

A possible catalytic nuclear fusion owing to weak interactions.

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Abstract. We examine a possible way to avoid the super-high temperatures that are generally introduced in nuclear fusion experiments in order to overcome the Coulomb barrier between electrically charged particles of the same sign. We start from the observation that although temperatures are very high in the hearts of stars, they are lower than the temperatures used in terrestrial experiments in nuclear fusion. We suggest the possibility of a catalyst that could be present in stars and absent from our experiments. It will be shown that neutrinos, in the stars, could play the role of this catalyst, since they are very abundant and subject to weak interactions, that enables them to play this role. But they cannot do so in terrestrial experiments, firstly because there are too few of them, and secondly because since they have no charge, they are scattered in all directions. Nevertheless, instead of neutrinos, we have at our disposal leptonic magnetic monopoles which were at first theoretically discovered and described and have now for many years been experimentally produced, observed and applied (see Part III and the references). These leptonic monopoles have the same weak interactions properties as neutrinos and could accelerate such phenomena as a proton-proton fusion at temperatures far lower than the temperatures used in other attempts at nuclear fusion. In addition, they can easily be focused and accelerated thanks to their magnetic charge, rather than being scattered in space. Thus they are potentially able to modify the problem of nuclear fusion.

I. Introduction.

One of the most difficult problems in applied physics today is the industrial development of nuclear fusion energy. As is well known, attempts at present are based on a race to giant temperatures of plasma (several hundreds of million degrees) in order to increase the velocity of nucleons with the same sign of charge, sufficiently to bring them near enough to each other to overcome the Coulomb repulsion. But there are two difficulties.

Firstly, there is no material enclosure that can survive such temperatures. The Tokamak of Tamm and Sakharov seemed to provide an answer: in it, electrically charged particles are obliged to rotate around a magnetic field to prevent them from approaching the walls. But then a second difficulty arises, namely that at high temperatures the Tokamak becomes unstable and works only for brief intervals of time; thus, the problem is not solved.

The reason for the present paper is that I think that the high temperatures must be abandoned. But how? Let us start from a few remarks.

- 1) Astrophysicists have discovered that although temperatures inside stars are very high, they are lower than those used in the terrestrial research installations for nuclear fusion. So I think that it is natural to ask whether there is not some catalyst in the stars that boosts fusion, but which would be absent from terrestrial laboratories.
- 2) What could such a catalyst be? It is interesting to observe that weak interactions constitute, in some manner, an obstacle to the strong interactions that are the sources of the energy of stars. For instance, they are in a position to slow down the carbon and hydrogen cycles. Thus one can ask if, conversely, they could speed up the strong interactions, and whether we could make use of this property.
- 3) The weak interactions that occur in the known astronomical cycles leads to the emission of neutrinos. Conversely, in the stars there are many antineutrinos produced by the β disintegration of free neutrons:



Consequently these antineutrinos can be absorbed in inverse β disintegration:



In this last reaction, an antineutrino coming from outside gives rise to the reaction (2): its absorption is equivalent to the forced emission of a neutrino. Such a reaction can boost an entire cycle, the antineutrino playing the role of a quasi-catalyst (only « quasi » because it disappears in the reaction).

4) Unfortunately, even if this hypothesis is justified, it cannot be applied in laboratories, in which there are not enough neutrinos. Furthermore, since neutrinos are neutral, they are diffused in all directions and cannot be focused. This is one of the reasons for which the famous experiment of F. Reines & C. Cowan [20], which proved the existence of the neutrino, was very difficult.

5) Nevertheless, a result due to Ivoilov [21] lends support to this hypothesis; he showed that when irradiating a β radioactive source with leptonic magnetic monopoles, the life time of the source decreases, in other words the β radioactivity is accelerated.

II. A possible catalyst for nuclear fusion.

Now, we shall show that a possible catalyst for nuclear fusion may be the leptonic nuclear monopoles that were theoretically predicted and then observed in our group [4, 7, 8, 10, 16, 17]. This theory is summarized in Part III of this paper, and developed – together with descriptions of experiments – in many other papers [10, 16, 21]. For now let us say briefly that these monopoles are very light (even massless in the present theory), contrary to the monopoles described by other authors, which are supposed to be very heavy. Furthermore, they have two main properties:

- a) They have a *magnetic charge* g equal to $137/2$ times the electron charge (in same Gaussian units).
- b) They are magnetically excited neutrinos, subject to the same weak interactions, and are thus able to influence the same nuclear phenomena. The most important observation is that contrary to neutrinos leptonic monopoles can be focused by electromagnetic forces and their energy can be increased in magnetic fields.

Therefore, we can substitute the following reaction to the reaction (2):



Here \tilde{m} is an anti-monopole with the same weak interactions as the antineutrino in the reaction (2). Below we suggest a test experiment in order to verify the reaction (3).

Some remarks :

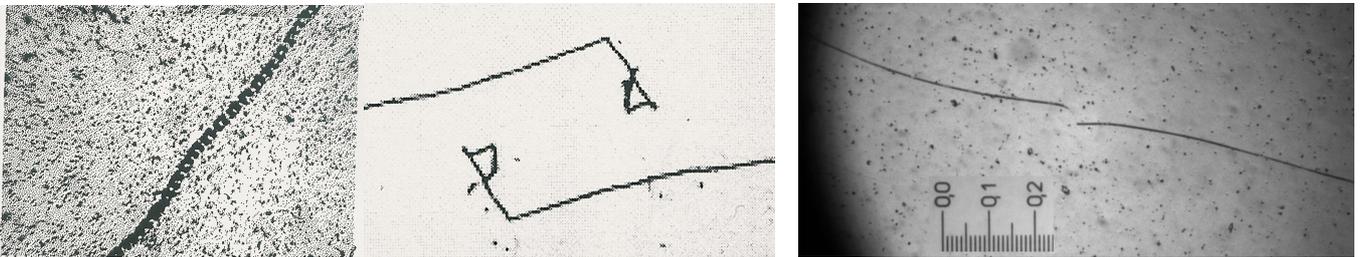
- a) *Concerning the reaction (3)*. It may be objected that energy is not conserved because a proton is lighter than a neutron. But that was already the case for the β inverse formula (2): such formulae are only written in conformity with quantum rules, and the conservation of energy is admitted for other reasons. Our case is simpler because the monopole may be accelerated in a magnetic field.
- b) *Concerning temperature*. The temperature required must be enough to create a plasma, which is much lower than the several hundred million degrees needed for other experiments in nuclear fusion.

III. A test-experiment.

Leptonic magnetic monopoles generally appear in disruptive electric phenomena in water, such as¹:

- 1) Explosion in water of a stepped up electric conductor (Urutskoiev, Moscow, reproduced in Nantes, France).
- 2) Electric arc in water (Ivoilov, Kazan).
- 3) Strong electric spark in water (Bergher, Fondation Louis de Broglie, Paris).

The monopoles are recorded in different manners, but most often on photographic films. Here are three characteristic tracks : 1) The first is greatly enlarged (characteristic caterpillar form). 2) The second is a track with its image in a germanium mirror; this image is **identical** to the original **rotated** by an angle of π , in accordance with the theoretical predictions. 3) The third track was observed on the magnetic north pole; a solar monopole created by a β decay in a strong solar magnetic field. We have hundreds of other different examples of tracks.



By definition, the recorded monopoles were originally present in the source. Thus, these same monopoles were able to accelerate the creation of deuterons, which is the first and principal stage of the hydrogen cycle :



But at this point there occurs a « forced » reaction due to an antimonopole coming from outside, which then disappears in the reaction, according to a formula of the following type:



A possible experiment could be to create, in a container of water, the explosion of an electric conductor (as in Urutskoiev's experiments), or an electric arc (as in Ivoilov's experiments). Then, the proportion of heavy water must increase as the water cools in the container.

I am aware that I am making several hypotheses here, but there is no science without hypotheses and I accept responsibility. Nevertheless, apart from other possible objections, one important question concerns the number of produced monopoles, and thus the probability of the purported nuclear phenomena.

Despite that, at a first glance, the reaction (5) seems to be easy to realize, **there is a difficulty : the number of monopoles** and consequently the probability of the reaction. If the number of monopoles produced by a source would correspond to the number of trajectories observed in the figures above, this number would be very small and the probability would be negligible.

¹ There are other situations, such as β radioactivity in a magnetic field.

But an important observation by Ivoilov, perhaps confirmed more recently by Daniel and Sonia Fargue, shows that apart from the rare large tracks generally observed, there are many other tracks which, contrary to the preceding, come directly from the direction of the source. These tracks are very thin and are easy to miss. Nevertheless, they have the charge of a monopole and they probably constitute the hidden but most significant emission of monopoles.

It seems that the first who observe (indirectly) these thin tracks was Urutskoiev [10]. When he obtained the first photographs of large monopole tracks on photographic film (curiously in a plane perpendicular to the direction of the monopole source), he tried to find 3D tracks in a bubble chamber. But he was disappointed because instead of 3D tracks he obtained a large white cloud. I now believe that this cloud consisted of the extremely numerous thin tracks later identified by Ivoilov. Actually, the large tracks correspond to deviated monopoles that strike the limit between the plastic film support and the photosensitive coating, and are strongly deviated from their initial trajectory. The large tracks are thus due to a kind of rare « accidents », which explains why they are so rare. On the contrary the “true” tracks (“true” because they are free) seem to be the numerous thin tracks.

Therefore, it seems that we can assert that the emitted monopoles are actually not few but instead extremely numerous. Thus, **it is possible that my test-experiment might be not so difficult to perform.**

Some other arguments lend support this idea, among which the macroscopic phenomena observed by Urutskoiev’s group after the Tchernobyl catastrophe², for example the following:

a) In the same hall there were two parallel conductors separated by some meters : one was a water pipe coming from the nuclear reactor, and the other an electric cable in a concrete boxing. During the catastrophe, this concrete protection was broken by the strength of the electric cable strongly attracted by the water pipe. Puzzled by this phenomenon a young physicist emitted, just as a joke, the audacious hypothesis that there could be magnetic monopoles in the water coming from the reactor. Actually, it was later confirmed, but **this implies an enormous quantity of monopoles.**

b) The reactor had a concrete cover weighing about 3000 tons. During the catastrophe, it was pushed aside and fell vertically against the wall of the reactor. If this was due to gas pressure inside the reactor, then a calculation proves that the walls would have exploded, whereas in fact the walls of the reactor were in perfect condition. The paint on the inside of these walls was not even burned, and it would have burned at a temperature of just 300°C. Two conclusions emerged from these observations:

c) There was no fire in the reactor except in a very limited volume (this was, of course, later verified directly) and thus no strong pressure.

d) If the cover was lifted, this means that its weight was far less than 3000 tons during the catastrophe. It was assumed that monopoles have modified gravitation. This was confirmed experimentally by Urutskoiev and theoretically by myself, on the basis of my theory of monopoles and of de Broglie’s theory of light which gives a quantum theory of gravitation (de Broglie proved the influence of electromagnetism on gravitation, i.e. the Einsteins’ unitary theory, in 1942 in his *General Theory of Spin Particles*. **All this would be impossible unless an enormous quantity of monopoles was produced.**

Two last remarks.

² It must be emphasized that we absolutely disagree with the official Soviet interpretation of the catastrophe as the result of « errors » of engineers. We have strong arguments in favor of the hypothesis of an explosion of an electrical machine (probably a transformer) which produced a stream of monopoles that then activated a chain of disintegrations never seen before. **An important point is that this hypothesis was emitted independently from myself : we met only several years later.** It must be added that two completely independent groups were sent to Tchernobyl in order to explain the catastrophe: one by a scientific center, the Kurtchatov Institute, under the direction of Urutskoiev, and the other, the official one, in order to find a guilty party. And this is the origin of the official « explanation ».

1) Urutskoiev is skeptic concerning the tokamak because it is unstable. Concerning the known tokamak, he is right, he was even among those who proved it. But I speak of a tokamak only in the sense of the russian acronym : « **tokamak** » means « **toroidal magnetic room** ». It is really unstable with electric particles like protons which rotate around the magnetic field, but I speak of anything else : a tokamak in which are introduced not electric particles but magnetic monopoles which rotate *not around but along the magnetic field*. It is another device : a monopole accelerator for which I have a patent with my colleague Maurice Bergher (deposit : Paris 23-7-2008, N°08-55034). But, despite that I worked during a long time on accelerators, I must confess that I have not examined the stability in this case. It remains to be done.

2) I disagree with my friend Urutskoiev when he asserts that we still know very few about monopoles. I beg his pardon but I see in this assertion a small mania of an experimenter who does not believe in theory ! Let me recall that I have predicted the existence and main properties of the leptonic monopole, on the theoretical basis of Dirac's equation of the electron (and not all on his calculations including a monopole) : I have found *Wave equations, mass nullity* (contrary to the heavy monopoles often predicted but never observed), *symmetry laws* (in accordance with the Pierre Curie), *magnetic charge* (that I deduced from physical *symmetry laws* and not by an algebraic artifice), *weak* (and not strong) *interactions* of the *leptonic monopoles* which I defined as *magnetically excited neutrinos*, but their weak interactions are focusable owing to their magnetic charge. Most of my theoretical predictions were experimentally verified. If some are not, the responsibility is the one of experimenters, not mine. Anyway, I think that one cannot assert that we know nothing or even « few » on monopoles ! Three hundred years after Newton, everybody believes in the primacy of experiment but it is a fact that theory can precede it ; and here, we are in such a case.

IV. Magnetic leptonic monopoles, a brief summary (see *Literature*).

Consider the Dirac matrices γ_μ ($\mu=1,\dots,4$) and the Clifford matrices built on them:

$$\Gamma_N = \left\{ I, \gamma_\mu, i\gamma_\mu\gamma_\nu, i\gamma_\mu\gamma_5, \gamma_5 = \gamma_1\gamma_2\gamma_3\gamma_4 \right\}^{(N=1,\dots,16)} \quad (1)$$

The following relations hold between the Γ_N (in which the sign \pm depends on μ and N):

$$\gamma_\mu \Gamma_N \gamma_\mu = \pm \Gamma_N \quad (2)$$

It is easy to show that only two Γ_N matrices commute in the same manner with the four matrices γ_μ , namely $\Gamma_1 = I$ (with a + sign) and $\Gamma_{16} = \gamma_5$ (with a – sign : they anticommute).

a) The first matrix $\Gamma_1 = I$ defines a phase- (or gauge-) invariance :

$$\psi \rightarrow e^{i\vartheta} \psi \quad (3)$$

This invariance leads to the invariance of the free Dirac equation, with a mass term but without external field:

$$\gamma_\mu \partial_\mu \psi + \frac{m_0 c}{\hbar} \psi = 0 \quad (4)$$

Owing to the preceding gauge invariance (3), a covariant derivation and a local gauge invariance may be deduced, with Lorentz potentials (their polar character is a consequence of the gauge) :

$$\nabla_\mu = \partial_\mu - i \frac{e}{\hbar c} A_\mu ; \psi \rightarrow e^{i \frac{e}{\hbar c} \phi} \psi, A_\mu \rightarrow A_\mu + \partial_\mu \phi \quad (5)$$

from which the Dirac equation of the electron follows:

$$\gamma_\mu \left(\partial_\mu - i \frac{e}{\hbar c} A_\mu \right) \psi + \frac{m_0 c}{\hbar} \psi = 0 \quad (6)$$

b) The second matrix $\Gamma_{16} = \gamma_5$ defines a new gauge invariance:

$$\psi \rightarrow e^{i \frac{e}{\hbar c} \gamma_5 \vartheta} \psi \quad (7)$$

Like the first one, it leads to the invariance of the free Dirac equation, but **without mass term because of the minus sign in (2)**:

$$\gamma_\mu \partial_\mu \psi = 0 \quad (5)$$

From the second gauge invariance (7) (see the references) we obtain a second *local invariance which no longer includes the Lorentz potentials A_μ but instead pseudo-potentials B_μ* :

$$\nabla_\mu = \partial_\mu - i \frac{g}{\hbar c} \gamma_5 B_\mu ; \psi \rightarrow e^{i \frac{g}{\hbar c} \gamma_5 \phi} \psi ; B_\mu \rightarrow B_\mu + \partial_\mu \phi \quad (8)$$

From this, I have deduced the equation of the leptonic magnetic monopole [7, 8, 17] which is massless because of the minus sign in (2):

$$\boxed{\gamma_\mu \left(\partial_\mu - i \frac{g}{\hbar c} \gamma_5 B_\mu \right) \psi = 0} \quad (9)$$

This equation is generally used to describe the leptonic monopole, and its predictions are experimentally verified. It automatically includes the symmetry laws discovered by Maxwell and Pierre Curie. **I have**

found two other more complicated equations which obey the same symmetry laws but with a non linear mass term,

The variance of the pseudo-quadri-potentials B_μ and ϕ in (8) is a consequence of the pseudo-scalar matrix γ_5 . For the same reason, the magnetic charge g becomes a true scalar, like all physical constants, and not a pseudo-scalar as in all the other monopole theories : in the present theory, the chirality of magnetism is no longer expressed through the physical constant g (which is scalar), but through a charge operator $G = g\gamma_5$, in the spirit of all quantum theories.

We know that (5) leads to the conservation electricity J_μ by the Dirac equation (6) :

$$\partial_\mu J_\mu = 0 \quad (J_\mu = i\bar{\psi}\gamma_\mu\psi) \quad (10)$$

All the same, the equation (9) implies, in virtue of (8), the conservation of the magnetic current :

$$\partial_\mu \Sigma_\mu = 0 \quad (\Sigma_\mu = i\bar{\psi}\gamma_\mu\gamma_5\psi) \quad (11)$$

The currents J_μ and Σ_μ are related by the algebraic formulae:

$$J_\mu \Sigma_\mu = 0; -J_\mu J_\mu = \Sigma_\mu \Sigma_\mu = \Omega_1^2 + \Omega_2^2 \quad (12)$$

$$(\Omega_1 = \bar{\psi}\psi; \Omega_2 = -i\bar{\psi}\gamma_5\psi)$$

Ω_1 and Ω_2 are the Dirac invariant and pseudo-invariant respectively. It follows from (12) that the electric current J_μ is time-like, as might be expected. On the contrary, the magnetic current Σ_μ is space-like, which is surprising. But all is cleared up in the Weyl representation :

$$\psi = \frac{1}{\sqrt{2}}(\gamma_4 + \gamma_5) \begin{pmatrix} \xi \\ \eta \end{pmatrix} \quad (13)$$

This equation (13), defining the two-component spinors ξ and η , enables us to break (9) into two independent left and right equations which generalize the Weyl form of the neutrino equations [8, 17] :

$$\boxed{\begin{aligned} \left(\frac{1}{c} \frac{\partial}{\partial t} - \mathbf{s} \cdot \nabla - i \frac{g}{\hbar c} (W + \mathbf{s} \cdot \mathbf{B}) \right) \xi &= 0 \\ \left(\frac{1}{c} \frac{\partial}{\partial t} + \mathbf{s} \cdot \nabla + i \frac{g}{\hbar c} (W - \mathbf{s} \cdot \mathbf{B}) \right) \eta &= 0 \end{aligned}} \quad (14)$$

The kinetic parts of these equations are the two-component monopole and anti-monopole, while the potential parts represent the electromagnetic interaction of a left and a right magnetic charge respectively. But it must be emphasized that the kinetic parts of (14) are nothing but the two-component of the left and right equations of a massless neutrino (here applied to spinors).

The difference between a neutrino and a leptonic monopole is not between the free particles, but only between their interactions with an electromagnetic field: this interaction does not exist for the neutrino, but for the leptonic monopole it corresponds to a plus or minus magnetic charge according to the left and right symmetry.

This is why it is precisely the Weyl representation (14) of the leptonic monopole that allows us to assert that the particles that we call monopoles are, in fact, magnetically excited forms of a neutrino and an antineutrino, subject like them to weak interactions and opposite magnetic charges [8, 9, 17, 21].

Here, the \mathbf{s} are the Pauli matrices and we have $iB_\mu = \{\mathbf{B}, iW\}$, where \mathbf{B} and W are a pseudo-vector and a pseudo-scalar in R^3 ; $B_4 = W$ is real because B_μ is axial. One can show that there are two isotropic conservative left and right currents related to electricity and magnetism :

$$X_\mu = \{\xi^+ \xi, -\xi^+ \mathbf{s} \xi\}; \quad Y_\mu = \{\eta^+ \eta, \eta^+ \mathbf{s} \eta\}; \quad J_\mu = X_\mu + Y_\mu; \quad \Sigma_\mu = X_\mu - Y_\mu; \quad \partial_\mu X_\mu = 0; \quad \partial_\mu Y_\mu = 0 \quad (15)$$

Here J_μ is the sum of isotropic currents and it is time-like, while on the contrary, Σ_μ is the difference of the same currents and is space-like since $X_\mu Y_\mu = 4|\xi^+ \eta|^2 \geq 0$.

References:

- [1] J.C. Maxwell, *A treatise on electricity and magnetism* (1873), Third Edition Clarendon Press (1991), two volumes reproduced by Dover.
- [2] P. Curie, *Journal de Physique*, 3^e série, t.III, 1894, p. 393, p. 415. *Ann. Fond. Louis de Broglie*, **19**, 1994, p.159
- [4] G. Lochak, *Ann. Fond. Louis de Broglie* (I) : **22**, 1997, p.1 (II) : p. 187.
- [5] P.A.M. Dirac, *Proc. Roy. Soc. Ser. A*, 133, 1931, p. 60.
- [6] W. Pauli, *Annales de l'Institut Henri Poincaré*, **6**, 1936, p. 109.
- [7] G. Lochak, Sur un monopôle de masse nulle, *Ann. Fond. Louis de Broglie*, **8**, 1983, p. 345 (I). **9**, 1984, p. 5 (II).
- [8] G. Lochak, Wave equation for a magnetic monopole, *IJTP*, **24**, 1985, p. 1019.
- [9] G. Lochak, *The Symmetry between Electricity and Magnetism and the Problem of the Existence of a Magnetic Monopole, contribution au recueil : Advanced Electromagnetism*, Ed. T.W. Barrett, D.M. Grimes, World Scientific, Singapore, 1995, p. 105-148.
- [10] L.I. Urutskoev, V.I. Liksonov, V.G. Tsinoev, Experimental observation of a « Strange Radiation » and of the transmutation of chemical elements, *Journal de Radio-électronique*, N°3, 2000 (in Russian) ; *Ann. Fond. Louis de Broglie*, **28**, 2002, p. 701 (in French).
- [11] G. Lochak, L'équation de Dirac sur le cône de lumière. Electrons de Majorana et monopôles magnétiques, *Ann. Fond. Louis de Broglie*, **28**, 2003, p. 403.
- [12] T. Borne, G. Lochak and H. Stumpf, *Non perturbative Quantum Field Theory and Structure of matter*, Kluwer, Dordrecht 2001.
- [13] H. Stumpf, *Ann. Fond. L. de Broglie*, **28**, 2003, 65.
- [14] H. Stumpf, *Z. Naturforsch.* **58a**, 2003, 1.
- [15] H. Stumpf, *Z. Naturforsch.* **60a**, 2005, 696.
- [16] G. Lochak, L. Urutskoev *Low-Energy Nuclear Reactions and Leptonic Monopoles*, Conférence Internationale sur la Fusion Froide (ICCF 11), Marseille 31.10.04 au 05.11.04, 2004.
- [17] G. Lochak, *Z. Naturforschung*, **62a**, 231-246, 2007
- [18] H. Stumpf, *Z.Naturforschung*, **66a**, 205-214,2011
- [19] H. Stumpf, *Z. Naturforschung* **67a**, 163-179, 2012
- [20] F. Reines & C.L.Cowan, *Phys. Rev.* 1953, T. 92, p.830.
- [21] N. Ivoilov, *Annales de la Fondation Louis de Broglie*, **31**, 2006, p. 115.

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