On Maxwell's Reversed Laws as Root of Magnetic Monopoles in Dark Matter

Russell Bagdoo
rbagdoo@gmail.com

Abstract

We propose the sterile magnetic neutrino as a possible candidate for dark matter. After a short summary on the role of dark matter in cosmology and the neutrino in particle physics, we bring the idea that dark matter would be made up of substances originating from black holes, in particular sterile neutrinos associated with a magnetic charge. These would not be sensitive only to the gravitational force. First, we conjectured to explain dark matter that it is composed of particles of the neutrino and antineutrino type associated with a magnetic charge and that these neutrinos come from primordial and classical black holes. We assumed that when baryonic matter crosses the event horizon, Maxwell's laws are reversed, the electric charge turns into a magnetic charge. Sterile magnetic neutrinos would be created and emitted, true magnetic monopoles. Second, we discuss dark matter consisting of sterile neutrinos associated with magnetic charge, the cosmic microwave background that displays non-baryonic dark matter, mini primordial black holes, and the formation of intermediate mass primordial black holes linked to dark matter and the formation of galaxies. Third, we review different mechanisms of how sterile magnetic neutrino could have escaped from the black hole to become dark matter. Fourth, we investigate the possibility that ordinary neutrinos could be produced by the weak interaction if sterile magnetic neutrinos from dark matter interact with active neutrinos from ordinary matter. Fifth, after examining some interactions between sterile magnetic neutrinos and standard neutrinos, as well as equations of possible production of gamma rays from the annihilation of neutrinos-antineutrinos, we propose that sterile magnetic neutrinos may exhibit a nonradiating current configuration in dark matter called "anapole", which would be weakly sensitive to electromagnetic forces. Before concluding, we deplore the ignorance of the absolute mass of the regular neutrino, we underline the relation between the distribution of the magnetic fields coming from the baryonic matter and that from the dark matter, which could potentially make it possible to detect in the cosmos the trace of this dark matter beyond its mere gravitational presence. And we bring out the gamma ray glows in the dark that can be attributed to the annihilation of dark matter with itself.

Keywords: dark matter, event horizon, magnetic monopole, inverted Maxwell's equations, magnetoelectric, Dirac equation, sterile magnetic neutrino, intermediate black hole, Lagrangian, anapole, magnetic field, halo, gamma-rays bursts.

Contents

l Introduction

According to cosmological models, dark matter would represent more than 80% of the matter in the universe [1] to constitute about 27% of the total energy density of the observable universe [2, 3]. It was imagined to explain the cohesion of galaxies and galactic clusters. Because it seems that galaxies are rotating too fast to be gravitationally maintained by the sheer mass of visible matter we observe in these galaxies [4, 5]. Dark matter provides the additional attraction preventing rotating galaxies from ejecting gas and stars from their most external regions.

Swiss astronomer Fritz Zwicky is credited with its discovery in the early 1930s [6]. He spoke about the problem of the missing mass at that time, but astrophysicists did not take this idea seriously. The question came up again in the late 1970s with the advent of radio astronomy and the work of Albert Bosma, in the Netherlands [7], and Vera Rubin, in the United States [8-10]. At that time, it was believed that the missing mass was ordinary matter, known as "baryonic", hidden, made mainly of hydrogen, therefore essentially of protons and neutrons [11]. Since all this time, astronomers have come to convince themselves that the luminous continents that we distinguish are distributed in a flattened disk. This flattened distribution of visible baryonic matter would only be the emerged part of a spherical cocoon five times larger made of dark matter that exerts a gravitational influence on ordinary matter, but that does not interact electromagnetically [12].

The problem is that nothing is known about its nature. This dark matter appears to be a new form of matter never made or detected in the laboratory or in particle accelerators [13]. In fact, to reconcile theory and observation, cosmologists must either change the material content of the universe with dark matter, or change the laws of gravity itself. These two options seem *a priori* equally admissible. However, the hypothesis of an unknown form of matter remains by far the simplest and most conservative [14].

Supersymmetry was assumed early in the universe, and the neutralino has proven to be the attractive candidate for dark matter [15]. The main goal of the theory of supersymmetry, which is an extension of the Standard Model (SM) of particle physics, is to allow a step towards the unification of the strong interaction and the electroweak interaction. It introduces unification between fermions and bosons. If nature is supersymmetric, the sea of quantum particles contains all types of particles that exist in nature, including superpartners. Like neutrinos, superpartner particles would have been created in large numbers in the early universe, while strong and weak electromagnetic forces would have had the same force at a single very high temperature. As the universe expands and cools, these types of particles all disintegrated into lighter particles except the neutralino [16]. The most stable and lightest of the superpartner particles, neutralino, from about 10 to 10,000 GeV, is the main Weakly Interacting Massive Particles (WIMP) candidate for dark matter [17, 18]. For direct observation, special experiments such as Cryogenic Dark Matter Search (CDMS) or Large Hadron Collider (LHC) seek to detect the rare impacts of WIMP in terrestrial detectors. For indirect observation, gamma-ray and neutrino telescopes looked for evidence of neutralino annihilation in regions with high dark matter density such as the galactic or solar center. So far, all attempts to detect

WIMP have failed. The fact is that the supersymmetry theory is not validated. Other avenues are of interest to experimenters, such as axions [19] or sterile neutrinos [20].

In the article *What Connects Dark Matter and Black Holes* [21] the author has proposed another avenue which he pursues in this paper with a quantitative theoretical model to support his conclusions. The idea is that dark matter is made up of substances from black holes, including sterile neutrinos associated with a magnetic charge. These neutrinos would not have been created during the big bang as the supersymmetric particles that would have supposedly been created in proportions identical to ordinary particles during the first microseconds of the big bang to evolve separately since. The surprise is that they would come from inside the black holes, from the primordial black holes to the present black holes. We know three species of neutrinos in the universe: it would suffice that a fourth exists, that it has concentrated in halo to completely immerse the galaxies to explain their accelerated rotation and solve suddenly the problem of dark matter. These neutrinos with magnetic charge would be magnetically neutral particles that rarely interact with ordinary matter, except through gravitation and possibly through the interactions of electromagnetic force (via magnetic fields) and weak [22].

Some sterile neutrinos with magnetic charge can have almost no mass, like the standard neutrino, or they can be incredibly heavy. They can be slow and congregate in dense clumps, or they can travel at almost the speed of light in a more or less evenly distributed cloud of matter. Slow sterile neutrinos with magnetic charge can behave like cold dark matter, while those that are light enough to move at speeds slightly below the speed of light are considered hot dark matter [23]. Together, cold and hot sterile neutrinos with magnetic charge can make up most of the missing mass in our universe. Section 2 reveals the inversion of the four laws of Maxwell applied to vacuum which allows changing the electric charge into magnetic charge. We performed the same exercise with the four laws written in a different form in a previous article [21]. This reversal occurs as a result of matter and light energy crossing the black hole's event horizon. There is then a blackout, the "code 137.03" is violated, the charge e is transformed into the charge g, reality becomes inaccessible by light and magnetic monopoles are generated. Section 3 shows that dark matter is made up of neutrinos associated with the magnetic charge that comes from black holes. The cosmological diffuse background indicates a non-baryonic dark matter from the beginning of the universe. From time immemorial, including our own, active black holes would have produced magnetically charged neutrinos. These neutrinos would have proliferated with the intermediate black holes that would be the missing link between stellar black holes and supermassive black holes at the heart of almost all galaxies. Section 4 describes different ways that allow the emission into space of neutrinos associated with the magnetic charge: Hawking effect, thermal radiation, tunneling effect. Fluctuations occur after matter is absorbed by the black hole. Quantum forces behave as if they override gravitational force and trigger particle exits. Section 5 shows the nature of the interactions of these sterile neutrinos associated with magnetic charge (they are magnetically neutral but become charged at high energies) emanating from black holes with the active neutrinos of ordinary matter. The result is production of active neutrinos, contrary to the predominant belief that sterile states interacting with active neutrinos produce sterile neutrinos. Section 6 reveals that dark matter is not so dark. We first consider interactions between dark matter neutrinos and baryonic matter neutrinos. We then deal with specific equations for the possible production of gamma rays from cosmic neutrinos-antineutrinos annihilation. Then we propose that sterile magnetic neutrinos can rub shoulders with anapoles sensitive to electromagnetic forces, although weakly in the current universe. These can annihilate at high speed. Section 7 gives a rough estimate of the neutrino mass and brings out that this model of sterile magnetic neutrinos interacts with magnetism and the weak force, emphasizes on the importance of magnetic fields in relation to the protection and distribution of visible and invisible matter. The energy from the magnetic fields of stars or pulsars acts on the halos around celestial objects. The halos form protective plasma. The energy transmitted to the neutrinos by the winds of magnetic fields can reach a level of result capable of leading to detectable glows.

2 Our theory for dark matter involves the inversion of Maxwell's laws: we find the magnetic charge (pole)

We conjectured to explain dark matter that it is composed of particles of the neutrino type and antineutrinos associated with a magnetic charge and that these neutrinos come mainly from primordial black holes and classical black holes. We assumed that when the baryonic matter crosses the event horizon and there is a blackout, Maxwell's laws are reversed, the electric charge is transformed into a magnetic charge and it is the magnetic current which induces the electric current. In the inner peripheral regions of the black hole, the density and temperature of baryonic matter are very high. The particles would undergo a phase transition and behave like magnetic particles. There is a violation of conservation of electrical charge, which we refer to as "code 137" violation. Standard neutrinos become sterile magnetic neutrinos, true magnetic monopoles.

2.1 Violation of "code 137"

The fine structure constant α is a dimensionless constant.

$$\boldsymbol{\alpha = \frac{ke^2}{\hbar c} = \frac{ee}{4\pi\varepsilon\hbar c} = 7.297354118 \times 10^{-3} = \frac{1}{137.03597}} \qquad (1)$$

Through the factor e^2 in the expression, α expresses the strength of the electromagnetic coupling between charged particles. It is a dimensionless number formed from the ratio between the square of the charge of the electron e^2 and the product of the Planck constant ħ, the speed of light c and a dimensioned constant, named permittivity of vacuum ε. Its experimental numerical value 1⁄137.0359895 characterizes the amplitude of electromagnetic phenomena [24].

To quote Richard Feynman, in formal jargon, the observed coupling constant $\boldsymbol{\alpha}$ − the amplitude of emission or absorption of a real photon by a real electron − is an enigmatic number whose experimental value revolves around $\mathbf{-0,08542455}$. Instead, most physicists retain the inverse of its square $[(\mathbf{-0,08542455})^{\mathbf{2}}]^{\mathbf{-1}}$, approximately $\mathbf{137,03597}$ with an uncertainty of about 2 on the last digit [25]. With a purely electronic quantum condition, we obtain the value $\boldsymbol{\alpha^{-1}}$ (in CGS system) given approximately by

$$\alpha^{-1} = \hbar c/e^2 = 137.03. \qquad (2)$$

This number, which we will call "code 137", is a magic and luminous number given to man by Nature.

Paul Dirac demonstrated in 1931 that the existence of magnetic monopoles was compatible with Maxwell's equations in the hypothesis of the quantification of the electrical charge [26]. The smallest electric charge that exists experimentally was $e = 1.6 \times 10^{-19} C$ until the advent of quarks which have a charge of $(e/3)$. There is some evidence that there are 'quasiparticles' in condensed matter physics with charges smaller than that [27]. However, the electron (symbol e^-) with a negative elementary electric charge belong to the first generation of the lepton particle family, and are generally thought to be elementary particles because they have no known components or substructure. This is why we keep $e = 1.6 \times 10^{-19} C$ as the minimum possible charge, since it is the fundamental unit attached to particles of matter, such as protons, electrons, muons etc. [21].

Dirac's theory turned out, when it was developed, to establish a connection between the electric elementary charge and the hypothetical magnetic elementary charge. Instead of finding a purely electronic quantum condition, such as (2), Dirac found reciprocity between the smallest electric charge and the smallest magnetic pole, i.e. the equation

$$\hbar c/(eg) = 2. \qquad (3)$$

(g: magnetic pole quantum, corresponding to the charge e).

His theory has the effect of creating the magnetic pole quantum which is a magnetic monopole. It shows symmetry between electricity and magnetism, which is still today completely foreign to established conceptions.

If the charges and poles are so similar, why hasn't nature provided us with poles? (Poles have not been seen despite careful searches [28]). However, if poles are found they must have much larger charges than the unit electrical charges found on elementary particles such as the electron. So this universe cannot be completely symmetric between pole and charge on the microscopic level [29].

And if the universe was constructed in such a way that there is no electrical charge, but only magnetic poles not having the same value of pole strength as the fundamental charge strength, so that the LH side of equations (2) or (3) no longer corresponds to the experimental value 137 or the theoretical value 2, we think we would be in a total darkness that would have the appearance of a dark matter.

By substituting an elementary electric charge in the expression $\boldsymbol{e^2}$ by $\boldsymbol{g}$ the elementary force of the magnetic pole, the code 137 is violated and we can anticipate obtaining a number where light gives way to dark

$$\frac{\boldsymbol{keg}}{\hbar \boldsymbol{c}} = \frac{\boldsymbol{eg}}{\boldsymbol{4\pi\varepsilon}\hbar \boldsymbol{c}} \neq \mathbf{7.297354118 \times 10^{-3}} \neq \frac{\mathbf{1}}{\mathbf{137.03597}} \qquad \text{(4-a)}$$

Or, by substituting the two elementary electric charges in the expression e^2 by g^2, the code 137 is similarly violated

$$\frac{\boldsymbol{g^2}}{\hbar \boldsymbol{c}} \neq \mathbf{7.297354118 \times 10^{-3}} \neq \frac{\mathbf{1}}{\mathbf{137.03597}} \qquad \text{(4-b)}$$

In both cases we can also anticipate obtaining a number which is not related to the minimum Dirac charge or to a multiple of this charge, which eliminates electromagnetic waves and light, hence the dark. We would have a magnetoelectric system where the charge g is directly undetectable.

We can imagine that the elements that make up this dark matter would be composed of elements charged magnetically, with electricity and the electric field considered as a relativistic consequence of the magnetic field, which involves reversing Maxwell's laws [21].

2.2 Inversion of Maxwell's Laws

The experimental dissymmetry of Maxwell's equations with respect to the electric-magnetic duality is related to the fact that the electric field is generated by the usual charges which give it a non-zero divergence, but the magnetic field is always of zero divergence because of the absence of corresponding punctual charge. Experimentally, the only source of the magnetic field comes from the existence of an electric current, i.e. a motion of electric charges. There are magnetic dipoles (particles with intrinsic spin) which are sources of magnetic field but without movement of electric charges or magnetic charges: there is no observable elementary magnetic monopole.

We display Maxwell's equations as applied to free space, that is, in the absence of any dielectric or magnetic material [30, 31]. The four fundamental equations in electromagnetism are

$$\oint E \cdot dA = \frac{e}{\epsilon_o} \qquad (5)$$

$$\oint B \cdot dA = 0 \qquad (6)$$

$$\oint E \cdot ds = -\frac{d\Phi_B}{dt} \qquad (7)$$

$$\oint B \cdot ds = \mu_o I + \epsilon_o \mu_o \frac{d\Phi_E}{dt} \qquad (8)$$

[E:electric field; B: magnetic field; A: closed surface; e: electric charge ($e = Q = q$); g: magnetic charge; Φ_B: magnetic flux; Φ_E: electric flux; ϵ_o: permittivity of space; μ_o: permeability of space; I: conduction current]

The first form of Gauss's law (Eq. 5) relates the electric field to electric charges. For the electrostatic field, whose lines begin and end on charges, it is equivalent to Coulomb's law. However, Eq. 5 is a more general statement: the total electric flux through any closed surface equals the net charge inside that surface divided by ϵ_o. This law relates an electric field to the charge distribution that creates it; it also applies to induced electric fields for which the lines are closed loops.

Equation (6), which can be considered Gauss's law in magnetism, states that the net magnetic flux through a closed surface is zero. That is, the number of magnetic field lines that enter a closed volume must equal the number of lines that leave that volume. This implies that magnetic field lines cannot begin or end at any point. If they did, it would mean that isolated magnetic monopoles existed at those points. The fact that isolated magnetic monopoles have not been observed in nature can be taken as a confirmation of Equation (6).

Equation 7 is Faraday's law of induction, which describes the creation of an electric field by a changing magnetic flux. This law states that the electromagnetic field, which is the line integral of the electric field around any closed path, equals the rate of change of magnetic flux through any surface area bounded by that path. One consequence of Faraday's law is the current induced in a conducting loop placed in a time-varying magnetic field. The negative sign of the right member means that the induced electric field is in the opposite sense to that of the integral. According to the Ampère-Maxwell law, a magnetic field is produced by a conduction current I and may also be associated with a changing electric flux.

Equation 8, usually called the Ampere-Maxwell law, is the generalized form of Ampère's law, which describes the creation of a magnetic field by an electric field and electric currents. The line integral of the magnetic field around any closed path is the sum of μ_o times the net current through that path and $\epsilon_o\mu_o$ times the rate of change of electric flux through any surface bounded by that path. The positive sign means that the magnetic field is in the same sense as that of the integral [32].

Assuming there is a magnetic charge (pole) and a magnetic current but no corresponding electrical counterpart, the equations would be asymmetric being fully subject to the magnetic charge. Maxwell's equations then become:

$$\oint B \cdot dA = \frac{g}{\epsilon_o} \tag{9}$$

$$\oint E \cdot dA = 0 \tag{10}$$

$$\oint B \cdot ds = -\frac{d\Phi_E}{dt} \tag{11}$$

$$\oint E \cdot ds = \mu_o I + \epsilon_o\mu_o \frac{d\Phi_B}{dt} \tag{12}$$

The equations are still asymmetrical but no longer subject to the electric charge. Equations 10 and 11 seem to miss something on their right sides. To see exactly what they are missing, we need to explain the meaning of $\nabla \cdot E$, also called divergence of E or simply of div$E$. Let V be a volume surrounded by a surface S in space. $\nabla \cdot E$ integrated on the volume V gives 4π times the total amount of electric charge e contained in V. Similarly, $\nabla \cdot E$ evaluated at point × gives 4π times the electric charge density at ×**.** Hence, Equation 10 indicates that there is no electric charge at any point in space. Basically, moving charges are equivalent to currents. But because the above reversed Maxwell's equations assume that there is no electric charge in dark matter, there is no electric current J_e on the right side of Equation 11. Equations 9 and 12 seem to have won something on their right sides. This means that $\nabla \cdot B$ integrated on the volume V surrounded by a surface S in space gives 4π times the total quantity of magnetic charge g contained in V. Similarly, $\nabla \cdot B$ evaluated at the point × gives 4π times the density of magnetic charge. As a result, Equation 9 indicates that there is a magnetic charge at any point in space.

Because the Maxwell equations above assume that there is a magnetic charge, there is a magnetic current J_g on the right side of Equation 12. Therefore, the absence of electric charge and the presence of magnetic charge reverse the asymmetry.

In fact, the electrical charge would become a magnetic charge, which would result in an attribution reversal, so that electricity should be considered as a secondary phenomenon whose existence depends on the flow of a magnetic current. The overthrow, in addition to the darkness caused, would in a way make that there would be free magnetic poles when there would be no more free electric charges. Magnetic monopoles would exchange "dark photons" [33-36].

Note: There is no question of continuing by presenting a critical analysis of the hypothesis of Maxwell's "inverted" laws, because these must not be considered in an absolute sense, as if the nature of dark matter had to conform precisely to these laws. It is only a simplistic schema of reality, a kind of approximation, an image. As such, it corresponds to reality, even if it does not identify with reality.

Having the “inverted” Maxwell's laws we must expect the conservation of “magnetic charges”. Effectively, if there are magnetic charges, generally called poles, those poles would provide a source of magnetic field just as an electric charge provides a source of electric field. Magnetic poles would have properties analogous to those of electric charges. Each pole would emit $4\pi g$ lines of magnetic field B, where g is the strength of the pole (corresponding to the charge e). If charges and poles were similar and symmetric in principle, we could have a universe made of protons, which have no electric charge but hold a unit magnetic pole strength, and electrons with no charge but with an opposite magnetic pole strength.

We could observe that magnetic charge is conserved; the net charge, or the amount of positive pole minus the amount of negative pole, will be conserved. Like the electric charge is conserved, the net charge, or the amount of positive charge minus the amount of negative charge, will be conserved in an isolated system.

However, if there are monopoles, and modern unified theories of elementary particles suggest that very heavy monopoles may exist [37-40], they must have much larger charges than the electrical charges found on elementary particles such as the electron. So this universe cannot be completely symmetric between pole and charge on the microscopic level [29, 41, 42].

2.3 Magnetoelectric wave and magnetoelectric force

Code 137 violation and inversion of Maxwell's equations (9)-(12) exhibit solutions of magnetoelectric waves, i.e. an oscillating magnetic field generating an oscillating electric current, and vice versa, which propagates in regions without the presence of any magnetic source. By their similarity with the "regular" Maxwell's equations (5)-(8), one could suppose that they also present solutions of electromagnetic waves, i.e. an oscillatory electric field generating an oscillatory magnetic field , and vice versa, which propagates in regions without the presence of any electric (or magnetic) source. That is not our assumption. Thus, the electromagnetic wave generated by an oscillating charged particle would be discernible from a magnetoelectric wave generated by an oscillating magnetic monopole; Fields that couple to magnetic monopoles are different from fields that couple to electrical charge. There is therefore a magnetoelectric wave different from the electromagnetic wave, and its quantization would give rise to photons discernible from the photons generated by the changes in motion of the charged electric particles – and there would be “dark photons”. And we can say that there is a dark magnetoelectric force with a dark photon wave, just as there is an electromagnetic force with a photonic wave. The magnetic charge resulting from the metamorphosis of the electric charge would replace the latter: $E = 0$, $B \neq 0$. We suggest the existence of an electric charge (known electric monopole) in ordinary matter and a magnetic charge (unrecognized magnetic monopole) in dark matter. There would be no electric monopole in dark matter just as there would apparently be no magnetic monopole in ordinary matter. In this sense these monopoles are subject only to gravitational interaction and they form dark matter.

Note that, on the contrary, Dirac's theory ensures that the magnetic monopole can coexist alongside an electric charge in ordinary matter. The monopole would result from the “Dirac string” [43] connecting the north and south poles which can stretch continuously to the point of becoming invisible: the dipole becomes two monopoles. This is the only way to incorporate magnetic monopoles into Maxwell's equations, since the magnetic flux running along the interior of the string maintains their validity. If, on the other hand, Maxwell's equations are modified to allow magnetic charges at the fundamental level, so as to obtain perfect symmetry ($E \neq 0$, $B \neq 0$), the resulting magnetic monopoles are no longer Dirac monopoles which require strings to attach them.

Note also that, despite extensive research, there is no experimental or observational evidence of magnetic monopoles [44, 45]. Gauss's law for magnetism says that "for every source there is a well", for every "north" pole there is a "south" pole (i.e. a source and a well). It describes a world in which these monopolies are non-existent. Maxwell's laws may not be based on the fact that magnetic monopoles don't exist, but they predict it. So Maxwell's equations only produce electromagnetic waves.

2.4 Sterile Neutrinos associated with “magnetic charge”

To penetrate the mystery of dark matter, we think that it is a different electromagnetism, a *magnetoelectrology*, with the necessity of qualifying this variant as a "new force". And that it is also a new particle: sterile neutrino associated with magnetic charge.

Physicists know three types of neutrinos. In early 2022, researchers with the KATRIN experiment determine that these neutrinos are lighter than 0.8 eV/c^2 [46-48]. Since the 1970s, many researchers have assumed that there is a fourth type, a "sterile" neutrino, much heavier, but which would interact even less than the others with ordinary matter. Its mass is unknown. Hints for neutrino oscillation anomalies and dark radiation (eV), sterile neutrino dark matter scenarios (keV) and experimentally testable theories of baryogenesis (GeV to TeV) suggest mass ranges that could take any value between less than 1 eV and 10^{15} GeV [49]. It is a right chirality neutrino or a left chirality antineutrino that can be added to the SM and can take part in phenomena such as the mixing of neutrinos.

If this sterile neutrino exists, we further conjecture the existence of a fifth type of neutrino: a sterile neutrino linked to magnetic charge, that would belong to dark matter and that would be a magnetic monopole. The term *sterile magnetic neutrino* (ν_g) is used to distinguish it from *sterile neutrino*. They are two hypothetical types of neutrino that do not interact through any of the fundamental interactions of the SM of particle physics except gravity. But while the sterile neutrino is electrically neutral with respect to the charge e, and does not question it, **the sterile magnetic neutrino comes from the permutation of the electric charge into a magnetic charge. This *sterile neutrino* would depend on a magnetic charge g that would be undetectable since it is not an integral multiple of the conventional electric charge. According to our conjecture, dark matter would consist of invisible sterile magnetic neutrinos that swarm in the universe and exert a gravitational attraction everywhere [21].**

2.5 Dark matter wave equation and polarized vacuum

If we consider dark matter as a material medium, waves of black elementary particles can move through it like mechanical waves in an ordinary material medium. In all simplicity, one can compare a sterile magnetic neutrino wave to a stretched cord in the dark matter which serves as a support. The period T is the time the wave needs to travel a distance of wavelength γ, so that $= vT$ [32]. The speed of a wave is a function of the properties of the medium which serves as its support, such as its inertia and its elasticity. For a taut string, the elasticity is measured by the tension F; the higher the tension, the greater the elastic restoring force on an element of the rope. What characterizes inertia is μ, i.e. the mass per unit length of the string. The result of the dimension analysis gives: $v = \sqrt{F/\mu}$. The wave equation

$$\frac{\partial^2 y}{\partial x^2} = \frac{\mu \partial^2 y}{F\partial\ ^2} \qquad (13)$$

is the differential equation that describes the propagation of a wave in a string of mass per unit length μ and tension F.

When dark matter does not move: the sterile magnetic neutrino is like a non-dispersive harmonic wave that travels without changing shape. When there is a change in energy, the sterile magnetic neutrino is like a dispersive wave, the speed of each component is different for each frequency. We suppose a dark matter, with invisible magnetoelectric radiation, but whose gravitational action "welds" the clusters of galaxies.

2.6 Paradox of a dark matter that regains light

Although there does not seem to be a coexistence of the two charges in ordinary matter or in dark matter (sect. 2.3), and that sterile magnetic neutrinos would only interact by gravity with ordinary matter, it is attributed a little ability to mix with the familiar neutrinos of the SM. This means that even if the magnetic and electric fields present in equations (9)-(12) are not equivalent to the fields which interact with the charged particles of equations (5)-(8), they present a certain number common reference points that make that monopoles are not completely decoupled from known physics. The fields involved in equations (9)-(12) not identical to the fields described by the “regular” Maxwell equations can also exceptionally act with ordinary matter by the electromagnetic force and the weak force.

For example, one can assume that a sterile magnetically charged neutrino can strike (or ricochet against) an electron while remaining a sterile magnetically charged neutrino. Therefore, it can be predicted that the electron accelerated during the shock radiates photons, some of which materialize into neutrino-antineutrino pairs of ordinary matter, and whose directions are bent in opposite directions by the magnetic field.

Thus, in this way, magnetically charged sterile neutrinos (right handed (RH), electrically and magnetically neutral) considered as dark matter, could interact **via the weak interaction and electromagnetism**, producing regular left handed (LH) neutrinos. Which opens up the possibility of being detected indirectly - and that's why they appear to be candidates for dark matter. A dark matter which in this sense, strictly speaking, would not be so dark.

2.7 Oscillations of sterile magnetic dark matter neutrinos

If we consider that the vacuum of quantum mechanics is only the minimum energy state of any field, of any particle, or of any energy, the sterile magnetic neutrinos are in the quantum vacuum as virtual particles, all the more that they belong to a code other than code 137 which covers the entire spectrum of electromagnetic waves. A great density of energy is necessary to succeed in making them “visible” [50]. There will be recovery of code 137 if the sterile magnetic neutrinos oscillate enough to transform into ordinary neutrinos (this transformation implies that the quantum numbers, different according to their chirality, are also transformed) [51]. Since all forms of energy are equivalent to mass, whatever they are – electric, thermal, magnetic and gravitational – can convert dark particles into ordinary particles. Suppose that a force field, for example a magnetic field, is superimposed on the vacuum. When a virtual neutrino-antineutrino pair arises from vacuum, the neutrino is deflected by the magnetic field in a certain direction while the antineutrino is deflected in the opposite direction. If the magnetic field is strong enough, the couple separates by such a distance that they become unable to remerge to annihilate. From virtual, the particles become real: the vacuum has become polarized. Dark matter is perhaps an ocean of Dirac filled with sterile magnetic neutrinos that require a high energy density to manage to separate the virtual couples and materialize them.

On the other hand, one can consider that the sterile magnetic neutrinos, supposed to have a right chirality, could oscillate in regular LH neutrinos, which opens another possibility to be detected indirectly. The phenomenon of oscillations is a process allowed in quantum mechanics which spontaneously transforms a defined type of neutrino into a different type. The oscillations of these neutrinos involve two parameters: mass and charge. The wavelength or period of the phenomenon depends on the square masses between the two neutrinos involved in the phenomenon and that we will write δm^2. The amplitude of the oscillation which describes the degree of mixing between two different flavors of neutrinos, that is to say their overlapping, must take into account that these neutrinos were created with a magnetic lepton flavor which falls under a charge magnetic.

It is with a relativistic speed that the sterile magnetic neutrino is expelled from the black hole. When it propagates in matter or in a vacuum, it can change flavor depending on the distance traveled and its initial energy. Propelled not far from the black hole, many sterile magnetic neutrinos are likely to recover the code 137 and become active neutrinos of ordinary matter. Oscillation is a phenomenon that violates conservation of energy insofar as neutrinos have a mass, since a given mass state jumps into a different mass state without further ado. Oscillation also violates conservation of charge insofar neutrinos have an associated charge other than electrical charge, since a state of a given charge jumps to a state of a different charge.

3 Dark Matter constituted of sterile magnetic neutrinos from primordial and classical black holes

According to most cosmologists, dark matter was physically present in the early universe, but it did not participate significantly in the chain of reactions that led to the production of primordial elements. The rate of expansion was driven by *radiation*, that is, relativistic particles like photons and neutrinos. This physical presence of dark matter was in the form of *sterile states*. The whole mathematical apparatus of the sterile neutrino hypothesis starts from the idea of the creation of these sterile neutrinos following the interaction of the active neutrinos of ordinary matter with the sterile states.

Our hypothesis differs in that sterile magnetic neutrinos come from black holes and their interaction with active neutrinos will only promote the production of ordinary neutrinos. When the universe was still in its infancy, dark matter did not exist and did not play any role until the first black holes appeared. This sterile magnetic neutrino could have been produced by a disintegration in the heart of an atomic nucleus within the black hole, and this complex process would correspond to the implementation of a weak interaction transmitted via mass bosons very high (over a hundred GeV). Just as the intermediate bosons named W and Z^o could be observed when particle accelerators delivered sufficient energy to produce them and emit a neutrino at the same time as an electron, the immediate interior of black holes, in using Einstein's mass-energy relation, would produce more than enough energy to emit a sterile neutrino associated with a magnetic charge at the same time as a "magnetic" neutrino (coming from a decay of an "electric" electron).

Given the extraordinary weak interaction of sterile magnetic neutrinos outside black holes, it is easy to understand, on the one hand, that this will have had the effect of causing the sterile magnetic neutrinos to appear, which immediately annihilated, or are split into other sterile neutrinos, or have transformed into ordinary neutrinos. This last transformation involves the recovery of the code 137 and could help explain that more neutrinos have been counted than expected in ordinary matter. On the other hand, these huge numbers of magnetically flavored neutrinos and antineutrinos would fill the universe without us having any indication of their presence.

3.1 The cosmological diffuse background indicates a non-baryonic dark matter from the beginning of the universe

Thanks to astronomical observations, astrophysicists have come to rule out the baryonic trail for dark matter and conclude that the universe is filled with an unknown substance fundamentally different from anything astronomers have observed with their telescopes, or measured in their laboratories. To understand, you have to go back to the beginnings of the universe, when it was filled with very hot plasma of atomic nuclei and electrons. Photons were trapped because they constantly interacted with charged particles in the plasma. Then around 380,000 years, the temperature, which decreases with the expansion of the universe, became low enough for nuclei and electrons to combine into neutral atoms. The photons were then able to propagate and constitute a radiation still detectable today and rich in information on the primordial universe, the cosmic background radiation [52, 53]. Although the temperature associated with this radiation is globally homogeneous over the entire sky, the *WMAP* [54] and *Planck* [55] satellites have detected small thermal fluctuations, of relative amplitude reaching 10^{-5}. They correspond to more or less dense zones in the primordial plasma. Overdensity areas have attracted more and more matter over time and have given rise to large structures, clusters and galaxies.

However, given the weakness of the initial fluctuations, and if only baryonic matter is taken into account, the build-up effect was not strong and rapid enough to produce the large structures seen today. We know, thanks to primordial nucleosynthesis, that the density of baryonic matter reaches a maximum of 5% of the theoretical critical density which would make the universe globally Euclidean (flat), as the observations suggest. It is therefore necessary to add to the primordial plasma a non-baryonic dark matter [56].

3.2 Dark matter would be made up of sterile neutrinos associated with the magnetic charge issued from black holes

We have imagined a non-baryonic ingredient that does not interact with ordinary matter other than through its gravitational effects, but that helps increase the efficiency of large structure formation: sterile neutrinos with magnetic charge. These would come from black holes, as much from young black holes, including those that are still born today, as from older black holes and very old black holes, said primordial. However, confirmed black holes - stellar black holes [57] and supermassive black holes [58] - would be insufficient to fill these sterile magnetically charged neutrinos [59]. It is necessary to appeal to the primordial black holes [60]: the Hawking black holes appeared in the first second of the universe, and the intermediate massive black holes [61] appeared between approximately 50 days and 380,000 years, after nucleosynthesis primordial which gave birth to the first atomic nuclei. Note that by primordial epoch, we are not only talking here of the first second of age which united the great interactions, but also of the primordial epoch which followed primordial nucleosynthesis. For the first tens of thousands of years, before recombination, the universe is yet very young, still in a state of very high energy and temperature, and still subject to quantum gravity.

3.3 Cosmological reasoning from particles and fluctuations

Prior to recombination [62], ionized matter was bound to radiation. Radiation can be considered as a set of particles, or a gas of photons. These photons are constantly in collision with the free electrons of the ionized matter. Through these encounters, we can say that they are coupled. This means that whatever can happen to the radiation will also happen to the electrons. On the other hand, as the electrons are charged electrically in a negative way, they also attract the nuclei which are positively charged – it is not as strong a coupling as if each electron were connected to a nucleus inside an atom, but there’s still a coupling. Nothing can happen to matter without it also happening to radiation, and vice versa. If, for example, a multiplication of fluctuations causes photons to concentrate in a certain region of the universe, the electrons are forced to follow the radiation.

Galaxies, which are large concentrations of matter, could not come into being all at once. There would have been, long before the recombination, small concentrations of matter which would have slowly amplified. A fluctuation of matter, that is to say a future galaxy, must not only have a force which attracts it on itself, but it must, also, overcome the expansion which, on the contrary, tends to dilute. These fluctuations must have already been present at the time of the recombination and the cosmic microwave background makes it possible to observe the universe as it appeared at that time. The cosmic microwave background sky map, released in 2013 by the Planck cosmology probe team, shows subtle temperature fluctuations imprinted on the deep sky when the cosmos was about 370000 years old [63]. The imprint reflects ripples that arose early in the universe's existence that apparently gave rise to the present vast cosmic web of galaxy clusters. Even if the observations become more and more sensitive, it appears that the mass that can be measured in its usual form (stars, galaxies, gas) is insufficient to obtain a greater relative amplitude and a concentration of faster fluctuations. This is the reason why the dark mass would solve the problem without it coming into conflict with the observations that can be made.

Abnormal concentrations of matter create black holes. These are subject to the principle of contraction: in order for the black hole to contract, it must lose gravitational energy and, for it to lose it, it must be evacuated. There is no more light [64] to oppose the contraction since by inversion of the laws of electromagnetism the electric charge is transformed into magnetic charge, thus creating neutrinos associated with the magnetic charge. It is the latter who will escape without undergoing any interaction. Their presence will then only translate into what they take with them, a good amount of energy and impulse that escapes observation.

These magnetically charged neutrinos increase the mass of the universe. The formation of black holes is governed by gravitation. The more mass there is in the universe, the faster the concentration of fluctuations in matter. These neutrinos could accentuate these fluctuations in particles fields. Thus the missing particles would come from the black holes themselves which reject an invisible and undetectable matter, the sterile neutrinos with magnetic charge, true magnetic monopoles.

The fact that this hidden mass is sterile may be of some benefit. Even if in the days of recombination there were concentrations of this massive component, these would not necessarily have left traces on the radiation, unlike ordinary matter which was coupled to radiation. The missing mass or the "dark mass" could very well have been subject to significant fluctuations at the time of the recombination without this leading to the corresponding fluctuations on the radiation, from which we infer that this does not contradict the observations available of cosmological radiation, in which we do not see these fluctuations. The observation problem would thus be solved, as well as that of the nature of this mass [65, 66].

3.4 The mini black holes born less than a second after the Big Bang would have quickly evaporated, leaving a shower of light and sterile magnetic neutrinos

In 1967, Yakov Zeldovich imagined that small black holes may have formed in the early universe [67, 68]. The density was such that small regions could collapse on themselves into black holes without going through the star stage. The size of these primordial black holes is limited by causality: in the first moments of the cosmos, too distant points did not have time to interact; they cannot therefore be included in the collapse of the same region. Thus, a black hole formed some 10^{-21} seconds after the big bang would have a radius of barely one billionth of a millimeter and a maximum mass of the order of 10^{14} kilograms. S. Hawking discovered that black holes evaporate [69, 70]. The mechanism he proposed combines quantum mechanics and gravity. The temperature rises as the black hole loses mass, and therefore energy. When the black hole has lost most of its mass, evaporation gets carried away and the object disappears in a final burst of energetic particles [71].

We claim that they would have evacuated mostly sterile magnetic neutrinos before disappearing into primordial plasma.

In the 1990s, theorists then thought of micro-black holes formed in the first second of the universe, of the order of a nanometer, but weighing a hundredth of the mass of the Moon, except that their evaporation would have been detected by gamma satellites in the 2000s [59].

They too could have disappeared by evacuating sterile neutrinos associated with magnetic charge.

They also thought about the formation of billions of massive primordial black holes, but their influence on the movement of stars has not been seen.

3.5 Formation of “intermediate mass black holes”

In this universe dominated by particle physics, fluctuations could have been created in the beginning which would have the characteristics necessary to play the role of fluctuations pre-intermediate black holes. The intermediate mass primordial black holes would have been born after primordial nuclear nucleosynthesis, between a few weeks after the big bang and 380,000 years. It is at this time, wrongly considered as non-event by current cosmology, which would be born these monstrous objects of size between 100 and 1 million solar masses. Huge clouds of gas, instead of fragmenting to make stars, would have turned directly into a black hole, under specific circumstances, which would have caused all the gas to fall back towards the center and drag it into a spinning disc.

The nuclear reactions of the condensed gases inside the black holes are still so energetic that a huge flow of sterile magnetic neutrinos is blown out of the black hole by exceeding its gravitational force.

The fluctuations lost some force with the expansion, and then became pre-galactic fluctuations. In vast clouds of gas of the young universe, whose properties were different from today, would have been born extremely massive and very slightly metallic stars (poor in chemical elements other than hydrogen and helium). By collapsing on themselves once their fuel was used up, these stars ejected very little matter and could give rise to black holes of intermediate mass. We can also assume that these stars can merge and create a supermassive star that collapses into a black hole of tens of thousands of solar masses.

These black holes would act as seeds for the formation of the first galaxies and quasars. Their existence is suspected at the centre of dwarf galaxies and globular star clusters [72]. The accretion of matter as well as the absorption of less massive black holes would allow them to quickly attain the characteristics of supermassive black holes [73, 74]. These weigh millions, if not billions, of solar masses. They are found at the center of quasars and massive galaxies less than a billion years after the Big Bang: they were able to acquire such a gigantic mass in such a short time as thanks to the intermediate black holes formed very early in the history of the universe. Thus, the intermediate primordial black holes could be the missing link between the classic black holes of stellar mass and the supermassive black holes [75, 76].

Dark matter would be made up of undetectable magnetic neutrinos emanating from all black holes.

3.6 Intermediate primordial black holes linked to dark matter and the formation of galaxies

Sterile magnetic neutrinos from black holes would therefore form a relatively large part of the dark matter. Many astronomers believe that dark matter is mainly made up of intermediate primordial black holes, which is something else. They argue that primordial black hole clusters could solve the so-called dwarf galaxy problem, namely the apparent lack of small satellite galaxies that are theoretically expected to form around massive galaxies such as the Milky Way. Their simulations predict the existence of numerous dark matter minihalos orbiting massive galaxies. Each of these minihalos should house a dwarf galaxy, and there should be hundreds of them surrounding the Milky Way. However, astronomers have found far fewer dwarf galaxies than expected [77]. The galaxy formation simulations also predict a population of galaxies of intermediate size, between dwarfs and massive. Such objects would be large enough to easily form stars and would be easily visible. Nevertheless, they have not been found by astronomers who search the surroundings of the Milky Way. Explanations are given: they would be present, but difficult to detect because too little light; or the simulations would overestimate the number of these dwarf galaxies, because they would not correctly reproduce the influence of ordinary matter on the formation of dwarf galaxies; thousands more are predicted to be detected in orbit around the Milky Way using ultra-sensitive wide-field cameras [76].

Our explanation is that this undetectable dark matter is composed of sterile magnetic neutrinos arising from black holes. Hot hydrogen clouds formed intermediate black holes that blew outward neutrinos associated with magnetic charge. Our interpretation for the missing galaxies, as much dwarf and intermediate, is that massive primordial black holes present in the heart of dwarf or intermediate-sized galaxies would block star formation due to gas accretion and eject formed stars as well as sterile magnetic neutrinos. This is why these galaxies remain invisible for most records.

4 How sterile magnetic neutrinos are evaporated from black holes

We postulated that neutrinos rejected by black holes are in a sterile state and under the dependence of a magnetic charge due to the violation of code 137. We took advantage of the inversion of Maxwell's equations near the event horizon, with respect to the "variance" of the charges (electric charge transformed into magnetic charge), to build a paradoxical diagram where matter and energy can escape from the black hole to space-time. If one wonders why to have chosen only the neutrino to escape from the black hole rather than the other particles, the answer is that the neutrinos are the only by-products of the annihilations which manage to flee the core of the Sun; photons, like all antimatter particles, are quickly absorbed by the surrounding dense medium. For similar reasons we believe that only the neutrino can escape the black hole. Here, our aim is, first, to show three methods of emitting particles from inside the black hole to the outside and, second, to claim that these particles form dark matter.

4.1 Hawking Effect

In 1974, Stephen Hawking assumed that black holes are not completely black but radiate with a well-defined temperature. Hawking’s discovery revealed deep conceptual links between gravity, quantum theory, and thermodynamics. Hawking’s inference was that black holes actually emit something. They glow, rather than being completely “black,” and in doing so they gradually lose mass [78, 79]. Thus, a black hole isolated in space will actually “evaporate”. Hawking’s ideas on “black hole evaporation” was a by a major breakthrough in our understanding of nature [80].

4.2 Our conception

However, if we have the impression that the laws of black hole physics are now basically all "known" and that the job of a theoretical physicist is only to explain the observed phenomena in terms of these known laws, we are largely wrong. The fact that general relativity ceases to be relayed by quantum physics and that the conservation laws of the baryon and lepton are violated means that the laws of physics currently known have only a limited scope of validity.

We assume that the creation of quantum particles occurs not only outside the black hole, but also inside, near the event horizon. What is inside a black hole? [81] The singularity theorem assures us that some sort of spacetime singularity will be found inside a black hole. For the type of black hole formed by spherical collapse, this spacetime singularity is all-encompassing in the sense that any observer who enters the black hole will get pulled into it. Must this be the case for all types of black holes? The answer is no. Inside a body collapsing into a black hole, one might subsequently expect to observe the creation of particles

Our theoretical investigation of the particle emission process suggests three methods of emitting particles from inside the black hole to the outside: **the black hole as a black body** that emits particles with a characteristic spectrum which depends only on its temperature, the **Hawking effect** (the creation of quantum particles inside and outside the event horizon), and the **quantum tunnel effect**. At first glance, not all theorists will agree, seeing antinomies, categorically opting for blackbody thermal radiation, or Hawking radiation, or quantum tunnel effect. We believe, however, that these different versions are not mutually exclusive [82].

4.3 Thermal radiation from black bodies and from black holes

When Hawking discovered the creation of thermal particles near a black hole, he found that, at late times, the rate of particle "emission' to large distances does *not* drop off to zero but, rather, approaches a steady, nonzero rate. Even more surprising, this steady particle flux has precisely the character of thermal mission. By *thermal emission* we mean the following: If an ordinary body is kept in exact thermodynamic equilibrium at temperature T^0, it will emit particles with a characteristic spectrum that depends only on its temperature, not the detailed nature of the body. Such a body in exact equilibrium is referred to as a *blackbody* [83]. This process of thermal emission of the black body is completely different in character from the process of spontaneous creation of particles near a black hole.

In principle, particles are emitted by a perfect blackbody and when the temperature is extremely high (greater than a billion degrees centigrade) the emission of massive particles will be important and one will observe all species of massive particles. A perfect black body at temperatures below a billion degrees would emit low-mass particles, such as neutrinos, which may be the case for the black hole formed by the gravitational collapse of a star or by the collapse of a cluster of stars. When the temperature is extremely low (a few degrees centigrade), one will observe only photons, that is, electromagnetic radiation and, presumably, the "graviton" or "quantum of the gravitational field" [84, 82].

The photon picture allows us easily to understand the chief qualitative properties of black-body radiation. First, the principles of statistical mechanics tell us that the typical photon energy is proportional to the temperature ($E = KT^0$), while Einstein's rule tells us that any photon's wavelength is inversely proportional to the photon energy ($\lambda E = hc$). Hence, putting these two rules together, the typical wavelength of photons in black-body radiation is inversely proportional to the temperature ($\lambda KT^0 = hc$). To put it quantitatively, the typical wavelength near which most of the energy of black-body radiation is concentrated is 0.29 centimeters at a temperature of $1^0 K(1K - 273.15 = -272.1C^o)$, and proportionally less at higher temperatures [85].

4.4 According to the theory of Relation there is a fundamental law between Hawking thermal emission from the black hole and thermal radiation from the black body

We have seen previously in the paper *The Equation of the Universe* [86] that the basic equation of the theory of the Relation is reduced to

$$k\mathrm{e}^2 = \mathrm{M}_{\mathrm{VP}}^2\,\mathrm{t_o c}. \qquad (14)$$

[$k\mathrm{e}^2$ is the electrostatic force between the squared charge of two protons in the same nucleus. The value of Coulomb's constant k is $1/4\pi\varepsilon_o = 8{,}9875 \times 10^9\,\mathrm{Nm^2/coul^2}$. The value of the constant ε_o called vacuum permittivity is $1/4\pi\varepsilon_o = 8{,}9875 \times 10^9\,\mathrm{Nm^2/coul^2}$. The term $\mathrm{M}_{\mathrm{VP}}^2$ represents the squared mass of two protons in a single nucleus subjected to gravitational force. $\mathrm{M_{vp}}$ is the relativized mass of the proton: $\mathrm{M_{op}}/(1 - \mathrm{v^2/c^2})^{1/2}$. The term $\mathrm{t_o}$ represents the "irreversible" universal time of the expanding universe which is flowing at the speed of light.]

This equation can also be written

$$(k\mathrm{e}^2 = \mathrm{M}_{\mathrm{VP}}^2\,\mathrm{t_o c} = \mathrm{M}_{\mathrm{VP}}^2\,2\mathrm{GM^o}/c^2 = \mathrm{M}_{\mathrm{VP}}^2\,h/\mathrm{m_o c} = \mathrm{M}_{\mathrm{VP}}^2\,hc/KT^o;\quad k\mathrm{e}^2/\mathrm{M}_{\mathrm{VP}}^2 = hc/KT^o), \qquad (15)$$

$$\text{hence } T^o = \mathrm{M}_{\mathrm{VP}}^2\,hc/k\mathrm{e}^2 K. \qquad (16)$$

The temperature T^o is proportional to the quantum gravitational mass ($\mathrm{M}_{\mathrm{VP}}^2$) as well as to the photon mass-energy $\mathrm{m_o}$ ($KT^o = \mathrm{m_o}c^2$).

Note that in this model, the speed of the relativized protons is identified with the estimated speed of the recession of galaxies and that it determines all other variables. We found reasonable to adopt the speed $2/3\mathrm{c}$. Since this is dependent on astronomical observations which are constantly evolving, the speed will be adjusted accordingly.

$$k\mathrm{e}^2 = [\mathrm{M_{op}}/(1-\mathrm{v}^2/\mathrm{c}^2)^{1/2}]^2 hc/KT^o \qquad (17)$$

$$2.3\times10^{-28}\ \mathrm{kg\ m^3 s^{-2}} = (2.2439\times10^{-27}\ \mathrm{kg})^2 hc/KT^o$$

$$T^o = [(2.2439\times10^{-27}\ \mathrm{kg})^2\ hc/K] \div 2.3\times10^{-28}\ \mathrm{kg\ m^3 s^{-2}} = {\sim}1.3\mathrm{K}$$

Considering π

$$T^o = [(2.2439\times10^{-27}\ \mathrm{kg})^2\ hc\pi/K] \div 2.3\times10^{-28}\ \mathrm{kg\ m^3 s^{-2}} = {\sim}4.2\mathrm{K} \quad (18)$$

On the other hand, if we put $k\mathrm{e}^2 = \mathrm{M}_{\mathrm{VP}}^2\,\mathrm{t_o c} = \mathrm{M}_{\mathrm{VP}}^2\,2\mathrm{GM^o/c^2}$, we get

$$k\mathrm{e}^2\mathrm{c}^2/2G = \mathrm{M}_{\mathrm{VP}}^2\,\mathrm{M^o} \qquad (19)$$

$$(k\mathrm{e}^2/\mathrm{M}_{\mathrm{VP}}^2 = 2\mathrm{GM^o/c^2};\quad k\mathrm{e}^2\mathrm{c}^2 = 2G\mathrm{M}_{\mathrm{VP}}^2\,\mathrm{M^o})$$

We see that $\mathrm{M}_{\mathrm{VP}}^2$ transforms into $\mathrm{M^o}$, and vice versa: the quantum gravitational mass is inversely proportional to the classical gravitational mass. The latter is the mass of the black hole, in the expression $2\mathrm{GM^o/c^2}$ of the Schwarzschild radius.

According to the theory of Relation, there is more than a merely coincidence between the Hawking thermal emission of the black hole and the thermal radiation of the black body, there is a truly remarkable correspondence, even a deep and fundamental law of nature: the temperature rises when black body or black holes emit radiation. The black hole should be viewed as a black body.

4.5 Hawking thermal radiation: spontaneous creation of particles near the black hole

The evaporation of the black hole is based on exotic quantum mechanical processes occurring near small (and large) black holes causing the spontaneous creation of particles. S.W. Hawking suggested that small black holes may have been created during the time of the young universe by fluctuations in density, that is, by variations in density from one place to another, which creates the chaotic and turbulent movement of matter and radiation. According to his theory, each black hole loses mass until, reaching Planck's mass, it disappears in a shower of radiation [87]. But this process applies as much to stellar black holes and others as to mini black holes. In fact, he discovered that when quantum mechanics come into play, all black holes cease to be perfectly black and radiate minimal amounts of energy [88].

Quantum field theory indicates particle creation near a rotating black hole. Calculations show that pairs of particles (that is, a particle and its antiparticle) will be spontaneously created in the strong gravitational field outside a rotating black hole. All species of particles will be created (electron-positron pairs, neutrino-antineutrino pairs, photon pairs, and so on), but the more massive the particle the less copiously it will be produced. This quantum particle creation effect was expected to occur only for all rotating black holes. For collapse to a Schwarzschild black hole, one expected no particle creation to occur at late times following the collapse. However, Hawking found thermal particle creation near a nonrotating black hole. Given enough time, they would release, in the form of radiation, all the matter and energy they had ever swallowed. Stellar-mass black holes would take 10^{66} years to evaporate. Supermassive holes, the remnants of long-dead quasars, would take even longer – more than 10^{90} years for the largest discovered in galactic nuclei.

The parameter R_S, known as the Schwarzschild radius, of a body of mass M is defined by $R_S = 2GM/c^2$ [89]. The boundary of a black hole is called the event horizon. By definition, once one cross the event horizon and enters a black hole, one can never again go back to the distant part of the space-time where the gravitational field is weak. One the other hand, an observer who remains outside the black hole can never see anything that takes place inside the black hole. The singularity theorem assures that some sort of spacetime singularity will be found inside a black hole, but not everything that enters the black hole must go into the singularity. Roughly speaking, there is a truly infinite amount of spacetime contained within the black hole and, although Hawking's evaporation process is only important to microscopic black holes these days, it turns out that in an ever-expanding universe even the largest holes would eventually be affected [80].

One consequence of the process of black hole formation and evaporation is that it apparently violates the laws of conservation of baryons stating that in any process the total number of baryons minus the total number of antibaryons cannot be changed (same for the leptons). One further consequence is that in the last step of the evaporation process, the dimensional arguments indicate that general relativity breaks down and must be replaced by a quantum theory of gravity.

Particle creation in the vicinity of a black hole results in a flux of particles escaping to large distances. The temperature T^o of the thermal emission in inversely proportional to the mass M^{o} of the black hole. Particles are assumed to obey the principles of quantum theory, but the gravitational field that causes the creation of particles is considered a classical (i.e., not quantum) entity described by the general relativity theory. Thus, in the immediate vicinity of the event horizon, the "emission" of a Schwarzschild black hole of mass M^{o} turns out to be identical in all points to the thermal emission of a perfect black body at a temperature T^{o} above the absolute zero given by

$$T^{o} = hc^{3}/2G\mathrm{M}^{\mathrm{o}}K \tag{20}$$

$$(\mathrm{t_o c} = 2\mathrm{GM^o/c^2} = \mathrm{h/m_o c} = hc/KT^{o}\ ;\ 2\mathrm{GM^o/c^2} = hc/KT^{o};\ T^{o} = hc^{3}/2G\mathrm{M^o}K)$$

The temperature T^{o} of the thermal emission in inversely proportional to the mass M^{o} of the black hole. Let us find the temperature for the Planck mass (Planck mass: $(h\ c\ /G)^{1/2} = 5{,}4 \times 10^{-8} kg$.

$$T^{o} = hc^{3}/2GK\ 5{,}4 \times 10^{-8} = \sim 1{,}8 \times 10^{32}\mathrm{K}. \tag{21}$$

It is noted that the mass M^{o} decreases when the temperature increases, which is in perfect agreement with the theory of the Relation. Assuming the mass of the universe is about $1{,}55 \times 10^{52} kg$, the temperature will be close to $2{,}7\mathrm{K}$.

$$T^{o} = hc^{3}/(2GK\ 1{,}55 \times 10^{52} kg)/2.3 \times 10^{-28}\ \mathrm{kg\ m^3 s^{-2}} = \sim 2{,}7\mathrm{K}. \tag{22}$$

Note that in the latter case, we divide by $2.3 \times 10^{-28}\ \mathrm{kg\ m^3 s^{-2}}$ while we do not do it for the first case. This is explained in Relation theory because we have two scales of orders of value for the same equation. In the first case, there is 10^{60} between Planck's mass and the current mass of the universe. In the second case, which concerns radiation, there is 10^{120} (value of the cosmological constant) between the "mass" of the photon which has stretched 10^{60} from Planck's value to settle at $\sim 10^{-68} kg$ ($\mathrm{t_o c} = 2\mathrm{GM^o/c^2} = h/mc; m = \sim 10^{-68} kg$) while in the other direction but for the same time the Planck mass has "swelled" 10^{60} to come the current mass of the universe ($\sim 10^{52} kg$), hence a difference of the order of 10^{120} between radiation and current matter [82, 86].

4.6 Quantum tunnelling

In quantum mechanics it appears that phenomena prohibited by the laws of classical physics, such as the escape of a particle out of a black hole, have a chance to occur. This chance is small, of course, but nonetheless real. The mechanism responsible for this escape is called *tunnel effect*; it allows a particle to cross a “classic” barrier. By "classical" barrier we mean what would constitute an insurmountable obstacle if only the laws of classical physics were in play [90, 91].

Just as a neutron star can spontaneously decay and become a black hole, so any piece of matter-energy inside the black hole can undergo a similar evolution, to cross a barrier of potential thanks to the quantum tunnel effect, and thus lose mass in the form of dark energy (not to be confused with the supposed dark energy responsible for the expansion; mass and energy are bound by equation $E = mc^2$). But although this dark matter does not have enough energy to jump over the rim of the potential well of the event horizon and end up out of the black hole, it can squeeze through the barrier by means of the tunnel effect.

The important point is that in any case the black hole that comes from the collapse of ordinary matter (white dwarf, neutron star with or without the intervention of gravity) up to the state of black hole, can transform ordinary matter into dark matter, due to the magnetic charge resulting from a reversal of Maxwell's laws, then evacuates it out of the black hole by the quantum tunnel effect [92].

5 Lagrangian of right handed neutrinos (sterile magnetic neutrinos) coupled with left handed neutrinos (active neutrinos) which produce regular neutrinos

In this section, we investigate the possibility that ordinary neutrinos could be produced by the weak interaction if sterile magnetic neutrinos mix with active neutrinos. The terms *ordinary*, *regular*, *usual*, *standard*, *active* are used to designate the neutrino of the enlarged SM (which tolerates the oscillation of the neutrino). The active neutrino is an alternative name for the SM neutrino: it is sometimes convenient to call the usual LH neutrinos active as opposed to the sterile magnetic neutrinos of dark matter, the RH counterparts of the usual neutrinos. The main difference is that sterile magnetic neutrinos, due to the alienation of code 137, are not charged in the same defined way compared to SM gauge interactions. Strictly speaking, active neutrinos are eigenstates of charge. Indeed, neutrinos can be described as the *eigenstates of mass*, i.e. the eigenstates of the Hamiltonian defining the propagation of these particles, or as the *eigenstates of charge*, i.e. the states having charges defined with respect to the weak interactions of the SM. For each of the two kinds of neutrinos, the pure charge eigenstates are created via weak interactions and the mass eigenstates have defined propagation frequencies**. In our view, mass and charge operators would sometimes commute during interactions between sterile magnetic neutrinos and active neutrinos, and this would be responsible for reconstituting code 137.**

Over the past three decades, a growing number of neutrino experiments have observed neutrino flavor changes, indicating that neutrinos are massive and oscillate. They form active neutrinos (ordinary neutrinos that feel the weak interaction at full power) in the extension of the SM which carry an isospin charge of $\pm 1/2$ under weak interaction [51].

A big question is how neutrino masses appear. In the SM of particle physics, fermions only have mass due to interactions with the Higgs field. These interactions involve both LH and RH versions of the fermion. However, only LH neutrinos have been observed so far. As we have expressed, the sterile magnetic neutrinos could constitute these RH neutrinos which interact with the LH neutrinos and the Higgs field in a manner analogous to the rest of the fermions. **They would have been produced by the Higgs field inside the black hole before being expelled.** They would interact with other fermions in this way, would therefore not be directly observable and cannot be excluded phenomenologically. On the other hand, we exclude the assumption that there are only LH neutrinos and that their source of mass would come from the Majorana type of mass (making the neutrino its own antiparticle) which applies to electrically neutral particles.

Under the hypothesis that sterile magnetic neutrinos form dark matter and that they would be RH Dirac particles (v_R), these particles are not quantum neutrinos of well-defined energy (eigenstates of mass). **We consider the possibility that their eigenstates of interactions with active neutrinos produce SM neutrinos, contrary to the tendency that the interaction of active neutrinos with "sterile states" of dark matter results in sterile neutrinos.**

5.1 The right handed sterile magnetic neutrinos.

We consider the sterile magnetic neutrino as being the right chiral “partner” for the observed LH neutrino. Note that the terms “sterile neutrino”, “RH neutrino”, “heavy neutral lepton” and “singlet fermion” (particle whose spin vanishes or state of correlated particles whose total angular momentum is zero) are often used interchangeably in the literature. We have seen before that the neutrinos rejected by black holes are in a sterile state and under the dependence of a magnetic charge due to the violation of code 137. Sterile magnetic neutrinos do (by definition) not carry any SM gauge charges, i.e., they do not feel any of the known forces of nature except gravity. But in order to be viable dark matter candidates, they must have some interactions with other particles. This can be realized in at least two different ways. The first two ways can be classified as "thermal production", since they involve scattering of particles in the primordial plasma which are in good approximation in thermal equilibrium. The decay of the third way can be considered as a “non-thermal production” mechanism if it occurs long after the decaying particle has frozen out.

1) In the early universe, if the sterile states of magnetic neutrinos mix with active neutrinos, then ‘ordinary’ neutrinos can be produced by the weak interaction through this mixing. And these RH magnetic neutrinos can give mass to these brand new LH active neutrinos.

2) Neutrino states that appear to be sterile at the energies that are currently experimentally accessible may have new gauge interactions at higher energies.

3) Ordinary neutrinos can be produced in the out-of-equilibrium decay of heaver sterile magnetic neutrinos (issue from primordial black holes) in the early universe. There are probably, in a context of thermal non-equilibrium, countless possibilities to implement the idea in specific models that ordinary neutrinos can be produced during the decay of virtually any sterile magnetic neutrino heavier than the active neutrinos that can interact with it.

5.2 Production of ordinary neutrinos in the early universe by dark matter sterile magnetic neutrinos at keV scale

For the majority of cosmologists, particles were in thermal equilibrium in the early universe, that is, the processes in which lighter particles combine to form heavy particles and vice-versa happened at same rate. At some point of time, the conditions required for thermal equilibrium were contravened because the density of some particle species became too low. These particles are stated as "freeze-out" and they have a constant density which is known as relic density, because the abundance of particle remains same [93]. Research on sterile neutrinos as possible candidates for dark matter examined different mechanisms explaining how sterile neutrinos could have been produced in the early universe. The most efficient production mechanism appears to be via oscillations of neutrinos, as they are RH and the only direct coupling of these sterile states is with LH or active neutrinos ($v_L \rightarrow v_R$). In the early universe, it is therefore the active neutrinos which would be at the origin of the production of sterile neutrinos at the keV scale of dark matter [94, 95].

In the hypothesis of sterile magnetic neutrinos as possible candidates for dark matter that we propose, it is the reverse: sterile magnetic neutrinos, resulting from black holes, couple with active neutrinos, recover their code 137 and are converted into ordinary neutrinos. These "converted" particles have a non-constant density called "cumulative" density, because their abundance keeps increasing.

In our opinion, active neutrinos interacting with sterile magnetic neutrinos cause sterile magnetic neutrinos to reveal (they already exist and are not only "sterile states") which are immediately transform into ordinary neutrinos ($\boldsymbol{v_R \rightarrow v_L}$). So it is the sterile magnetic neutrinos that would produce, via oscillations, regular neutrinos; not the other way around.

This should help explain an overabundance of neutrinos. Although the population of neutrinos is not well known, it is expected to be roughly similar to that of photons. One would observe in the cosmos, on average, a billion light photons for each atom, which is inexplicable [96].

5.3 Sterile neutrino associated with a magnetic charge

The discovery of Higgs Boson in 2012 at CERN LHC has strengthened the low energy theory of SM explaining the dynamics of fundamental particles and their interactions. Nevertheless there still remain unanswered questions such as origin of neutrino mass and dark matter. Within the SM, neutrinos are massless because the Higgs field cannot couple to the neutrinos due to the absence of RH neutrinos. Despite this, neutrino oscillation experiments have shown at high level of statistical significance that neutrinos have non-zero but tiny mass, and flavor and mass eigenstates mix giving rise to quantum mechanical phenomena of neutrino oscillations. Paradoxically, the mass of the neutrino and RH neutrino have become the extension of SM.

There exist several scenarios for the extension of SM with RH neutrino. For example seesaw mechanisms, which may explain the origin of a dimension five operator (such the Weinberg operator which can generate the tiny Majorana mass for neutrinos with the SM Higgs field) and can account for the dynamical origin tiny Majorana neutrino masses by appropriately extending the contained field of the SM. This scenario beyond the SM (BSM) require unnatural fine tuning of the Yukawa couplings to generate sub-eV neutrino masses [53].

In the next two sections, we investigate the possibility that sterile neutrinos associated with a magnetic charge can produce active neutrinos, and also, although this is not the motive, the possibility that RH neutrinos and LH antineutrinos can exist as distinct particles. The experimental results so far show that all produced and observed neutrinos have LH helicities (spin antiparallel to momentum), and all antineutrinos have RH helicities, within the margin of error. We exclude the Majorana model which assumes that the neutrino is also its own antiparticle [94]. We use the Dirac model which accepts that a neutrino must be different in some aspect from its antineutrino. The sterile neutrino associated with a magnetic charge is a Dirac fermion and if it is massive, it must have non-zero magnetic and electric moments.

5.4 Seesaw mechanism

The seesaw mechanism makes it possible to generate small numbers from larger numbers. The type 1 model produces a light neutrino, for each of the three known neutrino flavors, and a corresponding very heavy neutrino for each flavor, which has yet to be observed. Mathematically, in quantum field theory, the seesaw mechanism corresponds to the fact that the 2×2 matrix is defined as

$$A = \begin{pmatrix} 0 & D \\ D & M \end{pmatrix}. \qquad (23)$$

(The matrix A is essentially the mass matrix for the neutrinos. M is the mass of the sterile neutrinos associated with a magnetic charge; it is comparable to the GUT scale and violates lepton number. D are the Dirac mass components of order of the much smaller electroweak scale, or vacuum expectation value). It has two eigenvalues :

$$\lambda_{(+)} = (M + \sqrt{M^2 + 4D^2})/2 \tag{24}$$

$$\lambda_{(-)} = (M - \sqrt{M^2 + 4D^2})/2 \tag{25}$$

The geometric mean of $\lambda_{(+)}$ and $\lambda_{(-)}$ equals $|D|$, since the determinant is equal to $\lambda_{(+)}\lambda_{(-)} = -D^2$. If one of the eigenvalues goes up, the other goes down, and *vice versa*. Sterile magnetic neutrino M is taken to be much larger than D. Then the larger eigenvalue, $\lambda_{(+)}$, is approximately equal to M, while the smaller eigenvalue is approximately equal to $\lambda_{(-)} \approx -D^2/M$. The smaller eigenvalue then leads to a very small neutrino mass, comparable to 1 eV [97].

5.5 Lagrangian of right handed neutrinos (sterile magnetic neutrinos) coupled with left handed neutrinos (active neutrinos)

The author was inspired by the conjecture of physicists who consider RH sterile neutrinos coupled only to LH active neutrinos [94, 98]. Conjecture which wants that the active neutrinos enter into interaction with the neutrino of Majorana considered as the sterile neutrino and that this interaction would produce RH sterile neutrinos. **We have taken the liberty of using the sterile magnetic neutrino from black holes instead of the Majorana neutrino. We assume that it is regular (or active) neutrinos that result from this interaction and not sterile neutrinos. And if RH sterile neutrinos were to result, they would be mostly spontaneously transformed into regular neutrinos, thus covering code 137.**

For simplicity, we consider only one generation of neutrinos. The mass term for a model with RH neutrinos is given by the Lagrangian

$$\mathcal{L} = \boldsymbol{D}\left(\frac{\emptyset}{v}\right)\overline{v_L}v_R + Mv_Rv_R + h.c., \tag{26}$$

where $(\boldsymbol{v_L}, \boldsymbol{v_R})$ is a single generation of neutrino fields, $\boldsymbol{D}$ is Dirac mass, $\boldsymbol{M}$ is sterile magnetic mass for the RH components (it is also a Dirac mass and not a Majorana mass), $\emptyset$ is the Higgs field and $\boldsymbol{v}$ its vacuum expectation value (VEV). The usual hot dark matter (HDM) case, wherein the active neutrinos constitute the dark matter, corresponds to [$\boldsymbol{D} \sim 90h^2 eV$ and $M \ll D$] or [$D^2/M \sim 90h^2 eV$ and $M \gg D$].

When sterile magnetic neutrinos are candidates for dark matter, M is the relevant mass [98]. At tree-level, v_R couples only to v_L and therefore the most efficient way to produce sterile magnetic neutrinos is via oscillations $v_L \rightarrow v_R$ [99 - 101].

The probability of observing a RH neutrino after a time t given that one starts with a pure monoenergetic LH neutrino is $sin^2 2\theta_M sin^2 vt/L$ where θ_M is the ‘mixing angle’, L is the oscillation length, and v is the velocity of the neutrinos. **Here, we claim that the RH neutrino is a sterile magnetic neutrino which as soon as it appears transforms into a regular neutrino, thus recovering the code 137. In vacuum, and with $M \ll D$ (see 5.4: seesaw mechanism) $\theta_D = M/D$ and $L = 4E/(D^2 - M^2)$ where E is the energy of the neutrinos.** In the early Universe, the observation time t is replaced by the interaction time for the RH neutrinos. Works [102 - 104] has fine-tuned this picture taking into account the effect of finite density and temperature on the mixing angle [95].

The conjecture of most physicists considers that the active neutrinos enter into interaction with the neutrino of Majorana considered as the sterile neutrino, or with a "sterile state", which would produce sterile RH neutrinos: $v_L \rightarrow v_R$. **But according to the author, these sterile neutrinos would be immediately transformed into regular neutrinos. Consequently, regular neutrinos are mainly produced by neutrino oscillations between active neutrinos and sterile magnetic neutrinos:**

$$\boldsymbol{v_L \rightarrow v_R \rightarrow v_L}. \qquad \mathbf{(27)}$$

5.5.1 Lagrangian in the early universe: ordinary neutrinos from right handed magnetic neutrinos

In the early universe, when the temperature was high enough that Higgs particles were present in the primordial plasma ($T > T_{EW} \sim 140\ GeV$ for a Higgs mass $m_H \sim 125\ GeV$ [105, 106], the following Lagrangian, in which the fields v_R only interact via the Yukawa coupling F, allowed v_R-particles to participate in various different scattering processes. This Lagrangian is described by Marco Drewes in his article "*The Phenomenology of Right Handed Neutrinos*" [49]. **We took the liberty of replacing M_M, a Majorana mass term for the RH neutrinos v_R, by M_M, a sterile magnetic neutrino mass term for the RH neutrinos v_R. Our goal is the production of ordinary neutrinos by dark matter sterile magnetic neutrinos in the early universe.**

One adds n RH fermions $v_{R,i}$ to the SM that are singlet under all gauge interactions and couple to LH neutrinos in same way as RH charged leptons couple to LH charged leptons, *i.e.* via Yukawa interactions [107]. One will refer to these fields as *RH neutrinos* and to the index i that labels them as *flavour index*. Then the most general renormalizable Lagrangian in Minkowski space that only contains SM fields and v_R reads

$$\mathcal{L} = \mathcal{L}_{SM} + i\overline{v_R}\mathfrak{F}v_R - \overline{l_L}Fv_R\widetilde{\Phi} - \overline{v_R}F^{\dagger}l_L\widetilde{\Phi}^{\dagger} - \frac{1}{2}(\overline{v_R^c}M_M v_R + \overline{v_R}M_M^{\dagger}v_R^c). \qquad (28)$$

Here flavour and isospin indices are suppressed. $\mathcal{L}_{SM}$ is the Lagrangian of the SM. F is a matrix of Yukawa couplings and $\boldsymbol{M_M}$ **a magnetic mass term for the RH neutrinos** v_R. $l_L = (v_L, e_L)^T$ are the LH lepton doublets in the SM and Φ is the Higgs doublet. $\Phi = (\varepsilon\Phi)^\dagger$, where ε is the SU(2) antisymmetric tensor, and $v_R^c = C\overline{v_R}^T$, where the charge conjugation matrix is $C = i\gamma_2\gamma_0$ in the Weyl representation [49].

These considerations imply particle scatterings in the primordial plasma, which are in good approximation in thermal equilibrium and can be classified as "thermal" production. The initial thermal equilibrium implicitly assumes that the symmetry breaking scale of the new gauge group under which v_R is charged is smaller than the maximal temperature in the radiation dominated cosmological epoch. This temperature is unknown. The only observational constraint is that it should be larger than a few MeV to produce the observed amounts of light elements in the intergalactic medium in big bang nucleosynthesis [108].

Note that a physically rather different picture emerges if we assume that ordinary neutrinos can be produced during the non-equilibrium decay of heavier sterile magnetic neutrinos in the early universe. It would then be a truly non-thermal production mechanism. Heavy neutrinos can be produced in the decay of practically any heavier particle. In the minimal seesaw model below (12) they are e.g. produced in the decay of pions [109 - 111], the Higgs boson [112] and W bosons [113]. Similarly, it is a non-thermal production if this decay of massive sterile magnetic neutrinos from black holes into heavy ordinary neutrinos occurs far from thermal equilibrium (e.g., long after the decaying particle has frozen out or before it even reaches thermal equilibrium) [94].

5.5.2 Lagrangian in the Standard Model

One can choose a flavour basis where the charged lepton Yukawa couplings and M_M are diagonal and the interactions of neutrinos coupling to weak currents has the Lagrangian form in the SM

$$-\frac{g}{\sqrt{2}}\overline{v_L}\gamma^\mu e_L W_\mu^+ - \frac{g}{\sqrt{2}}\overline{e_L}\gamma^\mu v_L W_\mu^- - \frac{g}{2cos\theta_W}\overline{v_L}\gamma^\mu v_L Z_\mu \qquad (29)$$

where g is the SU(2) gauge coupling constant and θ_W the weak mixing angle. The Lagrangian term that describes the interactions in the SM defines the basis of weak interaction eigenstates (electron, muon and tau neutrino) [49].

5.6 Gauge Interactions: additional interactions related to the mechanism of neutrino mass generation

Neutrino states that appear to be sterile at the energies that are currently experimentally accessible may have new gauge interactions at higher energies. Many extensions of the

SM invoke additional gauge symmetries that are "broken" at some energy scale above the reach of the LHC. This gives masses of the order of the symmetry breaking scale to the gauge bosons, effectively switching off these gauge interaction at lower energies. If the maximal temperature in the early universe exceeds the mass of the new gauge bosons, the "sterile" neutrinos can be produced thermally by the new gauge interactions [94].

Sterile neutrinos are by definition not charged under any SM gauge group. In the minimal seesaw model (12), the v_R only couple to the SM via their Yukawa interactions F, and the low energy mass eigenstates N can only be produced via their θ-suppressed weak interaction. There is, however, no reason why the v_R should not be charged under new gauge interactions if the model (12) is embedded in a more general framework of particle physics. This possibility of a thermal production via new gauge interactions ("freeze out") could be expressed by the Yukawa interactions in the seesaw Lagrangian

$$\mathcal{L} = \mathcal{L}_{SM} + i\overline{v_{R\imath}}\mathfrak{F}v_{Ri} - \frac{1}{2}\left(\overline{v_{r\imath}}(M_D)_{ij}v_{Rj} + \overline{v_{R\imath}}(M_D)_{ij}v_{Rj}\right) - F_{ai}\overline{l_{La}}\epsilon\emptyset^* v_{Ri} - F_{ai}^*\overline{v_{R\imath}}\emptyset^T\varepsilon l_{La} \tag{30}$$

For physicists, it is not clear whether neutrinos are Dirac or Majorana particles. We consider that neutrinos are Dirac particles (active neutrinos), which requires the existence of RH neutrinos v_R to construct mass term $\overline{v_L}M_D v_R + h.c.$ M_D is a Dirac mass matrix for the singlet fields v_{Ri}. The Dirac mass term M_D is allowed for v_R because the v_R are gauge singlets. $\mathcal{L}_{SM}$ is the Lagrangian of the SM. L is LH neutrinos. R is RH neutrinos. v_i is mass states; three light neutrinos v_i can be identified with the known neutrinos. v_{Ri} is mass states for RH neutrinos: for us, they are sterile magnetic neutrinos from black holes. $l_L = (v_L, e_L)^T$ are the LH lepton doublets. Here $\emptyset$ is the Higgs field and $\overline{\emptyset} = \epsilon\emptyset^*$, where ε is the antisymmetric SU(2)-invariant tensor and F is a matrix of Yukawa interactions. The F_{ai} are Yukawa couplings between the v_{Ri}, the Higgs field $\emptyset$ and the SM leptons l_{La}.

Gauge theories try to explain the ordering and interactions between elementary particles. The general framework of these theories is the quantum field theory which symmetrically quantifies particles and interaction fields in a relativistic framework [114]. Our goal is to try through the mechanism of the gauge theories to grasp that it is not active neutrinos in interactions with sterile states which produce sterile neutrinos but **sterile magnetic neutrinos in interaction with active neutrinos which are transformed into regular neutrinos**.

6 Dark matter not so dark after all; Academic hypotheses

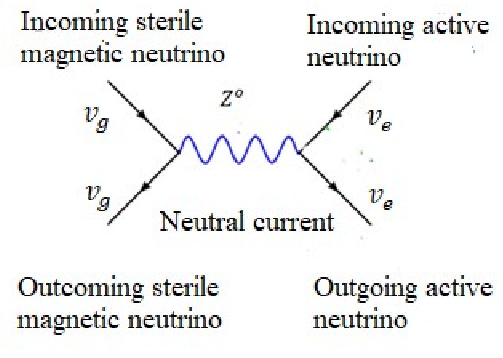
The following explanatory diagrams and diagrams are partially schematic, and are not images of the real microscopic world. They illustrate the relationships between different processes, but cannot substitute for detailed mathematics. We start by showing the interactions of the sterile magnetic neutrinos of dark matter with each other and with the active neutrinos of ordinary matter. Then, we cannot resist the temptation to deal with specific equations of possible production of gamma-rays from the cosmic annihilation of neutrinos-antineutrinos. Finally, we present the anapole which has already been suggested as a model of elementary particles describing dark matter in the universe [115, 116]. Here, we propose that sterile magnetic neutrinos may exhibit a nonradiating current setup in dark matter. An anapole mode can be viewed of as an overlap of electric and toroidal dipole moments that have resulted in destructive interference of radiation fields. When such an anapole (composed of Dirac neutrinos) moves at high speed in an electromagnetic field it couples to it all the more noticeably as it is in rapid motion. In this sense, dark matter has a pale glow.

6.1 Interactions between sterile magnetic neutrinos and active neutrinos

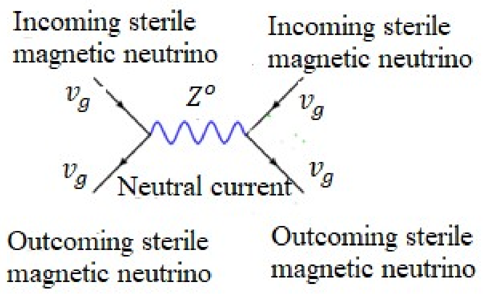
6.1.1 Weak neutral interactions

The presence of Z^o in the electroweak theory implies that there are neutral weak interactions, exchanges of Z^o without altering the identities or charges of the particles. These processes that do not involve the charge (electric or magnetic) of the particles involved are referred to as “neutral current”.

1 a)



1 b)



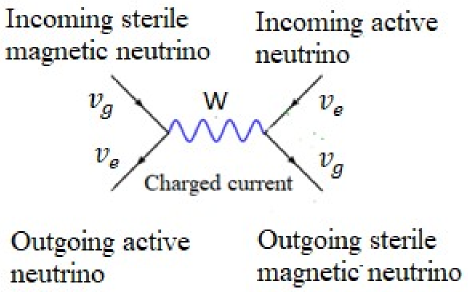
1 a) A sterile magnetic neutrino of dark matter passing close to an active neutrino of ordinary matter does not disturb the latter and generates no creation of particles, the neutrinos themselves being simply deflected.

1 b) A sterile magnetic neutrino of dark matter passing close to another sterile magnetic neutrino of dark matter does not disturb the latter and does not generate any particle creation, the neutrinos themselves being simply deflected.

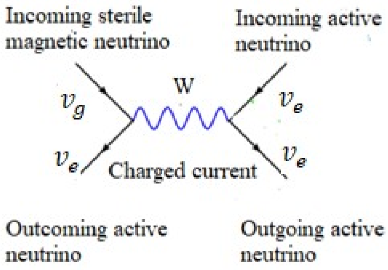
6.1.2 Interaction of a sterile magnetic neutrino of dark matter with an active neutrino of ordinary matter

The analogy with electromagnetic, Yukawa and weak interactions suggests that the interactions of sterile magnetic neutrinos of dark matter, between themselves or with active neutrinos of ordinary matter, would be due to the exchange of messenger particles (virtual quantum of a field) analogous to $W^{\pm}$. The interaction between two "weak currents", similar to the force between two electric currents, is carried by a particle resembling W. This type of W carries a magnetic or electric charge, positive (W^{+}) when the interaction carries a positive charge from left to right, or negative (W^{-}) in the other direction.

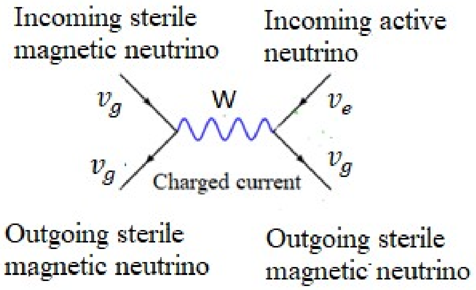
2 a)



2 b)



2 c)



2 a) We can consider that the weak charged currents circulate in both directions $(W^{\pm})$ and that, simultaneously, the sterile magnetic neutrino is transformed into an active neutrino on the left side while the active neutrino is transformed into a sterile magnetic neutrino on the right side.

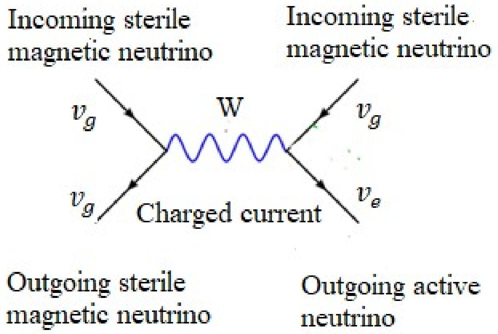
2 b) We can consider that a weak negative current (W^{-}) transforms a sterile magnetic neutrino into an active neutrino on the left side.

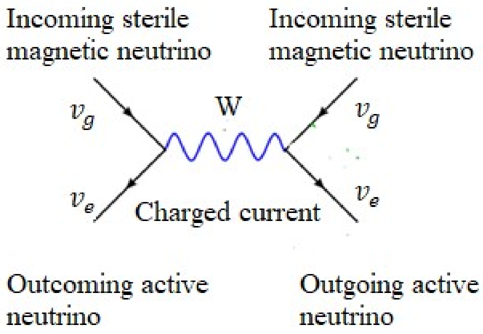
2 c) We can consider that a weak positive current (W^{+}) transforms an active neutrino into a sterile magnetic neutrino on the right side.

6.1.3 Interaction of a dark matter sterile magnetic neutrino with another dark matter sterile magnetic neutrino

3 a)

3 b)





3 a) We can consider that a weak positive current (W^+) transforms a sterile magnetic neutrino into an active neutrino on the right side.
3 b) We can consider that the weak charged currents flow in both directions ($W^{\pm}$) and the sterile magnetic neutrino is transformed into active neutrino on the left side while the sterile magnetic neutrino is also transformed into active neutrino on the right side .

Note that the weak force differs from other forces in that it changes the "type" of matter more readily than its motion; thus it can change dark matter into ordinary matter and vice versa. Electroweak theory involves low interaction processes that bring into play the electric or magnetic charge of the particles involved. The W bosons cause low interaction processes that modify the charges. To understand the weak interaction as an explanation of the transmutation of the particles, it is necessary to consider that the charged weak currents between the magnetic neutrinos of the dark matter and the neutrinos of the ordinary matter have this faculty through the transformations to decode or to restore the code 137.

6.2 Sterile magnetic neutrinos and gamma rays production

In this section, which is an extension of subsection 2.5.2 dealing with polarized vacuum, we address specific equations of possible gamma-ray production, both interstellar and intergalactic, from cosmic neutrino-antineutrino annihilation. These equations are all the more highly speculative as they come from sterile magnetic neutrinos. Nonetheless, they are justified by the importance of finding evidence for the existence of dark matter and sources of gamma-rays [117]. Gamma-rays undergo negligible absorption in most cases of astrophysical interest and travel in straight lines from their sources. In this, they differ from cosmic rays which, being charged particles, see their movements continuously modified by interactions with cosmic magnetic fields. Gamma rays are made up of ultra-energetic photons that cannot penetrate far into the Earth's atmosphere because they quickly interact with the high layers of air by bursting a cascade of particles. As a result, gamma ray detectors must operate above the atmosphere, on board satellites in orbit around the Earth. Therefore, much can be learned about the sources and interactions of cosmic rays by studying the spatial and energetic distribution of the gamma-rays (γ-rays) they produce.

Gamma-ray production from cosmic neutrino-antineutrino annihilation.

Neutrinos and antineutrinos can interact magnetoelectrically and thus annihilate each other to produce γ-rays. This annihilation can occur in the following ways.

1- A free antineutrino can annihilate with a free neutrino to produce, most often, two γ-rays:

$$\bar{v}_g + v_g \to \gamma + \gamma \tag{31}$$

2- A low energy neutrino and antineutrino can first combine to form a positronium-like system, consisting of a neutrino and an antineutrino bound together in an exotic and unstable atom that we will call "antineutrinium" (which we will refer to as with the symbol $\dot{v}$). The system can then annihilate into two, three or more γ-rays (ζ is the number of γ-rays):

$$\bar{v}_g + v_g \to \dot{v}_g \to \zeta\gamma \tag{32}$$

Absorption of gamma-rays by interaction with dark matter

There are two types of interactions to consider here. The first involves the conversion of a γ-rays into a neutrino-antineutrino pair in the magnetostatic field of a charged magnetic particle or a sterile magnetically charged neutrino. If we denote such a charge field by the symbol MCF, such an interaction can be symbolically written as

$$\gamma + MCF \to \bar{v}_g + v_g + MCF \tag{33}$$

The conversion interaction, or production of pairs as it is usually called, has a cross section (technical term to call the probability of interaction) which involves an additional factor of the fine structure constant, either $\alpha_g = keg/\hbar c$ (g is a magnetic charge) linked to equation (4-a), or $\alpha_g = g^2/hc$ linked to equation (4-b), because it involves an intermediate interaction with a magnetostatic field.

The second type of γ-ray absorption process in matter is the scattering interaction

$$\gamma + v_g \to \gamma + v_g \tag{34}$$

Compton scattering does not eliminate the γ-ray per se, but will in all probability result in the transfer of some of the energy of the γ-ray towards the neutrino, thus absorbing the energy from the γ-ray. For the γ-ray of energy $E_\gamma \ll mc^2$, almost all of the energy of the

γ-ray is absorbed, and then we can consider that the γ-ray has "disappeared". The ideal would be to define an "absorption cross section" σ_a, such that

$$\sigma_a = (\Delta E_\gamma / E_\gamma)\sigma_c \tag{35}$$

where ΔE_γ is the average amount of energy transferred from the γ-ray to the neutrino.

In the case of high energy $\bar{v}_g - v_g$ annihilation, reactions of the form

$$\bar{v}_g + v_g \rightarrow \; bosons \; \rightarrow photons \; + \gamma \tag{36}$$

can be considered, as well as the annihilation of types

$$\bar{v}_g + v_g \rightarrow \; \bar{v}_g + v_g + \gamma. \tag{37}$$

6.3 Anapole dark matter

We said that sterile neutrinos associated with a magnetic charge (as electron neutrinos are associated with an electric charge) were sensitive only to gravitational force. They would come from inside black holes where, as we have shown, there would have been an inversion of charges, the magnetic charge having replaced the electric charge. But then, how can these neutrinos associated with a magnetic charge, which therefore have a magnetic and electric structure primer, be insensitive to electromagnetic, electric and magnetic forces? There is a very particular configuration of electric and magnetic fields, the anapole, which can be associated with them. The term anapole means "without pole" in Greek. A magnetic anapole for a Dirac fermion was originally proposed in nuclear physics by physicist and cosmologist Yakov Zeldovich in 1958 [118]. The first experimental measurement of an anapole moment in atomic nuclei was noted by Woods *et al*. [119]. The coupling of an anapole dark matter to a dark photon has already been considered by Fitzpatrick and Zurek [120]. Unlike the electric and magnetic dipole moments which has been considered by a variety of authors for more than a decade as the way that dark matter might interact electromagnetically with ordinary matter, the anapole moment has been considered as a possible form of electromagnetic coupling to the dark matter [121] which has no classical analogue, as it does not correspond to a multipolar distribution.

Its simplest representation is that obtained with a magnetic coil, a solenoid, closed on itself and glued at its two ends to form a torus. The electric currents circulating along the small circles of the torus then generate a magnetic field along the large interior circles of the torus, and at this location only. Outside the torus there is neither electric field nor magnetic field.

We can thus illustrate the magnetic field inside the torus:

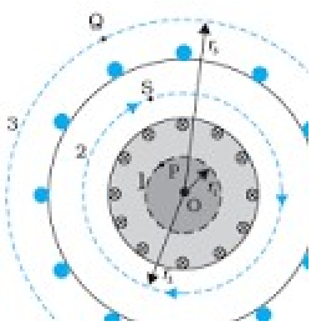


Figure. The magnetic field in the open space inside (point P) and exterior to the toroid (point Q) is zero. The field B inside the toroid is ***constant in magnitude for the ideal toroid of closely wound turns***. The direction of the magnetic field inside is clockwise as per the RH thumb rule for circular loops [122].

While electric dipoles can be understood as separated charges and magnetic dipoles as circular currents, axial (or electric) toroidal dipoles describes toroidal charge arrangements whereas polar (or magnetic) toroidal dipole (also called anapole) correspond to the field of a solenoid bent into a torus. Anapole is a balanced superposition of electric and toroidal dipoles. It emerges when the fields radiated by the electric and toroidal dipoles cancel each other out. Because the loop encloses no current, the magnetic moment of toroid is zero. Strangely, we obtain a nonradiating current configuration.

Thus in 2013, two American physicists [123, 124] proposed a model of dark matter particles that contradicts the claim that dark matter does not emit light because it cannot interact with the electromagnetic field. These particles are anapoles that are sensitive to electromagnetic forces, although very weakly in the current universe. In their article, they view the dark matter to be a Majorana fermion with spin $1/2$. Neutrinos would be their own antiparticle which can be described by the Dirac equation [125].

Dark matter was thought to be mostly a spin $1/2$ Majorana fermion, after Zeldovicth proposed in 1957 the possibility that particles could have an anapole moment. For the first time experimentally in cesium atoms in 1997 [119], it was measured that the anapole moment interaction breaks C and P, but preserves CP. According to that, the interaction operator for this anapole moment is of the form

$$\bar{\chi}\gamma^{\mu}\gamma^{5}\chi\partial^{\nu}F_{\mu\nu} \tag{38}$$

where χ is the dark matter and $F_{\mu\nu}$ is the electromagnetic field strength tensor. In their model, Majorana fermion have direct coupling to the SM photons.

6.3.1 Lagrangian of anapoles (Dirac neutrinos) seen as dark matter

Our model differs from all others in that we view dark matter as sterile magnetic neutrinos and as neutral Dirac fermions. The sterile magnetic neutrino can be modeled by the anapole, that is to say by a torus, which is a closed solenoid around which electric currents like meridians generate parallel magnetic fields, confined inside the torus. We notice that the corresponding anapole interaction operator for a Dirac fermion takes exactly the same form as for a Majorana fermion [123]. Dark matter magnetic neutrinos are also coupled to SM photons. The model with the Dirac fermion has a different Lagrangian as a result.

The interaction with photons of a Dirac fermion χ with spin $1/2$ due to its anapole moment can be expressed in a Lorentz invariant form as

$$L = \frac{1}{2}\frac{g}{\Lambda^2}\bar{\chi}\,\gamma^u\,\gamma^5\chi\eth^v F_{uv}. \tag{39}$$

where g is a dimensionless coupling constant and Λ is the new physics mass scale. In the non-relativistic limit, this contains the interaction of the particle spin with the curl of the magnetic field,

$$H = -\left(\frac{g}{\Lambda^2}\right)\sigma.\nabla \times B \tag{40}$$

Notice that $\overline{\chi}\,\gamma^u\chi$ are for Dirac anapoles [126, 127]. In principle, it remains that these anapoles can exist in the form of neutralized states. They can be thought to possess a nearly non-active magnetic charge (or some other type of charge) which minimizes their rate of interaction with ordinary matter.

6.3.2 Anapole sensitive to other forces

How can a uniquely anapole particle be sensitive to electromagnetic, electric or magnetic forces? It is not prohibited to think that the polar (or magnetic) toroidal dipole, which corresponds to the field of a solenoid folded into a torus, can also interact with external currents. In other words, it can present an anapole mode with a certain radiation in the visible. When such an anapole moves, in particular at high speed, in an electromagnetic field, it is coupled to it all the more strongly as it is in rapid movement. The interaction cross section decreases as the particle velocity slows down [122]. If dark matter is composed of Dirac fermions in the form of anapoles, in this case sterile magnetic neutrinos from black holes, so it can be sensitive to electromagnetic fields, electric fields and magnetic fields. In some way, properly speaking, it is not quite dark, although it still cannot radiate like normal matter. Just as the term "sterile" in the expression "sterile magnetic neutrino" can mean as much absence of charge as presence of a potentially active “neutral” charge, the term “dark matter” may mean as much absence of radiating current as presence of non-radiating current weakly sensitive to electromagnetic forces.

As we said at the beginning of the introduction, cosmological models have established that dark matter would represent more than 80% of the matter of the universe to constitute approximately 27% of the total energy density of the universe observable. These figures come from cosmologists who have adopted a methodology that is not based on a physical theory but on a blind faith in overly schematic numerical models that manipulate the concepts of dark matter and dark energy with no relation to reality. Dark energy, as presented with the accelerating expansion of space, has not been predicted by any theory. It is based on the measured distance of the distance of very distant supernovae whose measurements cannot be trusted, and on the gratuitous and unprovable assumption that the intrinsic luminosity of supernovae is the same for all, independent of the measured object [128, 129]. Cosmologists have decreed that dark matter existed in its entirety from the beginning of the universe. Dark matter particles can annihilate into SM particles and SM particles annihilate into dark matter [74]. So, when the universe was denser and warmer, these particles of dark matter moved quickly, thus interacting with normal matter and electromagnetic fields more strongly than today. In fact, the more the universe cools, the more the speeds of these particles decrease, and the less they are sensitive to these fields, the number of dark matter particles then remains constant.

According to our hypothesis, the dark matter would come from the black holes that formed throughout the expansion. Even though the rate of annihilation in the universe is decreasing on average and the reactions that transform dark matter particles into SM particles are no longer as efficient, the number of dark matter particles is gradually increasing as well as the transformation of particles of dark matter into SM particles. Some *residual annihilations* could occur in regions of the universe displaying overdensity, such as galactic halos, including our own. The radiation produced by the annihilation of dark matter could be observed with gamma-ray telescopes.

Another alternative could be that the magnetic toroidal anapole is not simply bent, but also twisted on itself, much like a *Möbius strip* [130]. If we consider a kind of half-turned ribbon whose two ends have been joined like a road, the current can travel over it incessantly, finding itself sometimes on its interior surface, sometimes on its exterior surface. A Möbius torus is an efficient model to see how a current can be inside and outside at the same time [131]. Gravity, which passes through everything, is related to the torus. It is the same with magnetism up to a certain point. The weak magnetic fields that come from ordinary matter penetrate the outer magnetic surface of the torus. This time, there is an anapole mode with radiation in the visible.

Although such solutions remain highly speculative and, above all, difficult to test experimentally, we nevertheless have a new model of dark matter particle having additional possibilities of interaction with normal matter, which is not based on the introduction of new exotic forces.

7 Sterile magnetic neutrino interacts with magnetism and weak force

The field concept for electric force can be extended to magnetic force and also to gravitational force. The electric charge or magnetic pole is the source of the field, the intensity of which gradually decreases with distance from the source. These fields are long range and extend to infinity. The charges and the current of the weak force are very close to the charges and electric currents, to the poles and to the magnetic currents. The main difference is the short range of the interaction, governed by the mass of the W and Z particles [132]. We find in section 7.1 a neutrino mass probably less than 1 eV. The following sections use sterile magnetic neutrinos, some masses of which could be much higher. It is magnetically and electrically neutral and, despite its associative charge which makes it less prone to react with matter than the ordinary neutrino, it has something to do with the latter. We sketched above from a phenomenological point of view how they interacted together. Although its interaction with light and ordinary matter is very weak, this minimal hypothesis of an interaction has the power to bring together and reconcile diverse observations, covering scales from the size of a galaxy to part of the observable universe. All this, including observed decay glows and the results of numerical simulations, does not prove the existence of sterile magnetic neutrinos but gives it credibility.

7.1 Unknown value of the absolute mass of the ordinary neutrino

The SM of particle physics assumed that neutrinos had no mass [133]. The experimentally established phenomenon of neutrino oscillation, which mixes flavor states of neutrinos with mass states of neutrinos requires neutrinos to have non-zero masses [134]. In 1998, research results at the Super-Kamiokande Neutrino Detector determined that neutrinos can oscillate from flavor to flavor [135]. If the experiments seem to confirm that the neutrino does have a mass, it does not give its value. By measuring the length of these oscillations, they simply deliver the difference in mass between the different families: the longer the measured oscillation, the smaller this difference. The basic frame is improved to account for their mass by adding a RH Lagrangian. The absolute mass scale of neutrinos is still not known: neutrino oscillations are sensitive only to the difference of the squares of the masses [136, 137]. As of 2020, the best-fit value of the difference of the squares of the masses of the mass eigenstates 1 and 2 is

$|\Delta m_{21}^2| = 0.000074 eV^2$, whereas for eigenstates 2 and 3 it is $|\Delta m_{32}^2| = 0.00251 eV^2$. Since Δm_{32}^2 is the difference of two squared masses, at least one of them must have a value which is at least the square root of this value, i.e. $0.05\ eV$ [138, 139].

The strongest upper bound on neutrino masses comes from **cosmology**: the Big Bang model predicts that there is a fixed ratio between the number of neutrinos and the number of photons in the cosmic microwave background. If the total energy of the three types of neutrinos exceeded an average of $50\ eV$ per neutrino (the estimated density of dark mass divided by the estimated number of fossil neutrinos), there would be so much mass in the universe that it would collapse [140].

A stringent constraint comes from a careful analysis of cosmological data, such as the cosmic microwave background radiation, galaxy surveys, and the Lyman-alpha forest. Analysis of data from the WMAP microwave space telescope found that the sum of the masses of the three neutrino species must be less than $0.3\ eV$ [141]. In 2018 the Planck collaboration published a stronger bound of $0.11\ eV$, which was derived by combining their CMB total intensity, polarization and gravitational lensing observations with Baryon-Acoustic oscillation measurements from galaxy surveys and supernova measurements from Pantheon. A 2021 reanalysis that adds redshift space distortion measurements from the SDSS-IV eBOSS survey gets an even tighter upper limit of $0.09\ eV$ [142]. However, several ground-based telescopes with similarly sized error bars as Planck prefer higher values for the neutrino mass sum, indicating some tension in the data sets [143].

A number of efforts are under way to directly determine the absolute neutrino mass scale in **laboratory experiments**, especially using nuclear beta decay. Upper limits on the effective electron neutrino masses come from beta decays of tritium. The Mainz Neutrino Mass Experiment set an upper limit of $m < 2.2\ eV/c^2$ at a *confidence level* of 95% [144]. Since June 2018 the KATRIN experiment searches for a mass between 0.2 eV and 2 eV in tritium decays [145]. The February 2022 upper limit is $m < 0.8\ eV/c^2$ at a confidence level of 90% in combination with a previous 2019 KATRIN campaign [146, 147].

Thus, data from CMB and other methods indicate that the average mass of the three known flavors of neutrinos probably does not exceed 0.3 eV/c^2. This is far from the collective average of 50 eV/c^2 that it would take to saturate all the missing mass. If the estimates provided by *Sudbury Neutrino Ontario* are correct, the sum of all neutrinos can only represent between 0.1% and 18% of the mass of the universe.

With such a low mass, far from the expected total, the observed neutrinos cannot explain dark matter. [130]. Even in the most favorable case obtained after a few decades as $m(v_{e,\mu,\tau}) < 2\ eV/c^2$, it will be necessary to make use of other particles. We have stated that our candidate is the sterile magnetic neutrino. It is called "sterile" because it is associated with a magnetic charge instead of an electrical charge, and thus violates code 137 -- (we will be surprised that the magnetic charge is substituted for the electric charge, which is a violation of the conservation of the charge, but we are no longer surprised of the oscillation which is a process which violates the conservation of the energy). Unlike the ordinary neutrino, it is generally a slow and heavy that lets itself be glimpsed by its gravitational effects alone. It could be part of the WIMPs, extensions of the SM of particle physics. It seems unavoidable to account for the dark halos of galaxies. It remains trapped in these huge masses surrounding the structures and which emit no radiation. By agglutinating there, it never ceases to strengthen them.

7.2 Sterile neutrino with magnetic charge receives energy from magnetic fields of stars or pulsars

Magnetic fields have been detected almost everywhere in the universe: planets, stars, galaxies, and the largest webs can cover clusters of galaxies. Although these galactic magnetic field lines are only a billionth of the power of a typical fridge magnet, they more than make up for this shortcoming with their large size [148].

The Milky Way galaxy has its own magnetic field. It is thousands of times weaker compared to Earth. In a spinning star or accretion disk (gravitational capture of mass), electrons and ions tend to move at different speeds and on different paths. This leads to a separation of electric charges and the appearance of an electric field. According to the law of induction, an electric field generates a magnetic field. The interstellar medium receiving matter from stars, thanks to stellar winds or supernova explosions, would thus acquire a magnetic field. It is possible that these injected star fields could be amplified by a new "dynamo" (a weak magnetic field amplified by the transfer of part of the mechanical energy of a rotating gas) and end up resembling a galactic field. When a galaxy expels interstellar gas, the intergalactic medium could be seeded by these magnetic fields with a dynamo acting as an amplifier to bring their intensity to that seen in galaxy clusters. Astronomers have discovered that the intensities of magnetic fields near supermassive black holes at the center of these galaxies can be as strong as their intense gravitational fields. In general, magnetic forces are only important if the energy density in the magnetic field is of the same order of magnitude as the internal energy of the gas. In fact, the accretion discs surrounding black holes would generate magnetic fields capable of expelling matter from the vicinity to form very energetic outlets called "jets". The latter would also carry magnetic fields to surrounding galaxies and intergalactic space [149, 150].

There appears to be a relationship between the distribution of magnetic fields from baryonic matter and that of dark matter. Such a correlation can make it possible to detect in the cosmos the trace of this dark matter beyond its sole gravitational presence. The idea is to assume that magnetic fields, even if they are distributed diffusely, have areas strong enough that dark matter particles can sometimes interact with weak force [151]. By postulating that dark matter is composed of a neutrino with a positive magnetic charge (pole +) and a neutrino with negative magnetic charge (pole −), then a collision between two of these neutrinos produces a pair of photons or another pair particle-antiparticle, for example an electron and a positron. In the first case, the goal is to look for an excess of photons. However, since dark matter particles are likely to have a low velocity, it is expected that their mutual annihilation will give rise to photons located in a relatively narrow energy band. It is in search of a kind of emission line more or less marked that many astrophysicists devote themselves, but here again, the difficulty is to extract a signal of dark matter from the high-energy "noise" produced by much more conventional astrophysical processes.

On a galactic scale, many researchers believe that X-rays come from conventional sources such as ionized elements, while gamma-rays come from more ordinary sources, such as **pulsars.** Without venturing to assert that the path of sterile magnetic neutrinos is the only right path, we give it as much credit, if not more, than the path of pulsars or that of atomic processes involving phosphorus, sulfur or chlorine highly ionized.

There would be a large number of ultra-diffuse galaxies in the universe. These are galaxies with low density. Such a galaxy having a size similar to the Milky Way would count on average one hundred times less visible stars, having a very weak luminosity. The Subaru telescope has detected a large number of them in the Coma Berenices cluster. It is assumed that they must contain significant amounts of dark matter (up to 98%) for their structure to resist the tidal forces generated by nearby normal galaxies, without containing many stars and visible matter. However two ultra-diffuse galaxies containing very little dark matter seem to have been discovered in 2018 and 2019 in the group NGC 1052-DF2, potentially challenging theoretical models of dark matter [152, 153].

On the outskirts of the Milky Way, there are "ultra-diffuse dwarf galaxies". In other words, galaxies of very small size and very poor in stars, like Eridamus 11 [154]. There would be in these dwarf galaxies a thousand times more dark matter than visible matter which constitutes gas and stars. If this dark matter is made of sterile magnetic neutrinos, they must from time to time **be immersed in a magnetic field from stars.** The magnetic charges of the neutrinos then receive kinetic energy from these magnetic fields, which sooner or later leads to the annihilation of these particles and the appearance of an X-ray glow.

In this case, a process of dynamo amplification of magnetic fields may be at work: in early 2020, ESA's XMM-Newton discovered burning gas in the Milky Way halo: gas hiding in the halo reaches much hotter temperatures than previously thought and has a different chemical composition than expected [155]. The halo of the Milky Way (and any galaxy) would contain not one but three different components of hot gas, the hottest of them being a factor ten hotter than previously thought.

Faint gamma-rays have been detected in the heart of the Milky Way or coming from the center of galaxy clusters. This may suggest neutrinos with magnetic charge which have a low mass (of the order of KeV). A magnetic neutrino can disintegrate spontaneously. The encounter of dark matter with a magnetic field could further accentuate this disintegration. Just as it could cause neutrino-antineutrino collisions.

The light produced by dark matter annihilation is made up of high-energy photons, gamma-rays, whose energy would be comparable to the mass of dark matter particles. A greater gamma-ray glow at the heart of the Milky Way could emanate from stronger sterile magnetic neutrinos of the dark matter. In the case of the WIMP hypothesis, this mass is between about ten and ten thousand times the mass of a proton, which corresponds to energy between 10 GeV and 10 TeV [49]. The brilliance of these disintegrations could also mean that the state of charge is restored, code 137 is reintegrated and electromagnetism is reconstituted.

Even though the annihilation rate in the universe is very low on average, some residual annihilations could occur in areas of the universe with overdensity, such as galactic halos. Astrophysicists have suggested that the radiation produced by annihilation of dark matter can be observed with gamma-ray telescopes, which is an indirect way of proving the existence of dark matter. The latter is larger in galaxy clusters, mainly in the central part of the cluster. In these clusters, there are more stars, and certainly more black holes [74].

We assume that these black holes emitted sterile magnetic neutrinos that form this dominant dark matter. They are the dust of black holes.

Astrophysicists have observed that it is near massive celestial objects - white dwarfs, neutron stars, supernova, quasar, pulsar – that dark matter halos are almost nonexistent.
Nevertheless, due to the magnetic charge of sterile neutrinos, one would expect a **concentration of halos** around these celestial objects which have high density and strong magnetic field. As this is not the case, one could see a fatal danger for the thesis of the magnetic charge associated with sterile neutrinos. This argument is specious because whatever the nature of the dark particles, their low density clouds are immediately absorbed by the gigantic gravitational pull of these ultra-massive celestial objects. And if we temporarily disregard gravitational attraction, wouldn't the magnetic charge of sterile

neutrinos force dark matter to concentrate around these magnetic objects? Certainly not, because the star's magnetic field B, extending over the distance L from the halo, would transfer the gBL fraction of its total energy to sterile magnetic neutrinos relatively to rest. These latter would gain considerable kinetic energy and move apart in one direction or the other. Thus, the magnetic charge of sterile neutrinos could not force dark matter to shape a halo around a dense magnetic object like a neutron star, a pulsar or a magnetar [156], and that is what is found.

7.3 Sterile magnetic neutrino linked to the protection and distribution of visible and invisible matter

1) The shape of the gravitational field of the Galaxy, related to the distribution of visible and invisible matter, is rather spherical. However, visible matter in the Milky Way, including molecular hydrogen gas, is distributed in a flattened disc. Ordinary matter cannot therefore give the gravitational potential of the Galaxy its sphericity. The dark matter hypothesis is therefore necessary, not only with regard to the sphericity of the gravitational potential of the Milky Way, but also to explain the dynamics of galaxies and structures on a larger scale [157].

This supposed distribution of dark matter works for a good number of spiral galaxies. Numerical simulations of the formation of galaxies and their dark matter halo show that the latter has a spherical density and inversely proportional to the distance r from the center of the galaxy, that is to say a density profile in $1/r$. Strictly speaking, density does not become infinite at the centre: it is replaced by a small core of constant density [158, 159]. Assuming this dark matter halo with a small core and a $1/r$ profile, we get the right gas velocity profile in some galaxies.

We can imagine that the dark matter halo, which is a hypothetical component of a galaxy that envelops the galactic disk and extends well beyond the visible limits of the galaxy, forms a kind of protective belt like the Van Allen belts. Neutrinos associated with a positive magnetic pole and neutrinos associated with a negative magnetic pole that make up dark matter may be thought to have polarized to shape a dark magnetic field around the galaxy. Winds of dark matter, composed of sterile magnetic neutrinos, arrive from other galaxies. Such winds are plasmas. When these ionized winds, more or less warm, pass through the halo, they are nothing but magnetic poles, positive and negative, cutting lines of force. They are therefore able to produce dark electricity. By trapping the winds of dark matter, the dark magnetic field deflects these energetic magnetic monopoles and protects the galaxy's gaseous atmosphere from destruction. We can also anticipate winds that pass through the halo and add energy that accelerates unpolarized neutrinos near the

galaxy. When these magnetically charged particles interact with the hydrogen gases that envelop the galaxy, they transmit their energy and cause the gases to glow.

2) But this distribution of dark matter does not work for a large number of galaxies, especially those with **low-surface**-brightness [160-162]. Astrophysicists have noticed, since the beginning of the century, a correlation between the size of the core of constant density of dark matter necessary to obtain the good dynamics of rotation of the gas and the size of the baryonic matter disc [163]. In other words, the more diffuse and extensive the galaxy, the larger its core of constant density of dark matter is itself [164]. So there seems to be a direct relationship between the distribution of ordinary matter and that of dark matter. Such a strong correlation is difficult to explain if dark matter and baryonic matter interact only by gravitation or other very weak forces.

To explain the correlation between the core of dark matter and the distribution of ordinary matter, it is necessary a coupling between these two components of matter. As part of our model on sterile magnetic neutrinos, they may be sensitive to ordinary magnetic fields. These galaxies are very diffuse and very few stars form in them; gas predominates, hot gases, such as molecular hydrogen (H_2), which are difficult to observe [56].

For us, these gases can contain a lot of ferromagnetic dust which can interact with sterile magnetic neutrinos in dark matter. We assume that in low-surface-brightness galaxies, the magnetic aspect of baryons and the magnetic aspect of sterile neutrinos issued from black holes attract, harpoon, and exchange energy.

It is this kind of interaction, or cramping (gripping), on the cosmological scale, not foreseen by galactic formation simulations, that explains the direct relationship between the distribution of ordinary matter and that of dark matter. A strong correlation becomes easy to explain if baryonic matter and dark matter interact with the dark magnetic force, and not only through gravity or other weak forces.

3) But to understand the relationship between magnetic fields and sterile neutrinos with magnetic charge, let's go back to the 1940s, when scientists (H. Alvin [165], F. Hoyle [166], Bondy & Gold [167], etc.) understood that electromagnetic forces must have played an important role in the formation of astronomical systems. Before the existence of a magnetic field in galaxies was proved, the Soviet astronomer V. Dombrovski [168] and his American colleague WA Hiltner [169] independently observed a curious phenomenon: the light of a star, passing through the visual ray, it that is to say, following the line which goes from the star to the eye of an observer, turned out to be polarized, and this all the more so as the ray of light encountered more dark matter on its way.

Astrophysicists wondered why this is so. No matter how dark matter holds light, shouldn't it just weaken it instead of polarize it? The only explanation that specialists could come up with was that the dark matter may have consisted of an accumulation of grains of ferromagnetic dust. Under the effect of the magnetic field, the grains of dust polarized the light [170].

Our explanation is that dark matter consists of an accumulation of sterile magnetic neutrinos tapered like tiny needles. Under the influence of the magnetic field, neutrinos similarly orient themselves in space and polarize light.

7.4 Glows of gamma-rays in the dark: dark matter or pulsars

In 2009, Dan Hooper, theorist at the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois, and his colleague Lisa Goodenough discovered the unexplained glow of gamma-rays while studying data from NASA's Fermi Gamma-ray Space Telescope [171]. An excess of gamma-rays at an energy of 130 GeV in the direction of the galactic center. A difficult explanation to find in the framework of classical astrophysical models, but which echoes models of particle physics called «supersymmetric models». They immediately suggested that this glow that envelops the heart of the galaxy could be evidence of dark matter [172]. The opposite idea is to attribute an astrophysical origin to these high energy photons and to presuppose that they come from a set of individualized sources like pulsars. In 2015, Tracy Slatyer [173], particle astrophysicist at the Massachusetts Institute of Technology (MIT) at Cambridge, and her colleagues seemed to demonstrate that all the excess of the galactic centre could come from a population of pulsars too weak for Fermi to solve individually, which had the effect of cooling interest in dark matter. However, in 2019, Slatyer and MIT postdoc Rebecca Leane found a problem with the various spatial models or models used to subtract other contributions to gamma-ray flux, reviving hope for a true dark matter signal [174].

Distinguishing between dark matter or ordinary matter requires the ability to map a possible excess of high-energy photons with good angular resolution, but unfortunately the telescopes that might be suitable are among the most myopic. Particle theorists say the excess of the galactic center is likely to remain too ambiguous to be decisively analyzed. However, more recently, rays of the order of keV have been observed, involving lighter particles. This result was obtained in a hitherto relatively little explored energy band, in the field of the kiloelectrovolt. Between 2014 and 2016, several teams of astrophysicists observed from the center of galaxy clusters an X-ray (gamma) spectral line with an energy of about 3.5 keV. These excess energy have been detected by several X telescopes, the European *XMM-Newton* and then the Japanese *Hitomi* [175]. This precise spectral line does not correspond to anything known and seems very real, that is to say statistically significant. According to Kevork Abazajian, an American physicist who works at the University of California, the only remaining hypothesis to explain the existence of these photons appearing to come from where there is the darkest matter is that they would come from the decay of sterile neutrinos. He considers that all dark matter consists of such sterile 7 keV neutrinos. As they are a bit heavy, they would decay, producing "normal" neutrinos and photons. He demonstrated in an article by what mechanism sterile 7 keV neutrinos can be produced and be at the origin of the unknown gamma lines observed at 3.5 keV, an energy which is said to be half their mass [176].

Dessert *et al*. [177] tested the hypothesis of an unidentified astronomical X-ray emission line, interpreted as being caused by the decay of a dark matter particle, using observations from the XMM-Newton space telescope (X-ray Multi-Mirror Mission). Analyzing regions of white sky with a total exposure time of about a year, they found no evidence of the predicted line, ruling out the previously proposed dark matter interpretation.

8 Conclusion

The existence or nonexistence of dark matter in the universe is a question of importance in the fields of cosmology and particle physics. Since the existence of large amounts of dark matter in the universe was proposed to account for the condensation of matter into galaxies, physicists have found more and more evidence that it is real, but not a only sign of the substance itself. Omnipresent throughout the cosmos and elusive, it has resisted any attempt at detection, whether by astronomers or particle physicists. Far from giving up, they try a lot of things until they find something that works, bearing in mind that the negative results are just as important as the positive ones. For the past 40 years or so, most have agreed that most of the missing mass is not in condensed form (Macho). The commonly held idea since is that much of the dark mass is made up of a non-baryonic substance. In this regard, we have proposed for dark matter the existence of a large quantity of neutrinos and antineutrinos associated with the magnetic charge. And since the existence of this type of sterile magnetic neutrino is inexplicable in the current state of our knowledge, we have altered the laws of known electromagnetism to explain the metamorphosis of electric charge into magnetic charge in the black hole. **According to our model, these neutrinos come from black holes: it is not the black holes which constitute the dark matter but mainly the magnetic neutrinos generated by these black holes [8]**. In addition to this provenance indicating its production method and its physical properties (Sec. 4), **our model tries to define the nature of the interactions of these magnetic neutrinos from the black holes with ordinary matter: they lead to the production of standard neutrinos**, contrary to the current dominant thought where sterile states in interaction with active neutrinos produce sterile neutrinos (sect. 5). Our model also tries to find out if dark matter can annihilate with itself: gamma rays can be a byproduct of annihilation; the anapole, the Möbius strip as well as neutrinos, particles of antimatter can have energies much lower than that of gamma rays (sect. 6). Sterile magnetic neutrinos would interact with the weak force through the magnetic fields that shape the cosmos. These neutrinos form the halos that surround the galaxies. They receive energy from magnetic fields from stars in outer galaxies or pulsars and are thought to be related to the distribution of visible and invisible matter. The magnetic energy, converted to kinetic energy, they receive from magnetic fields could cause gamma ray glows in the dark (Sect. 7).

Can this model be scientifically proven? Our model is far from perfect. But no current construction with other particles makes it possible to interpret in a coherent way all the observational facts explained by the dark matter hypothesis. Demonstrating the existence of dark matter in this way is much more than an academic whim, it is the manifestation of a decisive paradigm shift in physics. We believe, despite no particles being found, that dark matter exists insofar as it provides the invisible scaffolding that holds all of the astrophysical structures of the universe together. But we refute the theoretical framework that has led to believe that this dark matter existed since the beginning of the universe. Let's dream that physics will highlight several predictions that follow from the existence of sterile magnetic neutrinos and they will be inexplicable in any theory that does not make this assumption.

References

[1] Dobrescu, B., Lincoln, D. (2017) Pour la science, Hors-série no 97, p. 26.

[2] NASA (2015) *WMAP Produces New Results*

[3] Bahcall, N.A., Fan, X. (1998) *A lightweight universe?* Proc Natl Acad Sci USA 95(11), p. 5956–5959.

[4] Roberts, M.S., Rots, A. H. (1973) *Comparison of Rotation Curves of Different Galaxy Types*, Astronomy and Astrophysics, Vol. 26, p. 483-485.

[5] Bagdoo, R. (2022) *Galaxy Rotation Curves Traced Out by the Theory of Relation,* European Journal of Applied Sciences, Vol. 10, No. 2. DOI:10.14738/aivp.102.11906

[6] Zwicky, Fritz (1929) PNAS, 15, 773-779. https://doi.org/10.1073/pnas.15.10.773

[7] Bosma, A. (1998) *The Dark Matter problem*. arXiv:astro-ph/9812015v1 DOI: 10.1023/A:1008366614769

[8] Rubin, Vera C., Ford, W. Kent Jr. (1970) *Rotation of the Andromeda Nebula from a Spectroscopic Survey of Emission Regions*, Astrophysical Journal, vol. 159, 379-403 DOI: 10.1086/15031

[9] Rubin, Vera C., Ford, W. Kent Jr., Thonnard, Norbert (1978) *Extended rotation curves of high- luminosity spiral galaxies. IV. Systematic dynamical properties, Sa through Sc,* The Astrophysical Journal, 225:L107-L111.

[10] Rubin, Vera C., Ford, W. Kent Jr., Thonnard, Norbert (1980) *Rotational properties*

of 21 SC galaxies with a large range of luminosities and radii, from NGC 4605 (R=4kpc) to UGC 2885 (R=122kpc), The Astrophysical Journal, 238:471–487.

[11] Ikonicoff, R. and Rey, B. (2019) *L'Univers caché*, Science & Vie. No. 1224, 60-81.

[12] White S.D.M., Navarro J.F., Evrard A.E., Frenk C.S. (1993) The baryon content of galaxy clusters: a challenge to cosmological orthodoxy, Nature, 366, p. 429–433.

[13] Riazuelo, A. (2011) Pour la Science, Dossier, No. 71, 66.

[14] Bahcall, N.A. (2015) *Dark matter universe*, PNAS, 112 (40) 12243-12245. https://doi.org/10.1073/pnas.1516944112

[15] Peskin, M.E. (2015) *Supersymmetric dark matter in the harsh light of the Large Hadron Collider*, PNAS, 112:12256–12263.

[16] Hooper, D. (2006) *Dark Cosmos in Search of our Universe Missing Mass and Energy*, Smithsonian Books, 75-79, 95-99.

[17] Martin, S.P. (2016) A Supersymmetry Primer, 95-114, 144.
arXiv:hep-ph/9709356v7
doi: 10.1142/9789812839657_0001

[18] Funk S. (2015) *Indirect detection of dark matter with γ rays*, PNAS, 112, 12264–12271.

[19] Rosenberg, L.J. (2015) *Dark matter QCD-axion searches*, Proceedings of the National Academy of Sciences USA, 112, 12278–12.

[20] Tracy, M. (2021) *MicroBooNE experiment's first results show no hint of a sterile neutrino*, Fermilab, media@fnal.gov, 224-290-7803.

[21] Bagdoo, R. (2020) What Connects Dark Matter and Black Holes? *Journal of Modern Physics*, **11**, 168-195. https://doi.org/10.4236/jmp.2020.112011

[22] Panek, R (2011) *The* 4% *Universe,* First Mariner Books, 192, 193.

[23] Chui, Glennda (2021) *Is dark matter cold, warm or hot?*, Symmetry. https://www.symmetrymagazine.org/article/is-dark-matter-cold-warm-or-hot

[24] Ratner, P. (2018) *Why the number 137 is one of the greatest mysteries in physics, Hard Science*. https://bigthink.com/hard-science/number-137-physics/

[25] Feynman, R. (1985) QED *the Strange Theory of Light and Matter*, Princeton University Press, Chapter 4, 129.

[26] Dirac, P.A.M. (1931) *Quantised Singularities in the Electromagnetic Field.* Proceedings of the Royal Society of London. Series A 133, 60, p. 9.

[27] Ronen, Y., Cohen, Y., Kang, J.-H., Haim, A., Rieder, M.-T., Heiblum, M., Mahalu, D., Shtrikman H. (2016) Charge of a quasiparticle in a superconductor, PNAS, 113 (7) 1743-1748. https://doi.org/10.1073/pnas.1515173113

[28] Siegel, E. (2014) *Nature is not symmetric*. https://medium.com/starts-with-a-bang/nature-is-not-symmetric-

[29] Adair, R.K. (1987) *The Great Design*. Oxford University Press, New York, 134, 247 Note 2.

[30] *Maxwell's equations*, Wikipedia. https://en.wikipedia.org/wiki/Maxwell's equations

[31] Serway, R.A., Beichner, R.J. (2000) *Physics*, Vol 2, 1076-1079.

[32] Benson, H. (1991) *University Physics*, John Wiley & Sons, Inc., 330, 681, 682, 691.

[33] *Dark photon*, Wikipedia. https://en.wikipedia.org/wiki/Dark_photon

[34] Alonso-Álvarez, G., Ertas, F., Jaeckel, J., Kahlhoefer, F., Thormaehlen, L. J. (2020) *Hidden Photon Dark Matter in the Light of XENON1T and Stellar Cooling*. arXiv:2006.11243v3 [hep-ph]

[35] Fabbrichesi, M., Gabrielli, E., Lanfranchi, G. (2020) *The Dark Photon*, SpringerBriefs in Physics. DOI:10.1007/978-3-030-62519-1 arXiv:2005.01515v3 [hep-ph]

[36] Essig, R., *et al.* (2013) *Dark Sectors and New, Light, Weakly-Coupled Particles.* arXiv:1311.0029v1 [hep-ph]

[37] Rajantie, A. (2016) *The search for magnetic monopoles*, Physics Today 69, 10, 40; doi: 10.1063/PT.3.3328 https://doi.org/10.1063/PT.3.3328

[38] *Why Magnetic Monopoles SHOULD Exist* (2021) YouTube. https://www.youtube.com/watch?v=dw1sekg6SUY

[39] 't Hooft, G. (1974) *Magnetic Monopoles in Unified Gauge Theories*, Nucl.Phys.B 79, 276-284. • DOI: 10.1016/0550-3213(74)90486-6

[40] Manton, N.S. (1977) *The Force Between 't Hooft-Polyakov Monopoles*, Nucl.Phys.B 126, 525-541. DOI: 10.1016/0550-3213(77)90294-2

[41] Cameron, R.P., Barnett, S.M. (2012) *Electric–magnetic symmetry and Noether's theorem,* New Journal of Physics, Vol. 14, 123019.

[42] Agullo, I., et al. (2017) *Electromagnetic Duality Anomaly in Curved Spacetimes*, Physical Review Letters. DOI: 10.1103/PhysRevLett.118.111301

[43] Cownden, B., Frey, A.R. (2018) *Variations on the Dirac string*, Phys. Rev. D 98, 105013. DOI:10.1103/PhysRevD.98.105013. arXiv:1807.07401v2 [hep-th]

[44] Danger Julius, T'., (2016) *The mysterious missing magnetic monopole*, The Conversation. https://phys.org/news/2016-08-mysterious-magnetic-monopole.html

[45] Rajantie, A. (2012) *Magnetic monopoles in field theory and cosmology*, Philosophical Transactions of the Royal Society A, 370, 5705–5717. doi:10.1098/rsta.2011.0394

[46] MIT News (2022) A new upper limit on the mass of neutrinos. https://news.mit.edu/2021/new-upper-limit-mass-neutrinos-0214

[47] Rini, M. (2022) *Maximum Neutrino Mass Drops Again*, Physics, Feb. 14, 15, 25. https://physics.aps.org/articles/v15/25

[48] de Salas, P.F., Gariazzo, S., Mena, O., Ternes, C.A., Tortola, M. (2018) Neutrino *Mass Ordering from Oscillations and Beyond: 2018 Status and Future Prospects*, Frontiers in Astronomy and Space Sciences. Doi.org/10.3389/fspas.2018.00036

[49] Drewes, M. (2013*) The Phenomenology of Right Handed Neutrinos*, International Journal of Modern Physics E, 22, 1330019. DOI: 10.1142/S0218301313300191. arXiv:1303.6912v3 [hep-ph]

[50] Luminet, J.-P. (1987) Trous Noirs, Belfond/sciences, p. 224-226, 244.

[51] Wikipedia, *Sterile neutrino*. https://en.wikipedia.org/wiki/Sterile_neutrino

[52] Wikipedia, *Cosmic microwave background*. https://en.wikipedia.org/wiki/Cosmic_microwave_background#cite_note-35

[53] Harrison, E. R. (1970). *Fluctuations at the threshold of classical cosmology*. Physical Review D. 1 (10): 2726–2730. doi:10.1103/PhysRevD.1.2726

[54] Hinshaw, G., *et al.* (2007) *Three-year Wilkinson Microwave Anisotropy Probe*

(WMAP) observations: temperature analysis, Astrophysical Journal Supplement Series. 170 (2): 288–334. arXiv:astro-ph/0603451. doi:10.1086/513698. S2CID 15554608.

[55] Planck Collaboration Team (2016). *Planck intermediate results. XXX. The angular power spectrum of polarized dust emission at intermediate and high Galactic latitudes*. Astronomy & Astrophysics. 586 (133): A133. arXiv:1409.5738. doi:10.1051/0004-6361/201425034. S2CID 9857299.

[56] Famaey, B. (2020) *La matière noire*, Pour la Science, Hors-Série, No **106**, 3, 46-49.

[57] *Stellar Black Hole*, Cosmos. https://astronomy.swin.edu.au/cosmos/s/Stellar+Black+Hole

[58] *Supermassive Black Hole*, Cosmos. https://astronomy.swin.edu.au/cosmos/s/supermassive+black+hole

[59] Fontez, M. Ikonicoff, R. Grousson, M. Rey, B. (2018) Science & Vie. No. 1204, 40-56.

[60] Klesman, A. (2019) *What are primordial black holes?* https://astronomy.com/news/2019/07/primordial-black-holes

[61] Park, J. (2019) *What are intermediate-mass black holes?* https://astronomy.com/news/2019/07/what-are-intermediate-mass-black-holes

[62] *Reionization*, Wikipedia. https://en.wikipedia.org/wiki/Reionization

[63] Planck Collaboration, Ade, P.A.R., *et al.* (2014) *Planck 2013 results. XIII. Galactic CO emission*, Astronomy & Astrophysics, Volume 571, A1. https://doi.org/10.1051/0004-6361/201321529. arXiv:1303.5073v2 [astro-ph.GA]

[64] Benmakhlouf, M. (2021) *Inédit : de la lumière détectée derrière un trou Noir*, National Geographic. https://www.nationalgeographic.fr/espace/inedit-de-la-lumiere-detectee-derriere-un-trou-noir

[65] Habib, S. (1997) *Dark Matter and Massive Neutrinos*, Los Alamos Science No 25. https://sgp.fas.org/othergov/doe/lanl/pubs/00326616.pdf

[66] Lachièze-Rey, M. (1986) *Chaos et Cosmos*, Le Mail, 62-68.

[67] Zeldovich, Y., Wikipedia. https://en.wikipedia.org/wiki/Yakov_Zeldovich

[68] Zel'dovich, Y.B., Novikov, I.D. (1971) *Stars and Relativity*, Dover Pub., Inc., p. 70, 144-151.

[69] Hawking, S. (1988) *A Brief History of Time*, Bantam Books. 99-113.

[70] Hawking, S. (1971) *Gravitationally collapsed objects of very low mass*, Monthly Notices of the Royal Astronomical Society, Volume 152, Issue 1, p. 75–78. doi:10.1093/mnras/152.1.75.

[71] Barrau, A., Gorecki, A. (2011) *Pour la Science,* Dossier, No. 71, 30-36.

[72] *A New Kind of Black Hole*. NASA's Goddard Space Flight Center https://www.nasa.gov/vision/universe/starsgalaxies/Black_Hole.html

[73] O'Callaghan, J. (2019) *How did supermassive black holes grow so fast?*, Horizon https://ec.europa.eu/research-and-innovation/en/horizon-magazine/how-did-supermassive-black-holes-grow-so-fast

[74] Bertone, G. (2013) *Le mystère de la matière noire*, Dunod, 100-102, 148-9, 160-163.

[75] Muezca, M. (2020) Ciel & Espace, No 570, 53-56.

[76] Bellido, J.G., Clesse, S. (2020) *La piste des trous noirs*, Pour la Science, Hors-Série, No **106**, 64-71.

[77] Guo, Q., *et al.* (2019) *Further evidence for a population of dark-matter-deficient dwarf galaxies*, Nature Astronomy. DOI: 10.1038/s41550-019-0930-9

[78] *Hawking radiation*, Wikipedia. https://www.cs.mcgill.ca/~rwest/wikispeedia/wpcd/wp/h/Hawking_radiation.htm

[79] Fore, M. (2019) *Stephen Hawking Was Right: Black Holes Can Evaporate, Weird New Study Shows*, Livescience. https://www.livescience.com/65683-sonic-black-hole-spews-hawking-radiation.html

[80] Begelman, M., Rees, M. (1998) *Gravity's fatal attraction*, Scientific American Library, 223-225.

[81] Rovelli, C. (2020) *Where does the stuff that falls into a black hole go?* NewScientist, Space, 28 October. https://www.newscientist.com/article/mg24833060-500-carlo-rovelli-where-does-the-stuff-that-falls-into-a-black-hole-go/

[82] Wald, M. R. (1992) *Space, Time, and Gravity*, The University of Chicago Press, 86-89, 127, 130-139.

[83] *Black-body radiation*, Wikipedia. https://en.wikipedia.org/wiki/Black-ody_radiation

[84] Bennett, C. L. (2013) *Nine-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Final Maps and Results*. arXiv:1212.5225v3 [astro-ph.CO] https://doi.org/10.1088/0067-0049/208/2/20

[85] Weinberg, S. (1977) *The First Three Minutes*, Basic Books, 62.

[86] Bagdoo, R. (2019) *The Equation of the Universe (According to the Theory of Relation)*. Journal of Modern Physics, 10, 310-343. https://doi.org/10.4236/jmp.2019.103022

[87] Hawking, S.W. (1975) *Particle creation by black holes*, Communications in Mathematical Physics vol. 43, p. 199–220.

[88] Wikipedia, *Hawking radiation*. https://en.wikipedia.org/wiki/Hawking_radiation#:

[89] Wikipedia, *Schwarzschild radius*. en.wikipedia.org/wiki/Schwarzschild_radius

[90] Nimtz, G. (2011) *Tunneling Violates Special Relativity*, Foundations of Physics, 41, 1193-1199. arXiv:1003.3944v1. https://doi.org/10.1007/s10701-011-9539-2

[91] Davies, P. C. W. (2005). *Quantum tunneling time*, American Journal of Physics, 73 (1): 23–27. arXiv:quant-ph/0403010. doi:10.1119/1.1810153. S2CID 119099861.

[92] Islam, J. N. (1983) *Le destin ultime de l'univers*, Cambridge University Press 104, 109, 113-117.

[93] Verma, R., Kashav, M., Verma, S., Chauhan, B. C. (2021) *Scalar Dark Matter in A4 based texture one-zero neutrino mass model within Inverse Seesaw Mechanism*. https://doi.org/10.48550/arXiv.2102.03074

[94] Boyarsky, A., Drewes, M., Lasserre, T., Mertens, S., Ruchayskiy, O. (2018) *Sterile Neutrino Dark Matter,* p. 14, 31, 40. 42. arXiv:1807.07938v2

https://doi.org/10.1016/j.ppnp.2018.07.004

[95] Dodelson, S., Widrow, L. M. (1994) *Sterile Neutrinos as Dark Matter*, Phys.Rev.Lett.72:17-20. https://doi.org/10.1103/PhysRevLett.72.17 arXiv:hep-ph/9303287v1

[96] Reeves, Hubert (1988) Patience dans l'azur, Éditions du Seuil, Points, p. 275.

[97] Wikipedia, *Seesaw mechanism*. https://en.wikipedia.org/wiki/Seesaw_mechanism

[98] Peter, P., Uzan, J.-P. (2009) Primordial Cosmology, Oxford University Press, p. 432.

[99] P. Langacker (1989) University of Pennsylvania Report No. UPR 0401T. https://web.sas.upenn.edu/pgl/selected-publications/

[100] Dolgov, A. (1981) *Neutrinos in the Early Universe*, Soviet Journal of Nuclear Physics, 33, p. 700.

[101] Manohar, A. (1987) *Statistical Mechanics of Noninteracting Particles*, Physics Letters B 186, 370. DOI: 10.1016/0370-2693(87)90310-8

[102] Barbieri, R., Dolgov, A. (1990) *Bounds on sterile neutrinos from nucleosynthesis*, Physics Letters B, Vol. 237, Issues 3–4, p. 440-445.

[103] Enqvist, K., Kainulainen, K., Maalampi, J. (1992) *Stringent cosmological bounds on inert neutrino mixing*, Nuclear Physics B, Vol. 373, Issue 2, p. 498-528.

[104] Cline, J.M. (1992) *Constraints on almost-Dirac neutrinos from neutrino-antineutrino oscillations*, Physical Review Letters, 68, p. 3137.

[105] Aad, G. *et al.* (2012) *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, ATLAS* Collaboration, Phys.Lett.B, 716, 1-29. https://doi.org/10.1016/j.physletb.2012.08.020 [arXiv:1207.7214].

[106] Chatrchyan, S. *et al*. (2012) *Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC,* The CMS Collaboration, Phys. Lett. B 716, 30. https://doi.org/10.1016/j.physletb.2012.08.021 [arXiv:1207.7235 v2].

[107] nLab, *Yukawa coupling*. https://ncatlab.org/nlab/show/Yukawa+coupling

[108] Barenboim, G., Park, W.-I. (2017) *Lepton number asymmetries and the lower bound on the reheating temperature*, Journal of Cosmology and Astroparticle Physics. arXiv:1708.04899, doi:10.1088/1475-7516/2017/12/037.

[109] Asaka, T., Laine, M., Shaposhnikov, M. (2007) *Lightest sterile neutrino abundance within the nuMSM*, Journal of High Energy Physics. Doi:10.1088/1126-6708/2007/01/091.

[110] Lello, L., Boyanovsky, D. (2016) *The case for mixed dark matter from sterile neutrinos*, Journal of Cosmology and Astroparticle Physics. arXiv:1508.04077v2 doi:10.1088/1475-7516/2016/06/011.

[111] Lello, L,. Boyanovsky, D. (2015) *Cosmological Implications of Light Sterile Neutrinos produced after the QCD Phase Transition*, Physical. Review D. arXiv:1411.2690v2, doi:10.1103/PhysRevD.91.063502.

[112] Bezrukov, F., Gorbunov, D., Shaposhnikov, M. (2009) *On initial conditions for the*

HotBig Bang, Journal of Cosmology and Astroparticle Physics. arXiv:0812.3622, doi:10.1088/1475-7516/2009/06/ 029.

[113] Lello, L,. Boyanovsky, D., Pisarski, R. D. (2017) *Production of heavy sterile neutrinos from vector boson decay at electroweak temperatures*, Phys. Rev. D. arXiv:1609.07647, doi:10.1103/PhysRevD.95.043524.

[114] Wikipedia, *Gauge theory*. https://en.wikipedia.org/wiki/Gauge_theory

[115] Miroshnichenko, A.E., *et al.* (2014) *Seeing the unseen: observation of an anapole with dielectric nanoparticles nanoparticles*. https://doi.org/10.48550/arXiv.1412.0299

[116] Gamboa, J., Mendez, F., Tapia, N. *Anapole Dark Matter Quantum Mechanics* (2019). arXiv:1909.04073v3. https://doi.org/10.1103/PhysRevD.101.015013

[117] Stecker, F.W. (1971) *Cosmic Gamma Rays*, NASA, 3, 41, 47, 77-81.

[118] Zel'Dovich, Y. B. (1958) *Electromagnetic Interaction with Parity Violation*, Soviet Phys. JETP, Vol: 6, 1184.

[119] Wood, C. S., *et al*. (1997) *Measurement of Parity Nonconservation and an Anapole Moment in Cesium*, Science, 275, 1759-63. Doi: 10.1126/science.275.5307.1759.

[120] Fitzpatrick, A. L., Zurek, K. M. (2010) *Dark Moments and the DAMA-CoGeNT Puzzle*, Physical Review D, Vol. 82, Iss. 7, 075004. arXiv:1007.5325

[121] Frandsen, M. T., *et al.* (2013) *The unbearable lightness of being: CDMS versus XENON*, Journal of Cosmology and Astroparticle Physics. doi.org/10.1088/1475-7516/2013/07/023. arXiv.1304.6066

[122] Wikipedia, *Toroidal moment*. https://en.wikipedia.org/wiki/Toroidal_moment

[123] Ho, C. M., Scherrer, R. J. (2013) *Anapole Dark Matter*, Physics Letters B, 722, 341. arXiv:1211.0503v3. doi.org/10.1016/j.physletb.2013.04.039

[124] Vanderbilt University Research News (2013) *New, simple theory may explain mysterious dark matter*. https://news.vanderbilt.edu/2013/06/10/dark-matter/

[125] Heo, J. H. (2010) *Minimal Dirac Fermionic Dark Matter with Nonzero Magnetic Dipole Moment*, Physics Letters B 693, 255-258, arXiv:0901.3815v2. https://doi.org/10.1016/j.physletb.2010.08.035

[126] Del Nobile, E., *et al*. (2014) *Direct detection of Light Anapole and Magnetic Dipole DM*, https://doi.org/10.48550/arXiv.1401.4508 https://doi.org/10.1088/1475-7516/2014/06/002

[127] Gao, Y., Ho, C., Scherrer, R.J. (2014) *Anapole dark Matter at the LHC*, Physical Review D 89, 045006. doi.org/10.1103/PhysRevD.89.04500. arXiv:1311.5630v2

[128] Bagdoo, R. (2011) *Cosmological Inconstant, Supernovæ 1a and Decelerating Expansion*, General Science Journal, viXra: 1304.0169v1, Internet Archive, ResearchGate.

[129] Magnan, C. (2011) *Le théorème du jardin*, amds édition, 244, 262.

[130] Wikipedia, *Möbius strip*. https://en.wikipedia.org/wiki/M%C3%B6bius_strip

[131] Müller, X. (2018) *Dark Matter, Elusive as Ever*, CNRS News. https://news.cnrs.fr/articles/dark-matter-elusive-as-ever

[132] Davies, P. (1988) *The Forces of Nature*, Cambridge University Press, 1.4, 4.5.

[133] Cottingham, W.N., Greenwood, D.A. (2007) *An Introduction to the Standard Model of Particle Physics* (2nd ed.). Cambridge University Press.

[134] Schechter, J., Valle, J. W. F. (1980) *Neutrino masses in SU(2) ⊗ U(1) theories*, Physical Review D. 22 (9): 2227–2235. Bibcode:1980PhRvD..22.2227S. doi:10.1103/PhysRevD.22.2227.

[135] Fukuda, Y., *et al.* (1998) *Measurements of the solar neutrino flux from Super-Kamiokande's first 300 days*. Physical Review Letters. 81 (6): 1158–1162. arXiv:hep-ex/9805021.

[136] Bouquet, A., Monnier, E. (2008) *Matière sombre et énergie noire*, Dunod, 178.

[137] Mohapatra, R. N., et al. (2007) *Theory of Neutrinos: a White Paper, Reports on Progress in Physics*. 70 (11): 1757–1867. arXiv:h ep-ph/0510213v2. doi:10.1088/0034-4885/70/11/R02. S2CID 119092531.

[138] Esteban, I., *et al*. (2020) *The fate of hints: updated global analysis of three-flavor neutrino oscillations*. arXiv:2007.14792v1 https://doi.org/10.1007/JHEP09%282020%29178

[139] Amsler, C., *et al.* (2008) *Review of Particle Physics*. Physics Letters B. Volume 667, Issues 1–5. p. 1-6. Bibcode:2008PhLB..667....1A. doi:10.1016/j.physletb.2008.07.018.

[140] Hut, P., Olive, K. A. (1979) *A cosmological upper limit on the mass of heavy neutrinos*, Physics Letters B. 87 (1–2): 144–146. Bibcode:1979PhLB...87..144H. doi:10.1016/0370-2693(79)90039-X.

[141] Goobar, A., Hannestad, S., Mörtsell, E., Tu, H. (2006) *The neutrino mass bound from WMAP 3 year data, the baryon acoustic peak, the SNLS supernovae and the Lyman-α forest,* Journal of Cosmology and Astroparticle Physics, 0606:019, 2006. arXiv:astro-ph/0602155v2 doi:10.1088/1475-7516/2006/06/019. S2CID 119535760.

[142] Di Valentino, E., Gariazzo, S., Mena, O. (2021) *On the most constraining cosmological neutrino mass bounds*, Physical Review D. 104: 083504. arXiv:2106.15267v3. doi:10.1103/PhysRevD.104.083504. S2CID 235669844.

[143] Di Valentino, E., Melchiorri, A. (2021) *Neutrino Mass Bounds in the era of Tension Cosmology*, The Astrophysical Journal Letters, Volume 931, Number 2. arXiv:2112.02993

[144] *The Mainz Neutrino Mass Experiment* (Press release). Archived from the original on 3 March 2016. http://www.physik.uni-mainz.de/exakt/neutrino/en_experiment.html

[145] *Die Neutrino-Waage geht in Betrieb Physik Journal*. Physik News. pro-physik.de (Press release(in German). 12 June 2018. Archived from the original on 16 June

2018. Retrieved 15 June 2018.

[146] The KATRIN Collaboration (2022) *Direct neutrino-mass measurement with sub-electronvolt sensitivity*, Nature Physics 18, 160–166 . doi:10.1038/s41567-021-01463-1

[147] Castelvecchi, D. (2022) *How light is a neutrino? The answer is closer than ever,* Nature. doi:10.1038/d41586-022-00430-x. PMID 35165410. S2CID 246827702.

[148] Kunze, K. E., *Cosmological Magnetic Fields*, Plasma Phys.Control.Fusion 55 (2013) 124026. doi.org/10.1088/0741-3335/55/12/124026. arXiv:1307.2153v1.

[149] Zweibel, Ellen, *De l'importance des champs magnétiques* (1998) Recherche, Hors-Série, avril, 10, 90-93.

[150] Zweibel, E., Heiles, C. (1997) *Magnetic fields in galaxies and beyond*, Nature, Vol. 385, p. 131-136.

[151] Riazuelo, A. (2020) Pour la Science, Hors-Série, No **106**, 54.

[152] Van Dokkum P. *et al.* (2018) *A galaxy lacking dark matter*. Nature 555, 629-632.

[153] Van Dokkum P. *et al.* (2019) *A second galaxy missing dark matter in the NGC 1052 group*. Astrophysical Journal Letters, Vol. 874, No 1, L5-L13 (2019).

[154] Wikipedia, *Eridanus II.* https://en.wikipedia.org/wiki/Eridanus_II

[155] The European Space Agency (ESA) (2020) *XMM-Newton discovers scorching gas in Milky Way's halo.* https://www.esa.int/Science_Exploration/Space_Science/

[156] Briggs, A. (2021) *What is a magnetar?* EarthSky. https://earthsky.org/space/what-is-a-magnetar/

[157] Navarro, J.F., Frenk, C.S., White, F.D.M. (1996) *The Structure of Cold Dark Matter Halos,* The Astrophysical Journal, vol. 463, p. 563. DOI 10.1086/177173, arXiv astro-ph/9508025

[158] Einasto, J. (1965), *Kinematics and dynamics of stellar systems*, Trudy Inst. Astrofiz. Alma-Ata 5, 87

[159] Merritt, D., Graham, A., *et al.* (2006) *Empirical Models for Dark Matter Halos*, The Astronomical Journal, 132 (6): 2685–2700. arXiv:astro-ph/0509417. doi:10.1086/508988. S2CID 14511019.

[160] Bothun, G., Impey, C., McGaugh, S. (1997) *Low-surface-brightness galaxies: hidden galaxies revealed*, Publications of the Astronomical Society of the Pacific, 109: 745-758.

[161] Gong, X., Tang, M., Xu, Z. (2021) *The Possible Equation Of State Of Dark Matter in Low Surface Brightness Galaxies*, https://doi.org/10.48550/arXiv.2007.02583v3

[162] Jackson, R.A., *et al.* (2021) *The origin of low-surface-brightness galaxies in the dwarf regime*, https://doi.org/10.48550/arXiv.2007.06581v2

[163] Kovacs, O.E., Bogdan, A., Canning, R.E.A. (2019) *Constraining the dark matter halo mass of isolated low-surface-brightness galaxies.* https://doi.org/10.48550/arXiv.1906.05867

[164] de Blok, W. J. G., McGaugh, S. S. (1997) *The dark and visible matter content of*

low surface brightness disc galaxies, Monthly Notices of the Royal Astronomical

[165] Hannes, A. (1942) *On the cosmogony of the solar system*, Stockholms Observatorium Annuler, vol. 14, pp.2.1-2.33 https://ui.adsabs.harvard.edu/abs/1942StoAn..14....2A/abstract

[166] Hoyle, F. (1949) *On the Cosmological Problem*, Journal: Monthly Notices of the Royal Astronomical Society, Vol. 109, p365. https://adsabs.harvard.edu/full/1949MNRAS.109..365H

[167] Bondi, H., Gold, T. (1948). *The steady-state theory of the expanding Universe*. Monthly Notices of the Royal Astronomical Society, 108 (3), 252-270.

[168] Dombrovski V.A. (1949), Doklady Akad. Nauk Armenia, 10, 199

[169] Wikipedia, *Hiltner, W.A*. https://en.wikipedia.org/wiki/W._Albert_Hiltner

[170] Tomoline, A. (1975) *La Cosmogonie récréative*, Éditions de Moscou, 220, 221.

[171] NASA's *Fermi Gamma-ray Space Telescope*. https://fermi.gsfc.nasa.gov/

[172] Goodenough, L., Hooper, D. (2009) *Possible Evidence For Dark Matter Annihilation In The Inner Milky Way From The Fermi Gamma Ray Space Telescope.* arXiv:0910.2998

[173] Sokol, J. (2016) *A Seeker of Dark Matter's Hidden Light,* Quanta Magazine. https://www.quantamagazine.org/tracy-slatyer-searches-for-dark-matters-hidden-light-20160901/

[174] Cho, A. (2019) *Physicists revive hunt for dark matter in the heart of the Milky Way*, Science. doi:10.1126/science.aba1956.

[175] Cartlidge, E. (2015) *X-ray signal from outer space points to dark matter*, Science. www.science.org/content/article/x-ray-signal-outer-space-points-dark-matter

[176] Abazajian, K. N. (2014) *Resonantly-Produced 7 keV Sterile Neutrino Dark Matter Models and the Properties of Milky Way Satellites*, Physcal Review Letters, 112, 161303. https://doi.org/10.1103/PhysRevLett.112.161303

[177] Dessert, C., Rodd, N.L., Safdi, B.R. (2020) *The dark matter interpretation of the 3.5-keV line is inconsistent with blank-sky observations*, Science, Vol. 367, Issue 6485, pp.1465-1467. DOI: 10.1126/science.aaw3772