The Dirac Sea and the Aether

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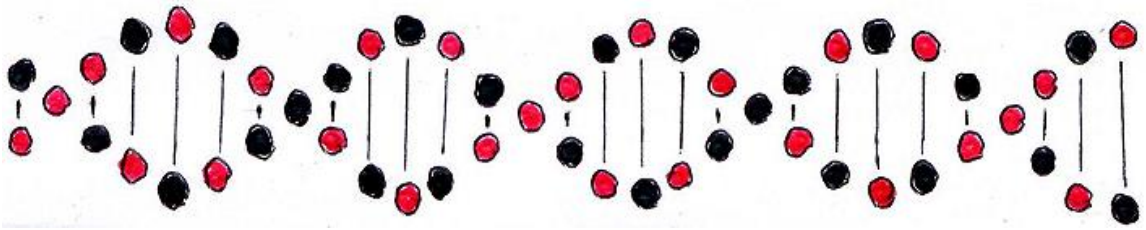
***Abstract*. The *Dirac Sea* was proposed by P.A.M. Dirac in the year 1930 to explain the negative solutions to the *Dirac Equation* of 1928. A few years later, in 1934, Dirac invoked the Dirac Sea idea to explain the phenomena of electron-positron pair production and annihilation, that had been discovered by Carl Anderson in 1931. The suggestion was, that throughout the universe there exists an all-pervading underworld in a negative energy state, and that this is filled with electrons. Similarities to nineteenth century luminiferous aethers will be discussed and the question asked as to why the Dirac Sea, and later theories of the quantum vacuum, have never been associated with the propagation medium for electromagnetic waves.**



The Positronium Orbit

I. Unlike in the case of a planetary orbit, the positronium orbit involving an electron and a positron, is a spiral orbit. When the two particles appear to touch each other, they seem to metamorphose into two gamma photons. This is much like in the case in one of Helen Bannerman's stories for children, where a group of tigers chase each other around a tree until they all turn into ghee, which is then used to make pancakes. In the positronium case, the energy in the gamma photons is said to have been supplied entirely from the mass of the electron and the positron, and meanwhile, just like the tigers, these two particles have ceased to exist entirely.

Electron-positron pair creation, which is the reverse process, can occur near an atomic nucleus when a gamma photon converts into an electron-positron pair. Just as it would be hard to imagine the ghee converting back into tigers again, we are left to wonder what the conversion process between photon and electron-positron pair would actually look like if we could see it up close.

The Dirac Sea

II. In 1934, Paul Dirac attempted to explain the emergence and disappearance of electron-positron pairs in terms of *the Dirac Sea*, [1]. This avoided the *tigers and ghee* approach, but it entailed having to believe in a kind of underworld with negative connotations, like the Halls of Hades in Greek mythology. There, was to be found stored, a plentiful supply of tiny electric particles (electrons) in a negative energy state. And indeed, every single electron belonging to this other realm was so precisely accounted for, that if one of them were to go missing, for whatever reason, its absence would be formally registered as a positron. The missing electron would not however be missing for long. It would partake in a mutual orbit, ***with its own absence***, then spiral back down into the House of Hades, and into its own box again.

A rough analogy would be a man imprisoned in the negative environment of an underground dungeon. Energy is put in to free him and bring him up the stairs to surface level. His absence down in the dungeon now takes the form of an anti-prisoner. The released prisoner then goes into orbit with the anti-prisoner, and he spirals back down the stairs again, yielding his kinetic energy to broken bones.

Despite the absurdity, the Dirac Sea proposal did however hint at the idea of an all-pervading sea of electrons and positrons, existing in a structured lattice framework. This idea is not so absurd though, because something of this nature had already been hinted at in the nineteenth century.

The Dielectric Sea

III. In the 1930s, there was nothing new about the idea of a dielectric sea. In the nineteenth century, André-Marie Ampère and James Clerk Maxwell had already proposed such an idea on purely classical grounds, without the need to involve relativity and quantum mechanics. In 1825, Ampère came up with two conceptions for the aether, [2]. In the first he speaks of an elastic fluid which extends throughout all space, whose vibrations produce the phenomenon of light. He said that this fluid or aether can *"be no other than that which results from the combination of the two electricities."*. In his second conception, he proposes that the interspaces between the metallic molecules of a current carrying wire are occupied by a fluid composed of the two electricities. In this inter-molecular fluid, the opposite electricities are continually being dissociated and recombined, [2].

Maxwell, meanwhile, in Parts I and II of his 1861 paper, ***"On Physical Lines of Force"***, [3], advocated a sea of molecular vortices as being the medium responsible for magnetic force and electromagnetic induction. In Part III of the

same paper, on elasticity and electrostatics, while introducing *displacement current*, Maxwell's sea of tiny vortices morphed into an elastic dielectric solid which Maxwell concluded to be the medium responsible for the propagation of light waves. In his 1865 paper ***"A Dynamical Theory of the Electromagnetic Field"***, **[4]**, Maxwell derived the electromagnetic wave equation. At the top of page 498, just before the displacement current equations (65), he says, *"if the medium in the field is a perfect dielectric there is no true conduction, and - - - - -"*. Maxwell was clearly alluding to the fact that considered the luminiferous medium to be a dielectric. Combining Maxwell's two perspectives, we might conclude that the electric particles that circulate around his molecular vortices must exist in equal and opposite charges.

The Mono-Electric Sea Idea

IV. While Ampère and Maxwell proposed dielectric seas, their nineteenth century contemporaries, Wilhelm Eduard Weber, **[5]**, and Lord Kelvin (William Thomson), **[6]**, proposed something akin to an all-pervading sea of electrons, but without them being counterbalanced with positrons. This was something more akin to the Dirac Sea, but without the facility to explain electron-positron pair production and annihilation. In Weber and Thomson's books, these negative particles existed in the normal state and not in some kind of negative underworld. The interesting thing though, is that while Dirac established this idea mathematically from the negative solutions of the Dirac equation, which served to unite quantum mechanics with special relativity, Weber and Thomson were inspired only by classical electromagnetism.

Conclusion

V. The Dirac equation, proposed by P.A.M. Dirac in 1928, united quantum mechanics and special relativity, and it led Dirac to predict the positron which he explained in the context of the *Dirac Sea*. The Dirac Sea was an all-pervading sea of electrons, very similar to that proposed by Wilhelm Eduard Weber and Lord Kelvin (William Thomson) in the nineteenth century, except that Dirac's sea existed in a negative energy state which enabled the emergence of a positron. This duality meant that the Dirac Sea was edging closer to the dielectric seas proposed by Ampère and Maxwell, also in the nineteenth century. An important feature of interest here is that Dirac predicted something in the likeness of what Weber and Lord Kelvin had already predicted, as in something like a sea of electrons, yet Dirac used a completely different line of reasoning. In fact, it's not at all clear how the negative solutions to the Dirac equation would actually lead to a conclusion such as the Dirac Sea.

Although the Dirac Sea was later shelved, other theories of the quantum vacuum emerged whereby particles and anti-particles keep popping in and out of existence. But never have any of these twentieth century mediums, proposed in connection with quantum electrodynamics, ever been associated with the electromagnetic wave propagation mechanism. It's hard to see though, that if the particles that comprise the all-pervading QED vacuum obey the laws of electromagnetism, how they wouldn't be somehow tied up with the electromagnetic wave propagation mechanism.

It is suggested that quantum mechanics has been slipping the nineteenth century luminiferous medium in again, but through the back door, and in disguise, in order to avoid a clash with Einstein's special theory of relativity. There needn't however be any hesitation about accepting the presence of an all-pervading sea of *very real* electrons and positrons that would link quantum electrodynamics with the nineteenth century luminiferous aether, and without causing any obstruction to the paths of the planetary orbits. There should be no obligation to render this medium virtual. See, ***"The Positronium Orbit in the Electron-Positron Sea"***, **[7]**, and, ***"Aether Friction in the Planetary Orbits"***, **[8]**.

See also the appendix after the reference section on the role of the all-pervading electron-positron dipole sea in Faraday's law of electromagnetic induction.

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"All space, according to the younger Bernoulli, is permeated by ***a fluid aether, containing an immense number of excessively small whirlpools.*** *The elasticity which the aether appears to possess, and in virtue of which it is able to transmit vibrations, is really due to the presence of these whirlpools;* ***for, owing to centrifugal force, each whirlpool is continually striving to dilate, and so presses against the neighbouring whirlpools****."*

Appendix on Faraday's Law of Electromagnetic Induction

We will treat Fig. 1 below as if it is an electron-positron dipole. If the dipole is static, then providing that the magnetic vector potential, **A**, represents the momentum field of an electric fluid (aether) that flows out from the positron and into the electron, the curl of **A** will be zero, and hence so will the curl of **E** be zero, where $\mathbf{E} = \partial\mathbf{A}/\partial t$.

If we now rotate the dipole on an axis pointing into the page, so that the electron and positron are orbiting each other, the **A** field pattern will curl and we will have $\nabla\times\mathbf{A} = \mathbf{B}$, where **B** represents a vorticity which is manifested as a magnetic field. The **A** field lines will now spiral into the electron and spiral out of the positron.

As regards the **E** field though, the field line pattern will not curl. The pattern will merely rotate while still rigidly retaining its shape. The curl of **E** will still be zero. However, if we now ***angularly accelerate*** the dipole, whether in the same plane, or by the act of precession, then this time, the **E** field lines will also curl. The **E** line pattern will spiral into the electron and out from the positron, and we will now have induced a new transverse component of **E**.

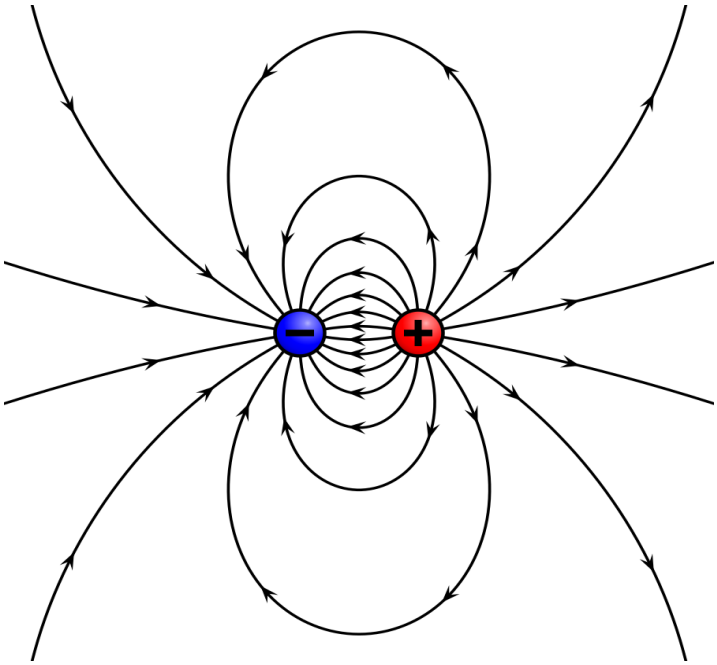

Fig. 1 – An Electric Dipole – see note at † below

We'll index the radial component as $\mathbf{E}_\mathbf{S}$, and the transverse component as $\mathbf{E}_\mathbf{K}$. The radial component is the electrostatic field, $\mathbf{E}_\mathbf{S} = -\nabla\psi$, where ψ is the electrostatic scalar potential, while the new transverse component is that which is induced by a time-varying magnetic field, such that $\mathbf{E}_\mathbf{K} = \partial\mathbf{A}_\mathbf{K}/\partial t$, and $\nabla\times\mathbf{E}_\mathbf{K} = \partial\mathbf{B}/\partial t$. The field indexed, $\mathbf{A}_\mathbf{K}$, is the transverse component of **A**. Therefore, a time-varying magnetic field in space exists due to the presence of tiny angularly accelerating electron-positron dipoles in the vicinity.

So, in order to have a wireless electromagnetic wave propagating in space, space needs to be filled with electron-positron dipoles, **[9]**. Wireless EM waves are transverse waves in the Coulomb gauge, where $\nabla\cdot\mathbf{A}_\mathbf{K} = 0$.

If we have two such rotating dipoles side-by-side, mutually aligned in their equatorial planes and rotating in the same direction, one might at first think that they would repel each other in the mutual equatorial plane, only when either the electrons of each dipole are doing a close fly-by of each other, or when the positrons of each dipole are doing a close fly-by, whereas that they would attract each other when the positron of one dipole is doing a close fly-by with the electron of the other dipole. This assumption however overlooks the effect of the transverse momentum field, $\mathbf{A}_\mathbf{K}$. If the two dipoles rotate fast enough, a

threshold will be reached whereby the flow of electric fluid (aether) between the positron of one dipole and the electron of the other dipole will be cut, and the two separate flows will now be in opposite directions and pressing against each other laterally while striving to expand, **[12]**, hence leading to a centrifugal repulsion acting between the two dipoles in their mutual equatorial plane.

If we introduce more such electron-positron dipoles and stack them axially on top of each other, the electrons of one dipole will attract the positrons of its neighbours, both above and below, in the axial direction, and a double helix will form, **[10]**, **[11]**. This double helix constitutes a single magnetic line of force, see Fig. 2 below, and hence the magnetic attraction that exists between a north and a south pole magnet is down to electrostatic attraction at a deeper level, acting along the double helix.

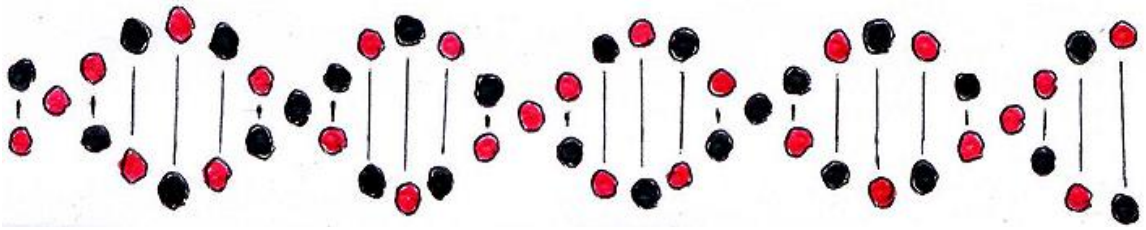

Fig. 2. A single magnetic tube of force. The electrons are shown in red, and the positrons are shown in black. The double helix is rotating about its axis with a circumferential speed equal to the speed of light, and the rotation axis represents the magnetic field vector **H**.

The magnetic lines of force between two like-magnetic poles, on the other hand, do not connect between the two like-poles. Instead, they spread out sideways in the space between the two poles, see Fig. 3 below, and they meet laterally such that the constituent rotating electron-positron dipoles in the field lines of each magnet, are mutually aligned in their equatorial planes at the interface, and hence they will push each other apart with centrifugal force.

If a charged particle moves through a magnetic field, the component of its motion that lies in the equatorial plane of the tiny electron-positron vortices, this component being at right-angles to the field lines themselves, will experience a differential centrifugal force acting at right-angles to its direction of motion, and also at right angles to the field lines. This is because the tiny-dipolar vortices that form the backdrop, are all rotating in the same direction as their immediate neighbours, and so the mutual aether speed on either side of the moving charged particle will be different, and hence so will the magnitude of the centrifugal pressure that is acting on either side of the motion. Hence the charged particle's direction of motion will be deflected perpendicularly.

This convectively induced **E** field takes the form, $\mathbf{E}_C = \mathbf{v}\times\mathbf{B}$. Together with the **E** field that is induced by a time-varying magnetic field, $\mathbf{E}_K = -\partial\mathbf{A}_K/\partial t$, these form the basis of Faraday's law of electromagnetic induction.

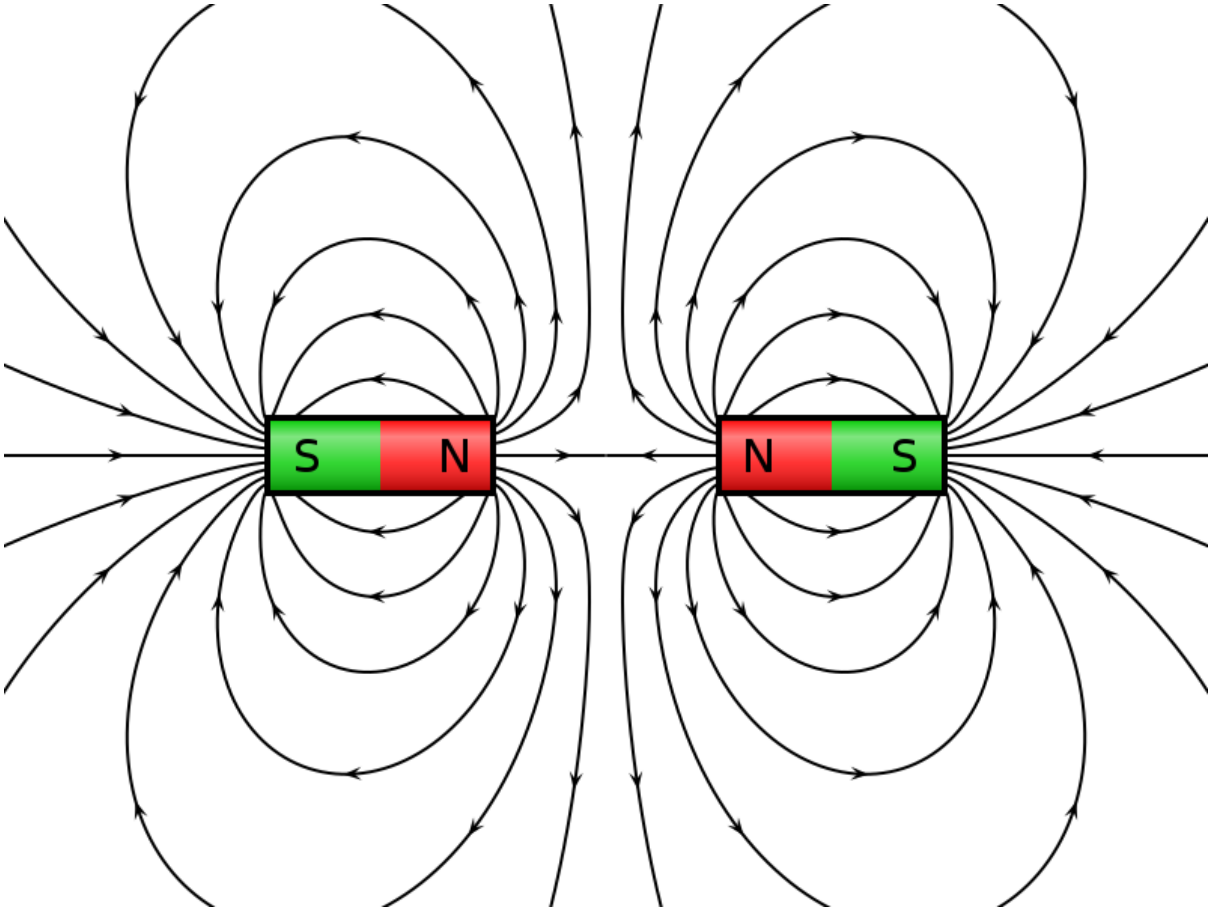

Fig. 3 – Magnetic lines of force between like-poles, repelling each other by lateral action

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https://commons.wikimedia.org/wiki/File:VFPt_dipole_electric.svg
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