetization with both a low mass and a density function that can be measured over a range of energies provides a test for the definition of a quantum particle. The excitation is a longitudinal spin wave [6] [9] which is an internally generated exciton with an axial angular momentum that couples to the allowed electronic transitions of the Fe spin states close to the Fermi surface. The longitudinal spin wave is a useful probe because of its low mass unlike the transverse spin wave it can span large volumes of material to find favorably oriented spins which lie parallel/antiparallel over many domains to the high local internal $B \sim 2.14T$ fields. These axial spin state transitions are excited by the small variable frequency field driving the source coil in Figure 1 and by coupling to the thermal phonon fields which can allow the transitions to conserve both energy and momentum. Any mass measurement of an exciton based on the longitudinal spin wave will be of the field energy alone and decoupled from the electron rest mass.

An important feature of iron and some of its alloys are the two spin bands available at the Fermi surface with opposing orientations [10] and a significant density of states. These two opposed states permit the axial spin transitions to occur efficiently. The high intrinsic internal $\boldsymbol{B}$ field within the magnetic domains lifts the degeneracy of the two spin states.

Because the longitudinal spin wave has a structure that can be measured on the order of $> .1$ meters and not on the micron scale allows the spin wave's density function to be mapped by simply moving a phase sensitive coaxial detector coil away from the source. Two different structures with dynamic features are detected for the longitudinal spin wave: a propagating mode and a stored energy mode that is a stationary Bose-Einstein condensation. The low mass of the longitudinal spin raises the transition temperature for forming the Bose-Einstein condensation well above the Curie temperature. Most atomic Bose-Einstein condensations have to be studied in the micro-Kelvin temperature regime. By making these measurements over a frequency range from 3kHz to 3MHz the individual contributions can be separated and the dispersion curve of the propagating component can be extracted. It is from the dispersion curve the first mass determination was made, see reference [6]. Because of the low mass of these spin waves must be treated as relativistic objects even at low energies. For frequencies greater than a few hundred kilo Hertz they are fully relativistic particles.

II. LOCAL STATISTICAL QUANTUM STATE EQUATION

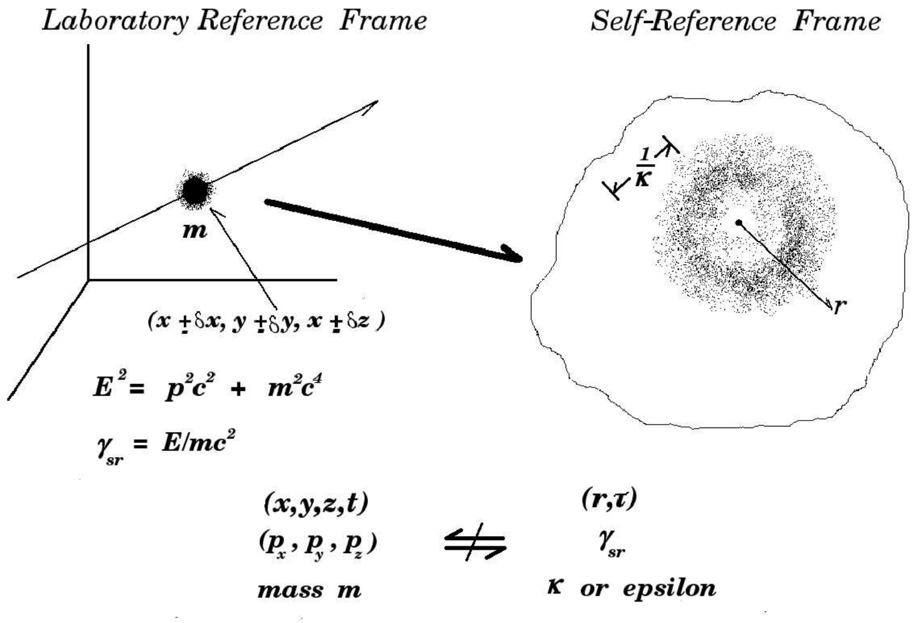
To describe the dynamics of a particle with a set of coordinate *(x,y,z,t)* and some kind of detector to locate our particle with some accuracy in the laboratory frame tells us little about the particle itself. Instead of using the laboratory frame of reference a frame of reference located at the particle's center of mass is selected.

The particle occupies a volume and there is significant support that a minimum volume is required to define a mass starting with the dimension, ϵ required for a minimum mass from the Compton effect relation, $\epsilon = \hbar/mc$. W. Heisenberg in 1930 [12], translation [13] used this relation to build an early field theory model of a particle not as a point mass. The second method to define mass-scale relation is by using the limiting case solutions of the Schrödinger equation for a weak and vanishing attractive interaction or a repulsive interaction with a spherically symmetric potential [4] [14]. All three methods produce the same result, an equation that links the mass of a particle, m, to ϵ, which is the linear dimension of the particle's minimum allowed volume over which the particle is defined.

$$\epsilon = \frac{\hbar}{mc} \tag{1}$$

This new frame of reference having its origin on the particles center of mass or center

FIG. 3: ***Self-reference frame compared to the laboratory frame for representing a particle's wave function. The self-reference frame is centered on the particle center of mass and there is no coordinate transformation in general that maps this frame into the laboratory frame. Only particle properties determined in the self-reference frame are transferred to the laboratory frame for use.***



of symmetry is called the self-reference frame for the particle. The mathematics of taking a field over to a particle description at a minimum only requires the location of the center of symmetry of a particle as opposed to a function describing a field over all space. If the particle distribution is determined by a random process acting on a field then there is only one significant spatial coordinate in the self-reference frame and that is the radial coordinate in a spherical coordinate system. Since the center of symmetry is only defined in the moment there is in general no simple set of transformations between the laboratory frame of reference and the self-reference frame. The particles density within this self-reference frame can then be computed from the resulting statistical description. This type of calculation will retain the statistical character of a quantum measurement but may also yield the characteristic that generate the particle properties. Spin is conveniently handled not in the self-reference frame where the total angular momentum is zero but in the laboratory frame. For the longitudinal spin wave with zero angular momentum this is not an issue. In the laboratory frame nothing has changed, where a particle with properties moves on some trajectory.

In this simple model the many-body effects are included which cannot be isolated by an observer in a random spatial variable. This statistical picture must also be compatible with relativity. There are two possible starting points for this derivation. The simplest is to use the dispersion relationship of a massless field [14], $\mathbf{cp} = \mathbf{E}$, and convert it to a linear differential equation operating on the spatial wave function of a field. This will generate the spatial differential equation 5. However, since the goal is to define a relativistic particle behavior it is useful to also include a derivation that begins at an earlier point with the relativistic energy-momentum relationship and then reduce the mass to zero before reconstructing the relation with a statistical basis. This allows capturing the time dependence in the new frame of reference.

The starting point for this derivation in a potential free space has the total energy, E, as the sum of the particles kinetic energy and the self-energy due to the particle's mass. The relativistic form of this relationship has the parameters [15] [16] mass, m, momentum, p, and speed of light, c.

$$c^2p^2 = E^2 - m^2c^4 \tag{2}$$

The energy, E, is the total energy made up from the particle's rest energy and the relativistically corrected kinetic energy. This expression can be factored:

$$(\pm cp)(\pm cp) = (E + mc^2)(E - mc^2) \tag{3}$$

The kinetic energy term on the right hand side of the equation $E - mc^2$ represents the energy in excess of the particles self energy and can be replaced by the energy operator $i\hbar\partial/\partial t$. This is an important point and it is a statement that time is defined by differential description tracing a single trajectory. This is the time description from classical mechanics as well as the one used in the Schrödinger and Dirac equations. This derivation is for any particle type. However, the excitation being examined is a boson and there is a previously developed theory for relativistic bosons by W. Pauli and V. Weisskopf from 1934 that was presented as a challenge to the 1932 paper of Dirac cited in the introduction [18], translation [13]. In the derivation of the Pauli-Wessikopf model a different substitution was used for the energy operator to generate the Klein-Gordon equation. The energy operator was substituted for E and not the kinetic energy, $E - mc^2$. This substitution is not consistent for a proper definition of time from dynamics. If they had taken the correct form of the energy operator another differential equation is produced that has a physically correct but has a very restricted solution set [19] not at all like the incorrect version they produced. Using the incorrect form for the energy operator their harmonic oscillator like solutions had unwanted nonphysical problems with time dependent probabilities for the stationary states [20]. These defects can be avoided on the quantum state equation if the the effects of the statistical interaction on a massless field can be first computed and then mass does not have to be injected artificially as a postulate rather is generated from the analysis.

To turn equation 3 into an operator relation requires a wave function $\psi(\mathbf{x}, t)$. The wave functions from both the Dirac and the Schrödinger equations are separable as a product of a coordinated dependent function $u(\mathbf{x})$ and a time dependent component $g(t)$. This will be true as long as the representation remains in the frame of reference of the particle where the coordinates in self-reference frame cannot be mixed by a Lorentz transformation. As that is a transformation that can only be used in the laboratory frame of reference. The total wave function is then $\psi(\mathbf{x}, t) = u(\mathbf{x})g(t)$.

Using the energy operator for $E - mc^2$ in the full energy-momentum relationship does one very important thing on the right side of equation 3 by requiring an eigenvalue on the left side of that equation. That then dictates how one of the momentum terms will be expressed on the left side as $\hbar k$ where k is the propagation vector. Secondly there is no operator expression for $E + mc^2$ for the remaining factor on the right side. This term then has to be an eigenvalue for the action of the remaining momentum operator on the left side of the equation. The momentum operator is $\widehat{p} = \frac{\hbar}{i}\nabla$. Applying the wave function to equation 3 and collecting terms results in the following expression:

$$(\pm c\widehat{p}u(\mathbf{x}))(\pm c\hbar k g(t)) = (E + mc^2)u(\mathbf{x})(i\hbar\frac{\partial g(t)}{\partial t}) \qquad (4)$$

The next step is to factor this equation again into two equations one with a time dependence and one with a space dependence. To factor the equation it is necessary to take the mass to zero. This yields a pair of equation for the description of a massless field with a spatial and a time dependent features.

$$i\hbar c\nabla u(\mathbf{x}) = Eu(\mathbf{x})$$

$$-c\hbar k g(t) = -\hbar\omega g(t) = i\hbar\frac{\partial g(t)}{\partial t} \tag{5}$$

For the positive energy solutions the time dependent portion has the solution $g(t) = e^{-i\omega t}$ where $\omega = (E - mc^2)/\hbar$, however, the space dependent portion is more involved for a quantum particle.

To incorporate the random action on the massless field the parameter ϵ is introduced into the wave function as the mean random coordinate offset from the many-body action on the massless field. If this parameter is assumed small then the functions can be expanded. Then the equation that result will describes a particle with mass generated from the massless field. Going from a massless field to a particle with mass generates another result, and that is the particle can then support its own self-reference frame. The starting spatial coordinates $\mathbf{x} = (x, y, z)$ are reduced in number for the field as it is locally randomized and all that is necessary to describe it is a single spatial variable r. The radial coordinate r is the only required spatial variable in the random walk problem in three dimensions [21]. Analytically the uncertainty is expressed as a random displacement in the spatial portion of the wave function to generate mass also establishes a center of mass or symmetry for the particle. The expansion of the various term become:

$$u(\mathbf{x}+\epsilon) \to u(r) + \epsilon\frac{\partial u(r)}{\partial r} = u(r) + \epsilon u'(r) \tag{6}$$

$$\nabla u(\mathbf{x}+\epsilon) \to \frac{\partial u(r)}{\partial r} + \epsilon(\frac{\partial^2 u(r)}{\partial r^2} + \frac{2}{r}\frac{\partial u(r)}{\partial r}) = \epsilon u''(r) + (1 + \frac{2\epsilon}{r})u'(r) \tag{7}$$

Introducing the random displacement is a critical feature in this analysis. If the interactions are weak and sparse then these events can be described by a time ordered series of stochastic events as is done in quantum electrodynamics. If, however, there is no assurance that these events are not dense or cannot be time ordered for other reasons then a stochastic ordered time series cannot be used. Since the description is not of a point particle but of a probability distribution over space then the consideration from relativity comes into force on the ambiguity for any observer to decern the order of events that can cause a displacement in space. This consideration eliminates a stochastic description.

Substituting the Taylor expanded terms into spatial equation 5 yields a second order differential equation. After the expansion it is convenient to define the parameter κ as $\kappa = 1/\epsilon$.

$$u''(r) + (\frac{2}{r} + \kappa\{1 - i\frac{E}{mc^2}\})u'(r) - i\kappa^2\frac{E}{mc^2}u(r) = 0 \tag{8}$$

Equation 8 is the form of the local statistical quantum state equation where the rest mass has been defined. The interesting feature of this equation is that energy enters as a ratio to the self-energy and becomes a unitless parameter that is valid in the range for a real mass when $|E/mc^2| \geq 1$. This equation is for a quantum particle description in the particle's frame of reference with a relative energy, E, referenced to another object. The implications for the solutions being in the particle's own frame of reference is that the angular momentum is automatically removed as that is a feature generated in the laboratory frame. This is a major simplification for the analysis. The relative self-energy will be represented by γ_{sr} as a symbol that is not to be confused with $\gamma = \sqrt{1 - v^2/c^2}$ which requires a dynamic trajectory and is used in the laboratory frame for the velocity dependent scaling in special relativity.

$$\gamma_{sr} = \frac{E}{mc^2} \tag{9}$$

Equation 8 from its inception satisfies the conditions of relativity through the relative energy term, and it can be transformed into Kummer's equation which has two solutions [22]. These two solutions are multiplied by the constants A and B respectively and in three dimensions are:

$$\begin{aligned} u(r,E) = {} & Ae^{-\kappa r}U[\frac{2}{1+i\gamma_{sr}}, 2, (1+i\gamma_{sr})\kappa r] \\ & +Be^{-\kappa r}F1[\frac{2}{1+i\gamma_{sr}}, 2, (1+i\gamma_{sr})\kappa r] \end{aligned} \tag{10}$$

Where *U[]* and *F1[]* are the confluent hypergeometric function [22]. In the limiting case where $\gamma_{sr} = 1$ which is a relative rest state the density of the wave function $\psi^*\psi r^2$ at $r = 0$ for the *U[]* solution is finite and for the *F1[]* there is no density at the origin, see Figure 4.

These two solutions are taken respectively as the description of a boson and a fermion. In the former case the interaction with the vacuum state is attractive, and there is a density maximum at the origin and in the latter there is a density minimum at the origin due to a local effective repulsion.

The concept of a boson and fermion being defined independent of an angular momentum requirement has its origin in the basic interaction in the particle's frame of reference between a massless field and the vacuum state which can either be locally attractive or repulsive [4]. The angular momentum features which we commonly associate with these two classes of particles are observed in the laboratory frame and are the result of interactions with the quantized radiation fields. The only particle that can have a finite density at the origin is one that can be observed in the $l = 0$ state and that is limited to bosons. The fermion at all energies has no density at its origin and this reinforced from equation 10 which yields a particle that has a finite angular momentum in its lowest energy form. The details of the angular momentum are well described for the particle families in the laboratory frame of reference where they are measured [23].

Incorporating the statistical features that randomize a field to generate particle like properties required a reference frame for the particle that differs from a laboratory frame of reference. The self-reference frame has no classical equivalent. There is no simple coordinate transformations that connects this frame to the laboratory frame. With the particle wave functions defined in this frame it is possible to extract properties such as mass. This allows the application of these solutions to the relativistic longitudinal spin wave problem. The experiments are inherently self referential in that the source field that drives particle creation can be compared to the displaced detected fields by phase sensitive measurements referenced to the source. In this case the entire self-reference frame can be mapped and measured. This allows phase sensitive data to be extracted from both the propagating and stationary components.

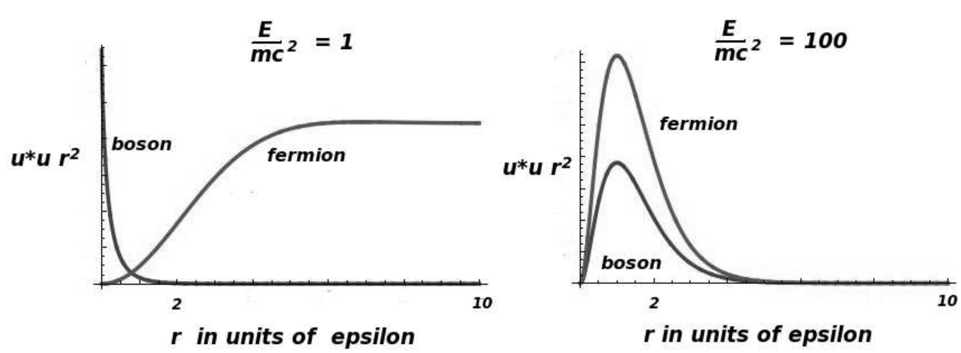
III. FERMION

$$\psi(r, E, t) \sim e^{-\kappa r} F1[\frac{2}{1 + i\gamma_{sr}}, 2, (1 + i\gamma_{sr})\kappa r]e^{-i\omega t} \tag{11}$$

The density function formed from the fermion functions is very interesting in that for the relative rest state solution is essentially a constant function and only decreases at the origin, see figure 4. As the relative energy is increased these functions transform to a localize density about the origin. They are not identical to the boson functions at high energies because their individual wave functions are quite different though their density functions appear similar. The elementary fermion function depending on the relative energy of the observer has both particle and wave like properties. There is no wave-particle duality these are characteristics built into the relativistic state function of the particle and differentiate by an observer under different conditions.

The self-reference frame fermion solution can be compared to free electron theory in metals where the plane wave solution from the constant potential form of the Schrödinger equation is used. In the electron theory of metals as covered by Bethe and Sommerfeld [24] soon after quantum mechanics became available they used a plane wave representation for the electrons in metals as a basis. The uniform density behavior of the plane wave is mirrored in the fermion wave function found in the *F1[]* term of equation 10, in figure 4 when $|\gamma_{sr}|$ is close to unity and the density is observed away from the origin. The density minimum at the origin is on the scale of the classical electron radius which generates the mass of the particle. The density function at $\gamma_{sr} = 1$ is then a finite constant away from the origin just as for a plane wave density at finite energy. The local density minimum at the origin is a feature not captured by the plane wave model of electronic behavior.

FIG. 4: ***Density function for boson and fermion from the the three dimensional local statistical quantum state equation at γ_{sr} of 1 and 100. Note the relative rest state boson function has a finite value at the origin.***



One of A. Einstein's main research goals was to find a representation where a particle description could be generated from a massless field [25]. It was a concept he thought necessary for quantum mechanics. The particles we know the most about are fermions and in particular the electron. Finding a representation for the low energy fermion or electron which can mimic the plane wave model of Bethe-Sommerfeld with the addition of a local characteristic that is indicative of mass represents a major advance for finding a quantitative description of a fermion. The requirements of relativity constrains our view point to the particle's frame of reference in this new description. The features of relativity were incorporated into the derivation of the local statistical quantum state equation through the requirement that the analysis be in the particle's reference frame with a scaled energy relative to another object. The relative quantum description can be used in relationship to any other object. This is the main requirements of relativity that is satisfied with the local statistical quantum state equation solutions for the description of a particle. The implication is that there is a single description and that it is unnecessary to have two theories: one for relativistic behavior and a second for non-relativistic behavior.

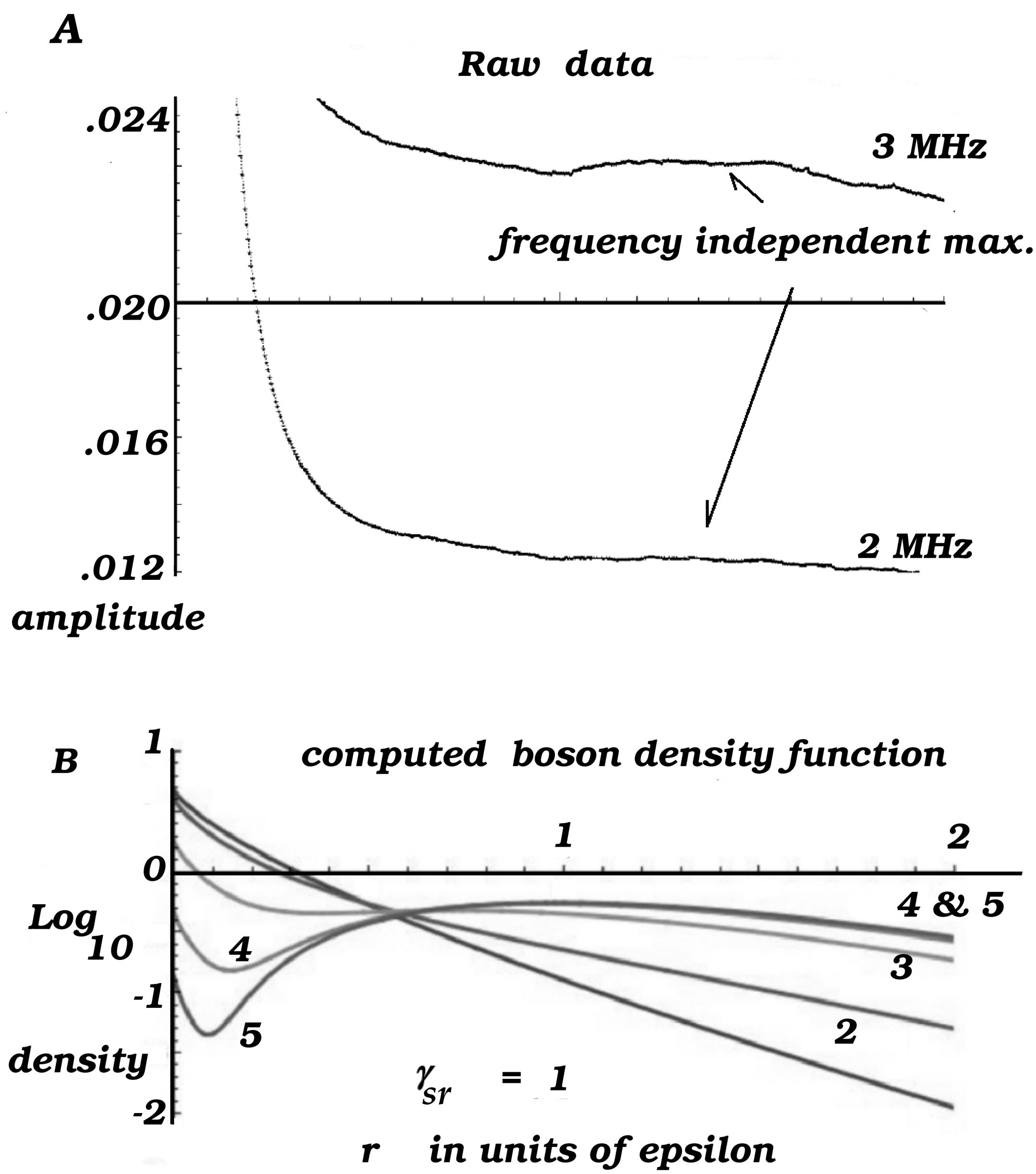
IV. BOSON AND THE LONGITUDINAL SPIN WAVE

$$\psi(r,E,t) \sim e^{-\kappa r} U[\frac{2}{1+i\gamma_{sr}}, 2, (1+i\gamma_{sr})\kappa r] e^{-i\omega t} \tag{12}$$

The boson density function in the relative rest state, $\gamma_{sr} = 1$, is basically a two sloped exponential decay. The initial steep slope from the origin is completed by a slower decaying exponential for large values of r. The particle in the relative rest state is very compact compared to the parameter, ϵ, as opposed to the fermion. Unlike the fermion functions near the rest state these functions are localized and can be normalized: see figure 5B where the plotted functions have been normalized. At higher energies the density at the origin decreases and the function around the origin begin to look like the fermion functions. There are major difference in the wave functions between the bosons and fermions that appear in the argument variation as well as the amplitude variations as a function of radius.

The stable boson we commonly deal with is a photon and on the laboratory scale in vacuum it is a massless field. However, when it enters a dense material it can take on new properties. The boson case is easier to study directly because in the case of the longitudinal spin wave it is possible to pump a steady state Bose-Einstein condensation with a weak induction field to generate a measurable population and also produce a propagating mode.

FIG. 5: ***A*) Axial detected magnetic field level measured displaced from the source as a function of frequency [6] from the signal source in a .0127m diameter low carbon steel rod. Two separate contributions make up this data: a propagating longitudinal spin wave that dominates near the source and a BEC of the spin wave that contributes away from the source at higher frequencies. The displaced peak in the 3MHz data at** $.14\ meters$ **represents the displaced boson maximum emerging. B) The calculated density function for boson particle as a function of energy showing the emergence of the displaced maximum for** $E/mc^2 \geq 3$



The local energy storage provided by the BEC allows a relatively large measurable amplitude to be produced for both cases. The one major advantage in studying the activity of the longitudinal spin wave is that the mass is so low it is possible to study its motion in the relativistic regime without the complication of building and operating an accelerator and finding a boson that is long lived enough to accelerate. The results for a longitudinal spin wave are that for energies from near rest to relativistic values show a measured density function that mirrors the boson solutions computed from equation 10, see figure 5. Also the experimental data contains a sum of excitations generated from domain boundary states with lower field splitting that result in greater characteristic lengths even though the states within the magnetic domain boundaries will dominate the response. There are two features in the progression of density functions as a function of energy that identify the boson function. First is the displaced maximum centered at $\epsilon = \ .14\ meters$ and it is calculated to correspond to $\gamma_{sr} \sim 3$ and is well resolved at 3 MHz. The second feature is the increasing amplitude of the signal away from the signal source with increasing frequency verses the source amplitude. The large scale of the exciton on the order of a fraction of a meter allows measurement of the coherently pumped state. The signal detected is proportional to the local time dependent density of the state that can be accurately monitored over a broad range of amplitudes and energy. Mass was first determined from the dispersion curve of the propagating mode of the longitudinal spin wave [6]. Since this quadratic curve fit to this data contains a few points at higher frequencies where the mass is increasing by the relativistic contribution, the mass estimate will be slightly higher. The mass can also be extracted from the measured displaced peak in the dispersion response to determine ϵ at 3 MHz for the BEC component of the longitudinal spin wave, figure 5, by using equation 1. The speed of light in the material, $c_{material}$ can be taken from the slope of the dispersion curve, $\sim .63 \pm .1 \times 10^6$ meters/sec. in reference [6] as that value is required to compute the mass.

$$m = \frac{\hbar}{\epsilon c_{material}} = \frac{\hbar \kappa}{c_{material}} \tag{13}$$

Finally the rest mass of the longitudinal spin wave can be computed from the energy of the transitions that supports the exciton. This is the energy for the spin parallel to anti-parallel transition can be computed within a domain from:

$$\delta E = \ 2g\mu S\overline{B} \tag{14}$$

g is the gyromagnetic ratio, μ_b is the Bohr magneton and S is the spin with a value of

Table 2 Rest mass of longitudinal spin wave in low carbon steel rod by three methods, where mass is in terms of the electron mass m_e

Method	**Value in m_e**	**Comments**
spin state transition energy $6 \times 10^{-4} eV$	1.1×10^{-9}	$m = \delta E/c^2$ equivalent mass
displaced maximum, figure 5 for a $\gamma_{sr} \sim 3$	$1.25 \pm .15 \times 10^{-9}$	equation 13
dispersion curve	$1.3 \pm .15 \times 10^{-9}$	[6]

one half. For a low carbon steel the local internal magnetic field is $\overline{B} \sim 2.16T$ [26] with $\mu = 2.2\mu_b$ per site has an energy separation $\delta E = 6 \times 10^{-4} eV$. These values are compared in tableIV. The mass values are all found to lie close together giving support to the notion that there is a longitudinal spin wave population that possess a mass close to $10^{-9} m_e$.

V. CONCLUSION

In looking for answers to explain the anomalous properties of induction measurements we were fortunate to find a description of the two quantum particle families and a reference frame where the statistical properties of a quantum particle are defined that allowed the integration of relativity with quantum mechanics.

Acknowledgments

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