Spinning Electrons as Physics Fantasy

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Abstract- Otto Stern and Walter Gerlach demonstrated in 1922 experimentally the "existence of space quantization in a magnetic field", using their own words. The result of this experiment is later on used to introduce the so-called intrinsic spin angular moment of elementary and other particles. This article describes what went wrong in the applied argumentation. In 1896 Zeeman and Lorentz showed experimentally and theoretically that atoms emit 'shifted' frequencies when exposed to an external magnetic field. This phenomenon has been used to demonstrate the existence of spinning electrons. However, it is shown that this demonstration is not convincing at all.

Introduction

Even the quoted text from Stern and Gerlach in the abstract already shows an imperfection: the words "angular moment" don't represent the real issue: an angular moment is meant to express a pure mechanical property of the subject under consideration. What should have been written is "magnetic moment". The origin of the so-called intrinsic spin angular moment of elementary particles, hadrons and atomic nuclei has to be found in the Stern-Gerlach experiment. Quoted from[1]:

> "Otto Stern and Walter Gerlach were carrying out experiments to demonstrate the existence of what they called Space Quantization in a Magnetic Field." Although the authors focused upon the Space Quantization in a Magnetic Field the significance of the article has become that of the first evidence of the spin of electrons."

Studying [1] leads to the conclusion that a large step has to be made to come from 'Space Quantization in a Magnetic Field' in order to end at 'spin magnetic moment' of electrons. This article describes what went wrong in making this large step.
Another phenomenon, called Zeeman-effect, has also been used to prove the existence of spinning electrons. This article shows why this supposed evidence is not valid.

Analysis of the Stern-Gerlach experiment

Stern and Gerlach realized an experiment schematically shown in figure 1, copied from [2]: "***silver atoms*** travel through an inhomogeneous magnetic field and ***are deflected up or down depending on their spin***. 1: furnace 2: beam of silver atoms 3: inhomogeneous magnetic field 4: expected result 5 what was actually observed." Mind the bold and italic printed words!

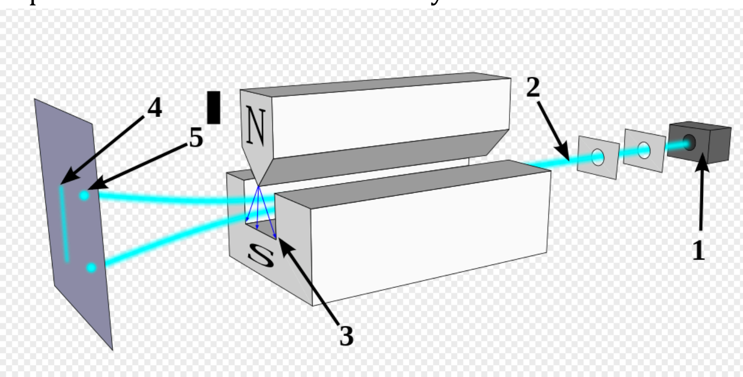

Figure 1 Schematic diagram of Stern-Gerlach experiment

Text copied from [2]:

> "The results show that particles possess an intrinsic angular momentum that is closely analogous to the angular momentum of a classically spinning object, but that takes only certain quantized values."

Comment:
This text shows another carelessness: "intrinsic angular moment" on the one hand and "angular moment of a classically spinning object" on the other hand.
Whatever is meant above, one should only use "angular moment of an orbiting particle" and "angular moment of a spinning particle".
With the text from [2] the mentioned large step has already been made, without presenting any evidence of its correctness. The conclusion of Stern and Gerlach was: "We view these results as direct experimental verifications of space quantization in a magnetic field." Whatever may be meant by these words, certainly not the above shown conclusion as presented by [2]. Besides the fact that one should have used 'magnetic moment' instead of 'angular moment', the question arises why the *magnetic moment* of *orbiting*, not *spinning*, electrons has not been investigated as an explanation for the obtained result? And if it might have been investigated, why is the result of such an investigation not presented?

A silver atom contains 47 orbiting electrons. Each electron represents a circular shaped current that causes a magnetic field as symbolically shown in figure 2.

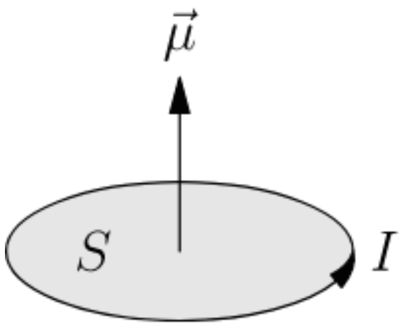

Figure 2

The symbol μ in vector notation is meant to express the *magnetic moment* IxS of such a configuration. But the symbol H could also have been drawn there in order to express symbolically the magnetic field as a result of the equivalent current I.
This current equals q/t_o, with q the electrical charge of an electron and t_0 the period time of an orbit. If r is the radius of the orbit and m the mass of the electron, then the following relations can be presented: $t_o = 2\pi r/v$ and $v = q(k_eZ/mr)^{½}$, with v the tangential velocity of the electron, Z the atom number and k_e Coulomb's constant ($1/4\pi\varepsilon_0 = 8.99*10^9\ Nm^2C^{-2}$).
Based on $H = I/2r$ and $I = qv/2\pi r$, it follows that $H = qv/4\pi r^2$.

The importance of the variable H is that it wants to align with the direction of an external magnetic field as applied to the silver atoms in the Stern-Gerlach experiment.

The magnetic moment IxS is the quantity that determines the torque the atom will experience in an external magnetic field when H is perpendicular oriented with respect to the direction of the external field. The mathematical expressions show that IxS=qvr/2.

This is a remarkable result: while the magnetic field strength decreases as function of the radius, the magnetic moment increases!
As shown by the equations, the surface enclosed by the orbit causes this effect.

Given these considerations the question now arises: what is, regarding this magnetic moment in the Stern-Gerlach experiment, the effect of 47 electrons orbiting the nucleus of the silver atom?

Suppose these electrons eventually generate a *net* magnetic field of whichever strength and with whichever direction with respect to the direction of an external field. To copy the words of Stern and Gerlach: "In a second communication it was shown that the normal silver atom has a magnetic moment."
N.B. Stern and Gerlach used the right term here!
It is assumed that the atoms that enter the external magnetic field are free to vary the orientation of their magnetic field w.r.t. the external field, because there is a bundle of silver atoms, created by the evaporation of (the metal) silver in a furnace.

Whatever the net magnetic field of each atom individually might be, only the orientation of this field w.r.t. the orientation of the external field, at the moment the atom enters this external field, determines the direction of the rotation of the atom in order to get aligned with the external field. But eventually the magnetic field of all atoms will be oriented in such a way that their north pole points to the south pole of the external field and vice versa. It is assumed that this rotation takes place in such a short time that directly after it enters the external field this rotation will be completed. Now a second process starts: the atom will be attracted by either the north or the south pole of the external field. The result is obvious: if the atom is just outside the middle between the north and south pole of the external field it will move into the direction of the shortest of these two distances with an increasing accelerated speed. Statistically considered, half of the atoms move upwards, the other half downwards, explaining the result of the measurements of the Stern-Gerlach experiment.

Up till now there is no reason to conclude that evidence of a "space quantization in a magnetic field" has been presented. Whatever these words may mean physically.
Neither is there any evidence that only the supposed (intrinsic) *spin* of (all) the electrons in the beam of silver atoms is responsible for the obtained result.
In [1] it is stated: "Stern and Gerlach worked with a beam of silver atoms but the effects were due to the valence electrons of the silver atoms so their beam was essentially a beam of massive electrons." This is not a logical conclusion, to put it mildly. There is no reason to assume that the evaporation leads to a detachment of an electron from the silver atom. But suppose they would do so and suppose only these separated electrons would cause the measured deflections, how do the words, as shown hereafter in the remark of Stern and Gerlach: *the layer of silver*, *deposited on the receiving plate,* have to be interpreted then?

> “The "irradiation time" was stretched out to eight hours without interruption. But even after eight hours of vaporization, the layer of silver, deposited on the receiving plate, was so thin because of the very narrow apertures and the great length of the beam that, just as previously reported, it had to be developed.”

A layer of silver is not a layer of electrons, supposed such a layer can be created! And if it would be a layer of electrons, what happened with the silver *ions*?

The creation of the concept: intrinsic spin magnetic moment of a charged particle

It has been shown above that there is no reason to introduce the concept intrinsic spin magnetic moment of a charged particle based on the Stern-Gerlach experiment. On the contrary: it has been shown that, based on the results of this experiment, most likely silver atoms have, based on their net magnetic moment due to their orbiting electrons, a fifty-fifty chance to be attracted by the north respectively south pole of the external field and no chance to go anywhere else.

Yet the spinning electron has been introduced. So the question is: how is this done, while there is no evidence of its existence at this moment.

Reference [3] shows the following description:

“Magnetic moment and angular momentum
The magnetic moment has a close connection with angular momentum called the gyromagnetic effect. This effect is expressed on a macroscopic scale in the Einstein-de Haas effect, or "rotation by magnetization," and its inverse, the Barnett effect, or "magnetization by rotation."[1] In particular, when a magnetic moment is subject to a torque in a magnetic field that tends to align it with the applied magnetic field, the moment precesses (rotates about the axis of the applied field). This is a consequence of the concomitance of magnetic moment and angular momentum, that in case of charged massive particles corresponds to the concomitance of charge and mass in a particle.”

Comment:
The close connection between the magnetic moment and the angular moment is effectively 2 times more repeated by means of the words: “the concomitance of magnetic moment and angular moment”. The second time it is, without any physical explanation, applied to the supposed spinning of a charged particle, simultaneously suggesting that the ratio between charge and mass of such a spinning particle is an important parameter of the concept under consideration, again without any explanation.
The question arises why the mass of such a spinning charged particle would play any role in its supposed *magnetic* moment. (The word ‘spinning’, from now on, will only be used to express ‘rotating around its own axis’.) If the particle would spin, it would have an angular moment equal to the product of its inertial moment $(2/5)mr^2$ (m is mass and r is radius of the particle, assumed to be shaped spherically) and its angular speed $\omega = v/r$, with v the tangential velocity of the spinning particle.
Might it be that the “concomitance of magnetic moment and angular moment” of an *orbiting* charged particle is misused, applying this concomitance to a supposed *spinning* charged particle?

The quotient ‘magnetic moment/angular moment’ of an *orbiting* charged particle is:
(qvr/2)/mvr = q/2m

In case of a *spinning* (charged) particle its angular moment is $(2/5)mr^2 . v/r = (2/5)mvr$.
But its magnetic moment still has to be determined. Although fully unacceptable from a scientific point of view, let us for fun apply the ratio q/2m to a spinning charged particle.
Then its magnetic moment would be q/2m . (2/5)mvr = qvr/5.
Nice to compare with the magnetic moment of an orbiting electron: qvr/2, but that’s all!

What has happened in the scientific literature regarding this phenomenon, assuming that reference [4] fulfils the criteria for “scientific literature”?
It presents the following description:

> “In atomic physics, the Bohr magneton (symbol μ_B) is a physical constant and the natural unit for expressing the magnetic moment of an electron caused by either its orbital or spin angular momentum.
>
> The Bohr magneton is defined in SI units by
>
> $\mu_B = e\,\hbar/2m_e$ [Am^2]
>
> where
>
> | | | |
> |---|---|---|
> | e | is the elementary charge | [C or A.s] |
> | ħ | is the reduced Planck constant | [kg m^2 s^{-1}] |
> | m_e | is the electron rest mass and | [kg] |
>
> The electron magnetic moment, which is the electron's intrinsic spin magnetic moment, is approximately one Bohr magneton.”

Comment:
Mind the statement: “....μ_B is a physical constant and the natural unit for expressing the magnetic moment of an electron caused by either its orbital or spin angular momentum”
However, $\mu_B = e\,\hbar/2m_e$ is nothing more than the multiplication of the just calculated quotient ‘magnetic moment/angular moment’ of an *orbiting* electron with the arbitrary constant $\hbar$, without any argumentation, so worthless from a scientific point of view.
The misleading text is that the magnetic moment would be caused by the angular moment, because the correct text would have been: the magnetic moment of an *orbiting* electron is caused by its charge q, its tangential velocity v, and the radius r of its orbit.
The magnetic moment of an orbiting particle is independent of the mass of that particle, but notwithstanding this fact the ratio $e/2m_e$ is chosen as a basis of the proposed new unit for magnetic moment.
Stating that “the electron magnetic moment, which is the electron's intrinsic spin magnetic moment, is approximately one Bohr magneton”, simultaneously presenting that one Bohr magneton equals $e\,\hbar/2m_e$, leads to the consequence that an orbiting electron has a magnetic moment of $mvr/\hbar$ [μ_B]. This in stead of ***simply*** qvr/2 [Am^2] !
What sense does that make? What is practical about this? It is even misleading, because it suggests that the magnetic moment depends on the mass of the electron.
So, still no theoretical physical evidence has been given at all about the magnetic moment of a spinning charged particle. Only a new, but not practical, unit for expressing ‘magnetic moment’ has been introduced.
Let us have a look at the description of the Einstein-de Haas effect. [5]

“The Einstein-de Haas effect is a physical phenomenon in which a change in the magnetic moment of a free body causes this body to rotate.”
Comment 1: the words “magnetic moment” have to be angular moment, but then at the same time it is not an Einstein-de Haas effect. Or the text has to be changed in: The Einstein-de Haas effect is a physical phenomenon in which a change in the magnetic moment of a free body *in an external magnetic field* causes this body to rotate. But this is the so-called Magnetic dipole–dipole interaction.

“The effect is a consequence of the conservation of angular momentum. It is strong enough to be observable in ferromagnetic materials. The experimental observation and accurate measurement of the effect demonstrated that the phenomenon of magnetization is caused by the alignment (polarization) of the angular momenta of the electrons in the material along the axis of magnetization.”
Comment 2: In this text all the words “angular moment” have to be changed in magnetic moment, as already suggested in comment 1. Secondly: the word “electrons” has to be changed in atoms.

“These measurements also allow the separation of the two contributions to the magnetization: that which is associated with the spin and with the orbital motion of the electrons.”
Comment 3: This conclusion is, given the Stern-Gerlach experiment, not correct.

“The effect also demonstrated the close relation between the notions of angular momentum in classical and in quantum physics.”
Comment 4: This conclusion is not correct either, as has been argued above.

Conclusion:
The description of the Einstein-de Haas effect causes a lot of confusion.
No demonstration at all is given of the existence of a spinning electron and its magnetic moment.
The fundamental question is why the concept ‘angular moment’ plays such an important role in all the descriptions? It is a pure mechanical property, having nothing to do with the magnetic moment!

Back to reference [3]:
“Viewing a magnetic dipole as a rotating charged particle brings out the close connection between magnetic moment and angular momentum. Both the magnetic moment and the angular momentum increase with the rate of rotation. The ratio of the two is called the gyromagnetic ratio and is simply the half of the charge-to-mass ratio.”
Comment:
Writing “viewing a magnetic dipole as a rotating charged particle” is putting physical science upside down. There are no problems in deducing the magnetic moment of a magnetic dipole. There are problems in demonstrating the existence of spinning charged particles and as a result their assumed magnetic moment. Therefor a better approach would be: Viewing a spinning charged particle as a magnetic dipole. However such an approach doesn’t help either to prove the existence of such a phenomenon.

Zeeman-effect: historical review

In order to fully understand the impact of Zeeman his famous experiment, leading to the expression 'Zeeman-effect', his scientific work has to be placed in a historical perspective. That history starts with Rydberg's work on this area. Copied from [6]:

"Johannes (Janne) Robert Rydberg (8 November 1854 – 28 December 1919) was a Swedish physicist mainly known for devising the Rydberg formula, in ***1888****, which is used to predict the wavelengths of photons (of light and other electromagnetic radiation) emitted by changes in the energy level of an electron in a hydrogen atom."*
Comment:
In1888 Rydberg did not know about energy levels of electrons in atoms! He succeeded in finding a relation between the measured frequency of light emitted by hydrogen atoms and a combination of two integers, expressed by: $f = c * R_\infty (1/n_1^2 - 1/n_2^2)$

Copied from [7]:
"*The Zeeman effect, named after the Dutch physicist Pieter Zeeman, is the effect of splitting a spectral line into several components in the presence of a static magnetic field."*
Comment:
This discovery happened in **1896**. Six years later Lorentz and Zeeman got the Nobel Prize for the combination of Zeeman his experiment and Lorentz his theory behind it. In this theory the existence of small electrically charged particles had been postulated, called 'ions' at that time. In order to explain the result of Zeeman's experiment they assumed that these 'ions' are (also) part of the atoms and that they are responsible, by means of 'vibrations', for the light emitted by the atoms.
N.B. Nothing indicates the existence of *spinning* electrons. The result of this experiment has been explained by only the existence of 'vibrating' electrons inside the atoms.
To resume: Rydberg observed *quantified* frequencies, Zeeman observed frequencies *in between* these 'Rydberg frequencies' by applying external magnetic fields and Lorentz explained Zeeman's results by postulating 'vibrating' electrons inside the atom.
At that time the phenomenon 'vibration' was not defined in more detail.
Today one would wonder whether these vibrating electrons are orbiting or spinning electrons.
In the mean time it has generally been accepted, based on the atomic model of Bohr, presented in **1913**, that 'Rydberg's frequencies' are generated by means of photons and that photons are generated by electrons jumping from an inner to an outer orbit in the atom. For a detailed description see for example [8], also indicating that the emitted frequencies are fully explained without any influence of possible spinning electrons.

Interpretation of the Zeeman-effect

The question thus is: what happens, and specifically why, with the frequency of light emitted by an atom, if an external magnetic field is applied to that atom?
It is important to realize that measurements have shown that the shifts in the 'Rydberg frequency' increases with an increasing strength of the external magnetic field.
That pleads for the following explanation.
Given the model shown in [8] it is likely that the external magnetic field influences the orbits of all the electrons around the nucleus of the atom, just like the orbit of such electrons determine the strength of the related internal field, based on the equation

$H = ev/4\pi r^2$, with e the electrical charge of the electron and v resp. r the tangential velocity along, resp. radius of the orbit of the electron.
Reference [8] shows, based on the Rydberg formula, that the characteristics of the inner and the outer orbit, represented by the numbers n_1 resp. n_2 in this formula, determine the frequency of the emitted photon. So, a change in one of the orbits, or in both orbits, will cause a change in that frequency. It can be considered as most likely that the smaller the change of the orbits, the smaller the change in frequency of that photon.
Due to the fact that the orbits are differently oriented in a 3-dimensional space, each orbit will be influenced by the external magnetic field in a different way. If all internal magnetic fields would align with the external field, all electrons would orbit in one and the same plane, which is assumed to be extremely unlikely.
In this way the result of Zeeman's experiment can be explained without using the phenomenon 'spinning electron'.
Besides that: in which way might a spinning electron, subject to an external magnetic field, have influence on the emitted frequency, fundamentally caused by the change in orbit of that same electron?
And also: why does a spinning electron seemingly not have any influence on the emitted frequency if no external magnetic field is applied?

Reference [7] also states:
"*Historically, one distinguishes between the normal and an anomalous Zeeman effect (discovered by Thomas Preston in Dublin, Ireland [2]). The anomalous effect appears on transitions where the net spin of the electrons is an odd half-integer, so that the number of Zeeman sub-levels is even. It was called "anomalous" because the electron spin had not yet been discovered, and so there was no good explanation for it at the time that Zeeman observed the effect.*"
Comment:
The question is: Was the effect called "anomalous" because the electron spin had not yet been discovered, or was the electron spin introduced in order to try to explain unexpected effects? In general it can be stated that if a phenomenon is not understood, unexpected results will show up.
The introduction of the spinning electron, in order to explain the so-called anomalous Zeeman-effect, has in scientific literature led to a coupling of the orbital angular moment and the spin angular moment of the electron into a total angular moment, presented as quantized angular moment. As mentioned already in the first part of this article angular moments do have a pure mechanical nature, having nothing to do with magnetic moment. As long as the supposed spin angular moment of an electron has not been transformed into a magnetic moment in a scientifically accountable way, the coupling of the *magnetic* moments of the orbital and spinning electron is impermissible.

At the same time the introduction of spinning electrons is not necessary in order to understand, in principle, the frequency shifts in the situations under consideration.
But it has to be realized that the external magnetic field disturbs the multi 3-dimensional orbital configurations of the atom in such a complicated way that a full and accurate prediction of these shifts cannot be calculated, in spite of the now-a-days mathematical models. Besides that: what might, eventually, be the scientific purpose of such an experiment?

Conclusions

No evidence at all has been found in the Stern-Gerlach experiment for the existence of spinning charged electrons. The result of this experiment can be explained perfectly by means of the phenomenon: orbiting electrons in an atom, leading to the property of most likely all atoms: they are intrinsically magnetic dipoles.

The same conclusion has to be drawn regarding the supposed evidence of spinning electrons delivered by the Zeeman-effect: the observed shift in emitted frequencies, when atoms are exposed to an external magnetic field, is caused by a disturbance of the orbits of the electrons in the atoms.

In both experiments the results can be explained by applying the original atomic model of Bohr.

No mathematical / theoretical model of the *magnetic moment* of a supposed spinning charged particle has been found in scientific literature. Only the *unit* 'Bohr magneton' [μ_B] is presented, meant to express the magnetic moment dealing with orbiting or supposed spinning electrons.

Scientific literature shows a lot of confusing words about spinning charged particles, of which no one reveals what their magnetic moment might be.

In scientific literature much more attention is paid to the pure mechanical concept 'angular moment' of supposed spinning charged particles than to, what is of course only relevant, the concept 'magnetic moment' of such particles.

It doesn't make sense to use the expression angular *momentum* instead of angular *moment*. The angular moment is the linear moment of an orbiting mass multiplied with the radius of its orbit. Its dimension thus is not equal to the dimension of linear moment, but certainly neither is the dimension of magnetic moment.

References

[1] http://www.applet-magic.com/sterngerlach.htm , San José State University, The translation of the article by Otto Stern and Walter Gerlach.

[2] https://en.wikipedia.org/wiki/Stern-Gerlach_experiment

[3] https://en.wikipedia.org/wiki/Magnetic_moment

[4] https://en.wikipedia.org/wiki/Bohr_magneton

[5] https://en.wikipedia.org/wiki/Einstein%E2%80%93de_Haas_effect

[6] https://en.wikipedia.org/wiki/Johannes_Rydberg

[7] https://en.wikipedia.org/wiki/Zeeman_effect

[8] http://vixra.org/pdf/1505.0225v5.pdf Why a Photon is not a Particle