Some remarks concerning the book

LEPTONIC MAGNETIC MONOPOLE
THEORY AND EXPERIMENTS
by Georges Lochak and Harald Stumpf
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I -Remarks concerning the part by G. Lochak

1) A brief reminder of Electricity and Magnetism.

While it certainly happened later than the observation of stars, the observation of electricity and magnetism began far in Antiquity, due to Greece and China.

Some 600 years B.C., Thales noticed the faculty of amber to attract light bodies when rubbed with a cat skin. But the Greeks also knew about magnets, whose name is *magnes* in Greek. And thus, since amber is called *elektron,* they left us not only the observation of electromagnetism but also the etymology.

The Chinese did not know electricity, but they knew magnets : probably they found – as did the Greeks - magnetite mines (a magnetic iron oxyde). But the Chinese also discovered the earth's magnetism and invented the compass, 1000 years B.C., later transmitted to the Occident where the science of electricity and magnetism was born many centuries later, in France, Italy and Great-Britain.

The high point of this discovery was the Maxwell equations, one of the greatest scientific events in the history of science : beside the empty world inherited from Democritus, filled with material points obeying Newton's laws of mechanics, appeared another physical world, a resurgence of the Anaxagoras world, filled with fields. *Maxwell's equations became the counterpart of Newton's mechanics*. But these contradictory worlds were destined to be united :

- In 1905, the Einstein photon (*Einstein*) brought corpuscles back into the theory of light from which they had been expelled by the wave theory of Huygens, Fresnel and Maxwell. Einstein proved that the still mysterious photoelectric effect was a consequence of his hypothesis.

- Conversely, in 1923, de Broglie discovered that material corpuscles have wave properties (*Broglie 1*). He gave the first formulae of matter waves, interpreted the spectrum of Bohr's atom by stationary electron waves, and predicted the **diffraction of electrons**. «*Matter and light»* - the title of one of his books – became the symbol of the new quantum world : the **wave-particle dualism**.

2) The beginnings of the magnetic monopole

a) Maxwell (1873), first magnetic poles.

For a long time, electromagnetism did not treat electricity and magnetism symmetrically, being biased in favour of electricity. According to Ampère's law, a *stationary electric current creates a stationary magnetic field* (the electromagnet) while the apparently converse Faraday law is more restricted since a *time variation of magnetism* is needed to create an electric current (Faraday's induction).

Nevertheless Coulomb had measured the same law of force in $1/r^2$, not only for electric charges but for magnetic charges (in 1785) even though he possessed only « electric poles » (small charged objects), but no « magnetic poles ». Instead he used long magnetic wires, whose extremities could not interact, as is explained by Maxwell in his *Treatise on Electricity and Magnetism* (*Maxwell*).

Maxwell gave a central place to the Coulomb law not only for electricity but also for magnetism. Magnetic poles are introduced in the beginning of Volume 2 of his *Treatise*, where it is shown that electric and magnetic charges are expressed in the same units.

But Maxwell was the first to understand that vectors representing electricity and magnetism are of a different nature. The first one is a *polar vector*, while the second is an *axial vector*.

Despite some analogies, electricity and magnetism are different and their difference appears in their symmetry properties : the image of a magnetic field, in a mirror perpendicular to it, is the field itself, while the image of an electric field perpendicular to a mirror is inverted : the image is the mirror image of the object. Conversely, the image of a magnetic field parallel to a mirror is parallel to the field, but inverted, while the image of an electric field parallel to a mirror is the field itself.

In other words there is no exact analogy between electricity and magnetism, contrary to what is often claimed and contrary to the analogy falsely attributed to Maxwell's equations. Errors which are due only to the fact that polar and axial vectors are represented by the same symbols. Mawxell knew that and Curie tried, for these reasons, to impose different notations, but in vain.

Through the discovery (quickly forgotten!) of the difference between polar and axial vectors, Maxwell was the second (after Pasteur) to approach the fundamental property of *enantiomorphism*, or *chirality* i.e. the difference between *left* and *right* : like the left and right hand. *Chiral* comes from the Greek *kheir*: *«hand».*

Chirality was first discovered by Pasteur, not in electromagnetism, but in the fact that *there are two kinds of crystals of tartaric acid : left or right*. Each of them is not its own mirror image but the image of the other in a mirror, like two hands.

It happens that beta radioactivity is chiral too and introduces enantiomorphism once more. In my opinion, it may be asserted that Pasteur and Maxwell, in two different fields of science, discovered in enantiomorphism one of the most important results of the 19th century. The following step was the discovery, by Lee and Yang, in 1956, of the «non conservation of parity» (a rather barbaric name for chirality !) of *weak interactions*. This is the last physical discovery that has changed our physical image of the world. Between Pasteur and Maxwell, and this discovery there were several great contributors : Pierre Curie, Poincaré and Dirac.

b) Pierre Curie (1894). General theory of symmetry laws in physics.

Pierre Curie was one of the great successors of Maxwell in electromagnetism. His paper entitled : *On the symmetry of physical phenomena, the symmetry of electric and magnetic fields* (*Curie*), was the first general paper on a subject which became of major importance in physics in the XXth century.

In this book, we shall later encounter different problems of symmetry, but we shall see them in a modern language, adding many questions that were unknown in the time of Pierre Curie (particles, transformations of charges, CPT theorem etc). A special point of Curie's paper will be particularly important for us : it is a kind of *post scriptum* to the principal paper (*Curie*) : *«On the possibility of the existence of magnetic conductibility and of free magnetism»* – in other words, magnetic monopoles, and Curie announced the symmetry laws of such phenomena if it should emerge that they existed. He looked for the condition of their observation and he showed that a magnetically charged sphere must have a *pseudoscalar symmetry* (i.e .: $(18)\ \infty L_{\infty}\,!\ldots$).

Such a magnetic sphere cannot be superposed on its image in a mirror because North and South poles are mutual images (right and left) in a mirror, contrary to electric charges + and –, which are mutual images too, not in space but *in time reversal*, as was shown by Feynman. The chiral property of magnetism will be more precisely described later in this book. The fact that North and South monopoles are antiparticles is a consequence of the theory of monopoles, but in the frame and language of quantum mechanics.

This difference between the classical and quantum theory is fundamental because the classical theory is subject to an objection, which is invalidated in quantum theory. The objection asserts that, to speak of electric or magnetic charges does not correspond to different physical objects but only to an arbitrary choice (see *Jackson* and many others). We rapidly give an answer.

Let us introduce densities of electric and magnetic currents and charges in the Maxwell equations[1] :

$$\nabla.\mathbf{E}=\rho_e\,;\quad \nabla\times\mathbf{H}=\frac{1}{c}\frac{\partial\mathbf{E}}{\partial t}+\frac{1}{c}\mathbf{J}_e$$
$$\nabla.\mathbf{H}=\rho_m\,;\quad -\nabla\times\mathbf{E}=\frac{1}{c}\frac{\partial\mathbf{H}}{\partial t}+\frac{1}{c}\mathbf{J}_m \qquad \text{(i)}$$

The system (i) remains invariant under the following transformation where α is an arbitrary angle :

$$\mathbf{E}=\mathbf{E}'\cos\alpha+\mathbf{H}'\sin\alpha\,;\quad \mathbf{H}=-\mathbf{E}'\sin\alpha+\mathbf{H}'\cos\alpha$$
$$\rho_e=\rho'_e\cos\alpha+\rho'_m\sin\alpha\quad \rho_m=-\rho'_e\sin\alpha+\rho'_m\cos\alpha \qquad \text{(j)}$$
$$\mathbf{J}_e=\mathbf{J}'_e\cos\alpha+\mathbf{J}'_m\sin\alpha\quad \mathbf{J}_m=-\mathbf{J}'_e\sin\alpha+\mathbf{J}'_m\cos\alpha$$

The primed and unprimed variables $\left(\mathbf{E}',\mathbf{H}',\rho'_e,\rho'_m,\mathbf{J}'_e,\mathbf{J}'_m\right)$ and $\left(\mathbf{E},\mathbf{H},\rho_e,\rho_m,\mathbf{J}_e,\mathbf{J}_m\right)$, obey the same equations (i). Now, let us suppose that $\rho_m=\mathbf{J}_m=0$, so that (i) represents *a purely electric particle*. α is at our disposal, so that we can put $\alpha=\frac{\pi}{2}$ and find, according to (j), the following equalities :

$$\mathbf{H}'=\mathbf{E},\ \mathbf{E}'=-\mathbf{H},\ \rho'_m=\rho_e,\ \mathbf{J}'_m=\mathbf{J}_e,\ \rho'_e=0,\ \mathbf{J}'_e=0 \qquad \text{(k)}$$

The primed system becomes :

$$\nabla.\mathbf{E}'=0;\quad \nabla\times\mathbf{H}'=\frac{1}{c}\frac{\partial\mathbf{E}'}{\partial t}$$
$$\nabla.\mathbf{H}'=4\pi\rho'_m;\quad -\nabla\times\mathbf{E}'=\frac{1}{c}\frac{\partial\mathbf{H}'}{\partial t}+\frac{4\pi}{c}\mathbf{J}'_m \qquad \text{(l)}$$

This is an electromagnetic field interacting with a purely magnetic particle, and it seems that we have changed the electric case into the magnetic one by a simple change of variables, so that the difference seems purely formal.

This change is formal indeed, but it is physically wrong because not only the equality of values (k), but already the transformations (j) are not covariant with respect to the symmetry laws : they equate or add vectors and pseudovectors. It must be emphasized, once more, that despite the strong links between electricity and magnetism, they are profoundly different by their symmetry properties.

Such an error will be impossible in our theory in which the difference of affine transformation between electricity and magnetism is evident, because $(\rho_e,\mathbf{J}_e)$ will automatically appear as a polar quadrivector,

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[1] We use the rationalised Gauss system of Heaviside-Lorentz, and we suppose that we are in the vacuum, which means that : a) The factor 4π disppears. b) We have : $\varepsilon=\mu=1$, so that : $\mathbf{D}=\mathbf{E},\mathbf{B}=\mathbf{H}$.

while $(\rho_m, \mathbf{J}_m)$ is an axial space-time quadrivector, *orthogonal to the first one*, in virtue of the Clifford algebra of Dirac's theory of the electron. Let us recall that the polar and axial transformations that will be deduced from our equations had already been proved by Maxwell and Pierre Curie. *Electric and magnetic particules are really different and the « choice » between them cannot be free.*

c) Poincaré (1896) gave the classical equation of a moving electric charge around a fixed magnetic pole, (which is equivalent to a moving magnetic charge around a fixed electric pole).

Two years after Curie, but independently of him, Poincaré wrote a short paper (*Poincaré*) about an experiment of Birkeland (*Birkeland*) : only some « remarks », he said. This paper had apparently no connection with the problem of the magnetic monopole ; but we shall later go back to it because actually, Poincaré gave the first differential equation describing, in classical physics, the interaction between an electron and a magnetic monopole. The paper is an important contribution to the theory of the monopole for three reasons :

(α) The problem of Poincaré was the collision between a moving electron with a motionless magnetic pole. But the equation is exactly the same for a moving magnetic monopole and a motionless electric pole.

(β) We shall prove later that the geometrical optics approximation of my quantum equation is exactly the Poincaré equation.

(γ) The Poincaré equation gave a theoretical explanation of the Birkeland effect. In consequence of the preceding points (α) and (β), we can assert that the quantum equation of the monopole was also confirmed by the classical approximation, even before any new experiment had been carried out.

d) Dirac (1931). Relation between electric and magnetic charges.

In a series of famous papers (*Dirac*), Dirac made, if not really a quantum theory of a magnetic monopole, at least a theory of the interaction between an electric charge and a fixed magnetic Coulomb pole. Despite the fact that Dirac did not speak of symmetry laws, the latter were implicitly introduced.

Dirac used a gauge reasoning - the first of this kind – and he obtained a remarkable law which claims that the product (eg) of the electric charge of the incident particle and the magnetic charge of the motionless target is *quantized*. Therefore, for a given magnetic charge, an electric charge must be a multiple of an elementary charge, in accordance with the experimental facts : it was the aim of Dirac to prove it.

Further it will be shown that our theory of the leptonic monopole gives the Dirac law in a more precise form. The fact that we find the same kind of law is not astonishing because *this law is a consequence of the discrepancy between electric and magnetic symmetries and it does not depend on a particular model.*

Nevertheless, it must be acknowledged that there has been, up to now, only one experimental proof of this law given in a series of experiments (*Mikhailov 1*) based on the method initiated by Millikan for the measurement of the electron charge. Unfortunately Mikhailov later gave another series of *results based on a quite different method*, and he found a charge more than ten thousand times smaller (*Mikhailov 2-5*). I think that the first result was the right one, but we obviously need other experiments !

Dirac's paper originated a fashion in physics of investigating magnetic monopoles. Many papers appeared, among which, many years later, two papers had a great success. In 1974 't Hooft (see *'t Hooft*) and Polyakov (see *Polyakov*) showed that the GUT (Great Unification Theory) *involves the existence* of magnetic monopoles. It gave confidence in the whole monopole theory, despite the fact that no new effect was predicted and no way was proposed for the observation of monopoles. It may be even asserted that the converse was true because this theory predicted a mass of the order of 10^{16} Gev for this monopole : if this was true, there would be no hope of ever creating such a particle, which must be sent back to the Big Bang ! It must also be added (but in such circumstances, it is a small detail), that this theory says nothing about symmetries.

In conclusion it may be said that after Dirac, the theory of monopoles was more or less put under the cover of the hypothesis of giant masses, which is the simplest way of explaining why they were not observed. Needless to say that this is not our problem, as far as we shall speak of a massless monopole which is confirmed by observable phenomena, while the rival theories are unable to find any experimental confirmation, precisely on account of the predicted giant masses.

3) Some introductory words about the leptonic monopole.

The theory that we shall further develop is quite different. It is now time to say in which way this theory is indepted to Dirac. Curiously, it owes nothing to his work on the magnetic monopole, except his authorship of the law of charges which is found in my theory in another way, and so provides a mutual confirmation.

Actually my theory is indebted to the Dirac *equation of the electron.* I worked on his equation in 1954, at the Institut Henri Poincaré, and all seemed to me « rotating » in the Dirac equation, obviously because of the spin. This is why I suggested in 1956 with a coworker (see *Jakobi & Lochak 1, 2*) a representation of the Dirac equation through a density and seven angles : six relativistic Euler angles (three real rotations in $\mathbb{R}^3$ and three imaginary angles for the velocity) plus an ugly duckling : **the angle A**. This strange angle was defined in the Dirac equation by Yvon and Takabayasi who discovered its central role in the theory of the electron (*Takabayasi*).

I knew Takabayasi quite well at that time, late in the fifties, when he worked in the de Broglie group at the Institut Henri Poincaré : everybody in our group (including de Broglie himself) was aware of the importance of this angle but without giving it any physical meaning. Only thirty years later I understood that it is related to magnetism as will be shown in the Chapter 2.

The « angular representation » so obtained was a complicated system of equations, but two equations stand out by their formal simplicity and their resemblance. Both implied *classical* Poisson brackets. The first equation seemed quite simple :

$\left[\frac{\varphi}{2}, J_4\right] = \delta(\mathbf{r}-\mathbf{r}')$: a canonical conjugation between the Euler angle of proper rotation and the time-component of the electric current J_μ which suggested the conservation of electricity [charge or current?] with the phase $\varphi/2$.

The second equation was :

$\left[\frac{A}{2}, \Sigma_4\right] = \delta(\mathbf{r}-\mathbf{r}')$: it was the same conjugation, but between the angle A and the time-component of the pseudo vector Σ_μ, defined by the Dirac equation just like the polar current vector J_μ. We shall meet it again later and it has already apppeared here above in the form of $(\rho_m, \mathbf{J}_m)$ but I didn't notice, at that time, that it was the same vector. The reason was that everybody considered the space part Σ_k of Σ_μ as the « spin vector » because Σ_k appears in the first integral of the linear momentum in Dirac's theory of the electron. But nobody and no book said anything about the time-component Σ_4. So that the second Poisson bracket was mysterious because neither the angle A nor Σ_4 was understandable.

Many years later, in 1983, I suddenly realized that A must be a *pseudo – scalar phase* and that this relation must be the counterpart of the first one and represent the conservation of magnetism. I rapidly deduced the equation of a magnetic monopole, which appeared as the hidden « second slope [?derivative?] » of the equation of the electron (*Lochak 3, 17*).

This theory is completely different from the other theories of monopoles : *the new monopole is a massless fermion, able to participate in weak energy interactions, and which automatically obeys the Curie symmetry laws and the Dirac law between the electric and magnetic charges*.

We shall see that the new monopole is *a magnetically excited neutrino,* a massless leptonic monopole with a quantized magnetic charge, a fundamental state of which has a zero charge the neutrino.

More than twenty five years of theoretical work and ten years of experiments were performed, the latter, essentially by Urutskoiev in Moscow and Ivoilov in Kazan (both in Russia) and more recently in Nantes (France). But there are other important contributions of Priakhin and Vyssotskij (in Russia).

Having initiated the idea, I carried out a great part of the theoretical work, but an important role was played by Prof. Dr. Harald Stumpf of the Tübingen University, a former co-worker of Werner Heisenberg (as I was of Louis de Broglie). The roots of our ideas may be found in old results due to both our masters and gathered in (*Borne, Lochak Stumpf*). The present book is devoted to the theory essentially due to myself and Prof. H. Stumpf.

4) Characteristic features of the theory.

Before discussing further details I would like to give a review of my theory, and show that it is profoundly anchored in the quantum theory and in the Curie symmetry-laws of electromagnetism.

1) **The monopole equation follows from a fact and a question :**

   a) The fact is the following : while Dirac's equation of a massive electron has only one gauge invariance - the phase invariance - which generates the theory of the electron, **the massless Dirac equation has two gauge invariances (and only two) : the first is the phase invariance based on the unit matrix *I* and the operator $e^{iI\theta}$, the second is based on the matrix γ_5 and on the operator $e^{i\gamma_5\theta}$** [2].

   b) The question (never asked before) is : **what is the electromagnetic interaction generated by the second gauge ?** The answer is : **it generates the electromagnetic interaction with a magnetic monopole.**

2) **The operator $e^{i\gamma_5\theta}$ entails a new covariant derivative and an equation which describes a magnetic monopole, just as the operator $e^{iI\theta}$ entailed the equation of the electron.**

3) The equation automaticaly defines magnetic pseudo – potentials which were precedingly deduced from different arguments (*Broglie 2, 3, 4* and *Cabibbo & Ferrari*). Nevertheless, in these earlier papers, the pseudo-potentials were considered for the global case, in the absence of electromagnetic field. **The present theory was the first to considered the interaction with an external field and to introduce the new covariant derivative, from which the magnetic charge follows.**

4) The equation gives **a renewall of Dirac's law** connecting electric and magnetic charges.

[2] Concerning the role of the operator $e^{i\gamma_5\theta}$ in Dirac's theory, see (*Jakobi & Lochak*).

5) At the geometrical optics approximation, the equation gives the **Poincaré equation. The cone defined by Poincaré in the classical theory plays the same role in the quantum case, with the same vertex angle.**

6) **The equation obeys the Curie laws of symmetry** (the chiral character of a free magnetic charge) : a crucial point because magnetism and electricity are conjugate in space–time in a sense that appears in the structure of the Maxwell tensor $F_{\mu\nu}$. In quantum mechanics, electron and positron are symmetric in time : *« A positron is an electron moving backward in time »* as Feynman said. As γ_5 defines the conjugation between space and time it may be expected that **a monopole and its anti - monopole are symmetric in space.** This is exactly what is deduced from the equation and it is the translation in the quantum language of a law formulated by Pierre Curie.

7) The equation shows that **the leptonic monopole is a magnetically excited state of the neutrino**. So that we have predicted that this monopole is able to **take part in weak interactions**, taking the place of a neutrino, which was experimentally confirmed by Urutskoiev and Ivoilov. As was predicted (*Lochak 5, 10*), **these monopoles may be produced on the Sun, as excited neutrinos.** And thus, in the vicinity of the Earth, they must follow the magnetic lines and fall on the poles, **which was confirmed by an expedition directed by Jean-Louis Etienne at the North pole** (*Bardout, Lochak, Fargue*). The link with β radioactivity was later proved by Ivoilov.

8) The $e^{i\gamma_5\theta}$ gauge invariance induces a **family of nonlinear equations** (including the famous nonlinear Heisenberg equation). The interaction between a nonlinear monopole and a fixed Coulomb field exactly admits the same first integrals as in the linear case. These integrals are the quantum form of the classical Poincaré integral : it is a proof of what was asserted above that Dirac's law is not the consequence of a model, but of a group invariance, i.e. of a geometrical property. It was also proved that the nonlinear equations (including the one of Heisenberg) describe **bradyon and tachyon states,** without any supplementary hypothesis. And it was proved, that the magnetic charge implies the **torsion of space,** in accordance with a work of the Russian physicist (*Rodichev*).

9) T**his theory of monopoles agrees with the de Broglie *Neutrino Theory of Light*,** in which the *photon is considered as the fusion of two Dirac neutral particles* (*Broglie 2, 3, 4*). The arguments are the following :

a) We have proved that **the theory of light contains a second photon, a magnetic photon** [*Lochak 9, 14*], which is related to the electromagnetic interaction found in the equation of monopole.

b) The **pseudo-potentials,** found in the theory of the monopole, now appear in the theory of light. De Broglie had met them in his own theory and associated them with « antifields » (a simple formal name). In our case, we define a **second electromagnetism,** related to the monopole**. The pseudo potentials take the role of the Lorentz potentials of the theory of the electron**. Here it must be stressed that de Broglie's theory of fusion gives not only a spin 1 particle but **a particle with a maximum spin 1** (analogue of a diatomic molecule). So, we shall find (*Chapter 6*) a « para-state » of spin 1 and an « ortho-state » of spin 0, corresponding to the de Broglie maxwellian and non-maxwellian state. As we have in addition electric and magnetic photons, the theory of light is finally based on **4 different photons**, instead of one, as it was in the de Broglie theory.

c) **The thory of the graviton of de Broglie and M. A. Tonnelat** considers the graviton as a fusion of four Dirac particles, three photons appear simultaneously with the graviton : this theory is a unified theory in the sense of Einstein. But we shall show that only two of these photons are electric : **the third one is magnetic** (*Lochak 14*). This intrusion of a magnetic photon in the relativistic theory of gravitation could be of great importance, for two reasons :

- *The first reason* is of a fundamental character, because the lack of magnetism in the Einstein Unified Theory of Fields could be the reason for which this theory has not been completed. The magnetic monopole opens a new way.

- *The second reason* is practical : a possibility of weakening the gravitational field in the vicinity of the starting area of a rocket, which would allow enormous energy savings. Some strange phenomena, possibly related to the monopole physics could suggest such an idea : the fact that the very heavy lid (of about 3500 tons) of the Chernobyl reactor, was lifted during the catastrophe and pushed as a whole beside the reactor. The hypothesis that this phenomenon was due to an enormous gas pressure within the reactor runs against the objection that such a presure would probably had led to an explosion of the reactor itself, which makes more plausible the assumption of a weakening of gravitation. It must be added that, in the Kurchatov laboratory, a heavy source of monopoles was pushed aside in the same manner and a gravimeter registered a variation of the gravitational field.

d) An important fact which will be further discussed is the problem of **the Dirac equation (with a proper mass) on the light cone,** which is defined as the cone on which the electric current is isotropic. **The Dirac equation splits into two equations : one for an ultrarelativistic electric particle and the other for a magnetic monopole.** So, at the ultrarelativistic limit of the Dirac equation, the electron and the monopole appear simultaneously and symmetrically, without the introduction of any other hypothesis.

e) **Two isotropic currents** appear in the theory, **which are space symmetrical with respect to each other**. **Their sum is the electric current and their difference the magnetic one.** Elementary algebraic properties automatically give all the physical properties in relativity and other symmetry laws. These properties are so striking, that it seems possible to ask whether these isotropic currents are of a more fundamental importance than electricity and magnetism.

f) **Last remark**. At the moment when these lines are written, our theory says nothing about the creation of monopoles and cannot explain the experimental fact that they appear in two circumstances : the disruptive electric phenomena and β - emitters plunged into a magnetic field (in this case, we have probably a magnetic excitation of a neutrino). I have nothing to say about that but the answer to this question is one of the brilliant results of my friend Prof. Dr. Stumpf, which may be found in his contribution to this book. It must be noted that the principal hypothesis of Stumpf is that the β-emission is the fundamental fact, which seems most probably true for reasons that cannot be discussed in an Introduction.

One aim of all these remarks was to suggest that the theory of a leptonic monopole is so strongly rooted in quantum theory, that, if it was contradicted by an experiment, the consequences would be so important that this eventuality seems to be very improbable. On the other hand, as was said above, the theory has the important experimental support of hundreds – even thousands – of observations made by L. Urutskoiev (Moscow), N. Ivoïlov (Kazan), the French groups of Nantes, of Fondation Louis de Broglie (Paris) and others.

Nevertheless, it must be recognized that the existence and the properties of the leptonic monopole are still a new domain in physics which needs new proofs of the theoretical predictions (due essentially to Lochak and Stumpf) and of the exactness of experiments due to the groups quoted above. And it must be recognized that the practical applications of these monopoles are at present very few and often only speculative. But it may be answered that, when the electron was discovered as a truly existing particle, this was only a daring conclusion, based on a relatively few experiments, with a perfectly nonexistent theory, which came only thirty years later : in those days, only some details were missing, such as relativity, quantum mechanics and atomic structure !… As for the practical applications how could it have been guessed at that time, that the electron would one day be at the very center of the future industry ?

In the present case, we have a theory which is probably not definitive, but which is embedded in the frame of quantum mechanics and which already gives an acceptable description of phenomena experimentally verified. On the other hand, the performed experiments are not at all (as it was the case for the electron) the first investigation concerning an elementary particle. They are based on the experience of a century of science.

The theory we are speaking of is not absolutely new because it is based on the discovery of many consequences of Dirac's theory of the electron, de Broglie's theory of light and of the general theory of spin particles. These forgotten consequences of old theories remained unknown because during almost two centuries the science of electromagnetism (except Maxwell !) was principally based on electricity. It could perhaps be said that it was the "fault" of Ampère whose discovery of the electromagnet made it possible to describe and even create magnetism from electricity, to which the attention was so that exclusively drawn. Therefore, physicists had somewhat forgotten the magnetism « in itself » ; except Maxwell, once more, who introduced magnetism in his famous treatise, on the basis of magnetic poles (*Maxwell*, T.2) ; and after him, Pierre Curie (*Curie*) who - just as Maxwell considered magnetic poles - considered magnetic currents and free magnetism.

The present book is an attempt to launch a renewal of electromagnetism and gravitation around electric and magnetic charges, respecting their different symmetry laws. Perhaps, such an attempt has a future. I am confident in the motto of the family of my old Master and friend Louis de Broglie : « Pour l'avenir ».

Now, it is interesting to note that we have, Harald and I, parallel origins : Stumpf was a near coworker and a friend of Werner Heisenberg, and Lochak was a near coworker and a friend of Louis de Broglie.

And I cannot finish this Foreword without warmly thanking our Editor Elsevier for his kind welcome and our friend, the Professor Peter Hawkes, who played the role of a Chief Editor to whom Professor Harald Stumpf and myself are profoundly grateful.

Only some words about our persons : 1- It must be noted that Peter Hawkes is a wellknown specialist in Imaging and Electron Physics, so that he comes, like Stumpf and myself from the same « electron world ». I take the opportunity to beg the pardon of Peter for my « very personal English ». 2 – Now, it is interesting to note that we have, Harald and me, parallel origins : Stumpf was a near coworker and a friend of Werner Heisenberg, and Lochak was a near coworker and a friend of Louis de Broglie.

It is well known that our celebrated masters were rivals, eternally discussing the meaning of quantum mechanics, but each of them recognized the genius of the other and their discord was not so serious if we recall that Einstein said : « If somebody tells you that he knows what $E=h.\nu$ means, tell him that he is a liar ». And Bohr said : « If somebody says that he understands quantum mechanics, this means that he does not understand physics ». This is why it is easy for the intellectuel sons of Heisenberg and de Broglie to be friends and coworkers.