Strong/nuclear force in the dynamic medium of reference (DMR) theory. Nuclear deflection of light, nuclear time delay of light, and proposed experiment

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Abstract: The theory of the dynamic medium of reference has already been presented in several articles [Pignard, Phys. Essays **32**, 422 (2019); **33**, 395 (2020); **34**, 61 (2021); **34**, 279 (2021)], and in particular in Pignard, Phys. Essays **32**, 422 (2019). The article [Pignard, Phys. Essays **34**, 279 (2021)] gives an explanation and mathematical developments of the gravitational acceleration from atomic nuclei of a massive body. General relativity considers a massive body, like the Earth or the Sun, globally, macroscopically, simply as an object of mass M (which curves space–time). However, when one goes into details, this mass M is made up of atoms which are themselves mainly made up of nuclei of nucleons (if we neglect the mass of electrons in comparison of that of the nucleus). *Thus, it is mainly the nuclei of a massive body that create the force of gravity!* The dynamic medium of reference theory determines the gravitational acceleration microscopically by taking into account all the atomic nuclei that make up a massive body [Pignard, Phys. Essays **32**, 422 (2019)]. *This creates a strong link between gravity and the nuclear domain*. This article goes further with the description of a model of the atomic nucleus. This makes it possible to establish that the strong force or nuclear force, which ensures the cohesion of the nucleus, is due to the strong acceleration of the flux of the medium which is a vector average of the flux of gravitons. This gives an expression of the nuclear force similar to the force of gravity but with a constant $K \approx 10^{31}$ m s^{-2}, much higher than the gravitational constant G. This article shows that the functioning, the mechanism of the nucleus, makes it possible to explain the nuclear force and also to find the gravitational acceleration. From there, it is deduced that the photons are deflected by the strong acceleration due to an atom nucleus. They are also slowed down by an atom nucleus which creates a delay in their travel time which we call the nuclear time delay of light. Finally, an experiment is proposed to verify the phenomenon of nuclear deflection of light and the nuclear time delay of light. © *2021 Physics Essays Publication*.
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Résumé: La théorie du Milieu Dynamique de Référence a déjà été présentée dans plusieurs articles [Pignard, Phys. Essays **32**, 422 (2019); **33**, 395 (2020); **34**, 61 (2021); **34**, 279 (2021)], en particulier [Pignard, Phys. Essays **32**, 422 (2019)]. L'article [Pignard, Phys. Essays **34**, 279 (2021)] donne une explication et les développements mathématiques de l'accélération gravitationnelle à partir des noyaux d'atome d'un corps massif. La relativité générale considère un corps massif, comme la Terre ou le Soleil, de façon globale, macroscopique, simplement comme un objet de masse M (qui courbe l'espace–temps). Cependant, quand on va dans le détail, cette masse M est constituée d'atomes qui sont eux-mêmes constitués principalement de noyaux de nucléons (si l'on néglige la masse des électrons devant celle du noyau). *Ainsi, ce sont bien principalement les noyaux d'un corps massif qui créent la force de gravitation!* La théorie du Milieu Dynamique de Référence détermine l'accélération gravitationnelle de façon microscopique en tenant compte de tous les noyaux d'atome constituant un corps massif. [Pignard, Phys. Essays **32**, 422 (2019)]. *Cela crée un lien fort entre la gravitation et le domaine nucléaire*. Cet article va plus loin avec la description d'un modèle du noyau d'atome. Cela permet d'établir que la force forte ou force nucléaire, qui assure la cohésion du noyau, est due à l'accélération forte du flux du milieu qui est une moyenne vectorielle des flux de gravitons. Cela donne une expression de la force nucléaire similaire à celle de la force de gravitation mais avec une constante $K \approx 10^{31}$ m s^{-2} bien plus élevée que la constante gravitationnelle G. Cet article montre que le fonctionnement, le mécanisme du noyau permet d'expliquer la force nucléaire et également de retrouver l'accélération gravitationnelle. De là, il est déduit que les photons sont déviés par l'accélération forte due à un noyau d'atome. Ils sont également ralentis par un noyau d'atome ce qui crée un retard dans leur temps de parcours que

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nous appelons “le retard nucléaire de la lumière”. Finalement, il est proposé une expérience afin de vérifier “la déflection nucléaire de la lumière” et “le retard nucléaire de la lumière.”

Key words: Dynamic Medium of Reference; Gravitons Field; Strong Force; Nuclear Deflection of Light; Nuclear Time Delay of Light.

I. CONCISE PRESENTATION OF THE THEORY OF THE DYNAMIC MEDIUM OF REFERENCE

Important preliminary remark:

This article does not present the theory of the Dynamic Medium of Reference (DMR).

To do this, refer to the article “Dynamic Medium of Reference: A new theory of gravitation”[1] which is strongly recommended to have read to understand this article.

The theory of the dynamic medium of reference[1] introduces a **dynamic non-material** medium which is present in the whole Universe.

The characteristics of this medium are as follows:

- This medium enables one to deduce a preferred frame of reference (PFR) or rather a REFERENCE in the whole Universe and at all scales.
- This REFERENCE enables one to obtain a privileged time. The present moment is universal, that is to say, the same in the whole Universe.
- This medium is also the medium of propagation of light.
- This medium verifies the principle of reciprocal action:
  - The medium is distorted by matter and energy like the space–time of general relativity.
  - The warping of this medium determines the trajectories of the particles (material particles and light particles).

The presence of a massive body creates a flux of the medium (centripetal, that is to say, directed towards the center of gravity of the massive body) of speed,

$$V_{\text{flux}} = \sqrt{\frac{2GM}{r}}, \tag{1}$$

and acceleration,

$$\gamma_{\text{flux}} = \frac{GM}{r^2}, \tag{2}$$

where r refers to the distance to the center of gravity of the massive body.

In the framework of Lorentz/Poincaré theory, in the absence of a gravitational field, material clocks (in the reference frame R) undergo a physical dilatation of their period according to their speed with respect to the PFR according to the formula

$$T = \gamma . T_0 \quad \text{with} \quad \gamma = \left(1 - \frac{V_{R/\text{PFR}}^2}{c_0^2}\right)^{-1/2}. \tag{3}$$

Within the framework of Lorentz/Poincaré theory, in the absence of a gravitational field, material rulers (in the reference frame R) undergo a physical contraction of their length according to their speed with respect to the PFR according to the formula

$$L = \frac{L_0}{\gamma} \quad \text{with} \quad \gamma = \left(1 - \frac{V_{R/\text{PFR}}^2}{c_0^2}\right)^{-1/2}. \tag{4}$$

In the presence of a massive body of mass M, the speed of the flux of the medium takes the following expression in the frame of reference linked to the massive body and at a distance r from the center of gravity of the massive body:[1]

$$\overrightarrow{V_{\text{flux}}} = -\sqrt{\frac{2GM}{r}}\overrightarrow{u_r}, \tag{5}$$

where $\overrightarrow{u_r}$ denotes the unit radial vector directed towards the exterior of the massive body.

The effects undergone by material clocks and rulers due to their speed with respect to the medium (which allows us to define the preferred frame of reference) are the same as the effects they undergo by the centripetal movement of the medium due to a massive body. Since clocks and rulers are assumed to be fixed with respect to the massive body, the centripetal movement of the medium (of speed V_{flux}) with respect to the center of gravity of the massive body can be interpreted as a movement of the clocks and rulers with respect to the medium.

The equivalence between the movement of the clocks and rulers with respect to the medium and the movement of the medium with respect to the clocks and rulers is a new way of stating the principle of equivalence.

In the presence of a massive body of mass M, material clocks undergo a physical dilatation of their period according to the following formula:[1]

$$T = T_0 . K(r) \quad \text{with} \quad K(r) = \left(1 - \frac{V_{\text{flux}}^2}{c_0^2}\right)^{-1/2} = \left(1 - \frac{2GM}{c_0^2 . r}\right)^{-1/2}. \tag{6}$$

In the presence of a massive body of mass M, material rulers undergo a physical contraction of their length according to the following formula:[1]

$$L = \frac{L_0}{K(r)} \quad \text{with} \quad K(r) = \left(1 - \frac{V_{\text{flux}}^2}{c_0^2}\right)^{-1/2} = \left(1 - \frac{2GM}{c_0^2 . r}\right)^{-1/2}. \tag{7}$$

Light is slowed down by a gravitational field, and the expression of its speed is[1]

$$c = \frac{c_0}{K\sqrt{1 + (K^2 - 1)\cos^2\beta}}. \tag{8}$$

We name $\beta = (\overrightarrow{u_r}, \overrightarrow{c})$ the angle between the unit radial vector $\overrightarrow{u_r}$ and the speed vector of light $\overrightarrow{c}$. The vector $\overrightarrow{c_0}$ represents the speed vector of light if there was not any massive body.

In the case of a radial trajectory of the light, we have the following simple expression:

$$c = \frac{c_0}{n(r)} = \frac{c_0}{K^2(r)}. \tag{9}$$

If we call ε_0 the permittivity and μ_0 the permeability of the medium without gravitational field, then we have $c_0 = (\varepsilon_0\mu_0)^{-1/2}$.

If we call ε the permittivity and μ the permeability of the medium in the presence of a gravitational field created by a massive body of mass M, then we have $c = (\varepsilon\mu)^{-1/2}$ with

$$\varepsilon = \varepsilon_0.\varepsilon_r = \varepsilon_0\left(1 - \frac{2GM}{c_0^2 r}\right)^{-1} \tag{10}$$

and

$$\mu = \mu_0.\mu_r = \mu_0\left(1 - \frac{2GM}{c_0^2 r}\right)^{-1}. \tag{11}$$

The refractive index is given by the formula

$$n = \sqrt{\varepsilon_r\mu_r} = \left(1 - \frac{2GM}{c_0^2 r}\right)^{-1}, \tag{12}$$

with

$$\varepsilon_r = \varepsilon/\varepsilon_0 = \left(1 - \frac{2GM}{c_0^2 r}\right)^{-1} \tag{13}$$

and

$$\mu_r = \mu/\mu_0 = \left(1 - \frac{2GM}{c_0^2 r}\right)^{-1}. \tag{14}$$

All these formulas show that the medium is related to electricity, magnetism, electromagnetism, and gravitation.

a) Case of the photon
The exploitation of the previous results makes it possible to establish the Lagrangian formulation of the trajectory of a photon,[1]

$$L = K^2\left[c_0^2 - \left(K^2\frac{dr}{dt}\right)^2 - \left(Kr\frac{d\phi}{dt}\right)^2\right] = 0, \tag{15}$$

which we can write

$$\left(K^2\frac{dr}{dt}\right)^2 + \left(Kr\frac{d\phi}{dt}\right)^2 = c_0^2. \tag{16}$$

After the development of calculations, we end up with the following equation:[1]

$$\frac{d^2u}{d\phi^2} + u = \frac{3GM}{c_0^2}u^2 . \tag{17}$$

This equation makes it possible to determine the deflection of light rays by a massive body, for example, the Sun, and also by clusters of galaxies (gravitational lens, gravitational mirage, and Einstein ring).

b) Case of a material particle
The exploitation of the previous results makes it possible to establish the Lagrangian formulation of the trajectory of a material particle,[1]

$$c_0^2 - L = K^2\left[\left(K^2\frac{dr}{dt}\right)^2 + \left(Kr\frac{d\phi}{dt}\right)^2 - \frac{2GM}{r} - C^2\right] = 0, \tag{18}$$

which we can write

$$\left(K^2\frac{dr}{dt}\right)^2 + \left(Kr\frac{d\phi}{dt}\right)^2 = \frac{2GM}{r} + C^2 = V_{\text{flux}}^2 + C^2. \tag{19}$$

After the development of calculations, we end up with the following equation:[1]

$$\frac{d^2u}{d\phi^2} + u = \frac{GM}{A^2} + \frac{3GM}{c_0^2}u^2 . \tag{20}$$

This equation makes it possible to determine the trajectory of the planets of the solar system and, in particular, the precession of the perihelion of Mercury.

II. A POSSIBLE DESCRIPTION OF THE DYNAMIC MEDIUM OF REFERENCE: THE GRAVITONS FIELD

This part gives a possible description of the dynamic medium of reference: the gravitons field.

The gravitons field is based on Le Sage theory, but it adds many deep changes and evolutions.

Numerous scientists have studied Le Sage theory. Just to mention a few of them:

Newton, Huygens, Leibniz, Euler, Laplace, Lord Kelvin, Maxwell, Lorentz, Hilbert, Darwin, Poincaré, Feynman.

Henri Poincaré has studied this theory and written a synthesis in *Science et Méthode*.[5] Poincaré sums up the principle of Le Sage theory like this:

> "It is proper to establish a parallel between these considerations and a theory proposed a long time ago in order to explain the universal gravitation. Let's suppose that, in the interplanetary spaces, very tiny particles move in all directions, with very high speeds. A single body in the space will not be affected, apparently, by the impact of these corpuscles, since these impacts are equally divided in all directions. But, if two bodies A and B are in the space, the body B will play the role of a screen and will intercept a part of these corpuscles which would have hit A. Then, the impacts received by A

in the opposite direction of the one of B, will not have compensation any longer, or will be imperfectly compensated, and they will push A towards B. Such is Le Sage theory."

It is possible to demonstrate rather easily that the "push" is inversely proportional to the square distance between the two bodies (like the Newton law).

One can also demonstrate that, if the corpuscles are very tiny, the push is approximately proportional to the number of nucleons and so the mass of the body, and not the apparent surface of the body.

Moreover, only a tiny fraction of corpuscles hits the atoms of the body, which explains that the push (the gravitational force) is so weak.

The main evolutions of the gravitons field versus Le Sage theory are the following:

- One must not use the notion of impact between the corpuscles and matter.
- One must consider that the corpuscles are **non-material** and constitute a **medium**.
- The total energy of an entity is the sum of its kinetic energy of translation and of its kinetic energy of rotation about itself.
- Fundamental law: conservation of the total energy of an entity: the total energy of one entity remains constant:

$$E_{\text{total}} = E_{\text{translation}} + E_{\text{rotation}} = \text{constant}. \quad (21)$$

Afterwards we will call these entities **gravitons** (but these gravitons have nothing to do with the graviton of spin 2 of quantum mechanics).

If the total energy of the gravitons remains constant, then the gravitons do not give energy to the atoms of the Earth and so do not raise the temperature of the Earth contrary to the conclusion made by Poincaré[5] on the original theory of Le Sage.

It is postulated that the gravitons which interact with the atoms of a massive body lose some of their kinetic energy of **translation** which turns into kinetic energy of **rotation**.

The gravitons which interact with the atoms of a massive body lose a part of their translation speed and win some rotation speed, and are called **gravitons-spin**.

So a massive body would be a huge "transformer" of "standard gravitons" in "gravitons-spin."

This physical phenomenon does not raise the temperature of a massive body, but it has an effect on the **medium**.

The medium undergoes a centripetal flux due to the presence of the massive body.

Indeed, let us consider a reference frame at the surface of the massive body and an elementary volume linked to it.

If one measures the speed vectors of all the gravitons in this elementary volume, the **average of the speed vectors** gives a **resulting speed vector which is centripetal** (because the gravitons-spin coming from the ground have a smallest translation speed than the standard gravitons coming from the sky).

It has been demonstrated in a previous article[4] that the acceleration of the flux of the medium has the following expression $\overrightarrow{\gamma_{\text{flux}}} = -\frac{GM}{r^2}\overrightarrow{u_r}$ from which one can deduce that the centripetal speed of the flux of the medium at a distance r from the center of gravity of a massive body of mass M is equal to (measured in a reference frame R linked to the massive body),

$$\overrightarrow{C_{G/R}} = \frac{\sum_{i=1}^{N_G}\overrightarrow{V_{G/R}}}{N_G} = \overrightarrow{V_{\text{flux}}} = -\sqrt{\frac{2GM}{r}}\overrightarrow{u_r}. \quad (22)$$

Definition of the preferred frame of reference based on the entities constituting the medium:

Let us consider a Galilean referential R (a laboratory) and an elementary volume linked to this referential.

In this very small volume, imagine that we can count the entities in it (gravitons), and we can also know the speed vector of each graviton $\overrightarrow{V_{G/R}}$.

Knowing this, it is possible to compute the vectorial average of the speed vectors of the gravitons: $\overrightarrow{C_{G/R}} = \frac{\sum_{i=1}^{N_G}\overrightarrow{V_{G/R}}}{N_G}$.

This resultant vector means that, at the center of this given elementary volume, the preferred frame of reference moves at the speed $\overrightarrow{C_{G/R}}$ versus the referential R and that the referential R (the laboratory) moves at the speed $-\overrightarrow{C_{G/R}}$ versus the preferred frame of reference (defined by the medium), i.e., versus the medium.

Another way to present the PFR is to define it as the unique referential for which, at any point M in space, we have

$$\overrightarrow{C_{G/\text{PFR}}}(M) = \frac{\sum_{i=1}^{N_G}\overrightarrow{V_{G/\text{PFR}}}}{N_G} = \overrightarrow{0}. \quad (23)$$

Figure 1 shows the distortion of the medium due to the Earth.

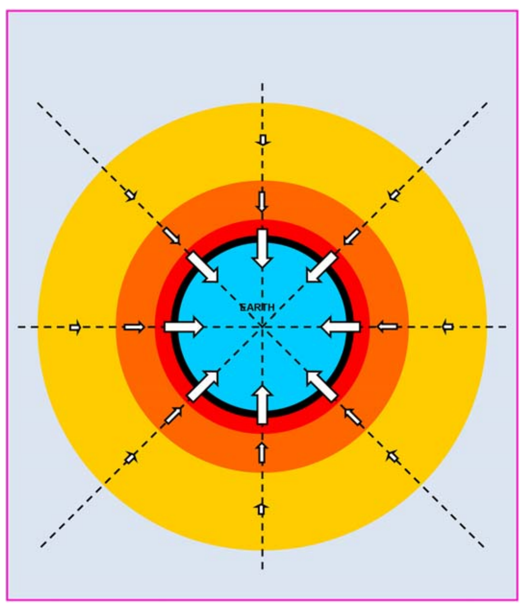

FIG. 1. (Color online) Distortion of the medium due to the Earth.

The flux of the medium

- is generated by the presence of the matter of the Earth,
- is always centripetal, i.e. radial, oriented towards the center of gravity of the Earth,
- is maximum at the surface of the Earth and decreases when going away from the Earth,
- has a constant modulus on every sphere whose center is the one of the Earth,
- gives the impression to follow the Earth in its movement (whatever its speed) because it remains identical to itself.

III. REMINDER ON THE GRAVITATIONAL ACCELERATION IN THE THEORY OF THE DMR

In a previous article,[4] we have determined the acceleration of the flux of the medium created by a massive body at a point M by taking into account the flux of gravitons arriving from all directions in space, these directions being symbolized by elementary cones of elementary solid angle Ω_e and of section s_e at the distance r from point M. Then we have the relation

$$\Omega_e = \frac{s_e}{r^2}. \tag{24}$$

An elementary cone is associated with only one direction of arrival of the incident gravitons at the given point M.

The number of elementary cones describing all directions of 3D space is

$$N_{c(3D)} = \frac{4\pi r^2}{s_e} = \frac{4\pi}{\Omega_e} \quad . \tag{25}$$

The acceleration of the **flux of the medium** is given by the **vector average** of the flux of gravitons,

$$\overrightarrow{\gamma_{\text{flux}}} = \frac{1}{N_{\text{tot}}} \sum_{i=1}^{N_{c(3D)}} F_i \overrightarrow{V_{Gi}} \quad . \tag{26}$$

$F_i = \frac{N_i}{\Delta t}$ is the flux of gravitons in a given direction, that is to say, the number of incident gravitons crossing the section of an elementary cone **per second** ($\Delta t = 1$ s) and moving towards the apex of the cone.

We also consider that the flux of gravitons is the same in all directions; therefore, in all elementary cones, we have

$$F_i = \frac{N_i}{\Delta t} = F_G = \frac{N_G}{\Delta t} = \text{constant}.$$

Regarding N_{tot}, we have

$$N_{\text{tot}} = \sum_{i=1}^{N_{c(3D)}} N_i = N_G.N_{c(3D)} = \frac{4\pi N_G}{\Omega_e} \quad . \tag{27}$$

In a previous article,[4] we have demonstrated that the acceleration of the flux of the medium **generated** by a massive body of mass M at a point located at the distance r from the center of gravity of the massive body has the following formula:

$$\overrightarrow{\gamma_{\text{flux}}} = -G\frac{M}{r^2}\overrightarrow{u_r} \quad \text{with} \quad G = \frac{k_n}{4\pi}\frac{s_n}{m_n}\left(V_G - V_{\text{Gspin}}\right) \ , \tag{28}$$

where

- k_n is the proportion of gravitons having encountered an atom nucleus which have interacted with the nucleus and reemitted in the form of gravitons-spin. $1 - k_n$ is the proportion of gravitons having encountered an atom nucleus and not having interacted with this atom nucleus;
- m_n is the mass of a nucleon and s_n is the section of a nucleon;
- V_G is the speed of the incident gravitons; and
- V_{Gspin} is the speed of the gravitons-spin re-emitted by the nuclei of the atoms of the massive body.

In the theory of the dynamic medium of reference, the acceleration of the flux of the medium is the gravitational acceleration and we therefore find Newton's well-known formula.

IV. ACCELERATION OF THE FLUX OF THE MEDIUM CREATED BY A NUCLEUS

In the proposed model, the proportion k_n of incident gravitons which interact with an atom nucleus or a nucleon belonging to an atom nucleus are re-emitted in gravitons-spin but only in two privileged directions called poles of the nucleus or the nucleon.

This model will be justified in a future article on nucleons and atomic nuclei.

An observer located along the poles of the nucleus (zone 2) receives the flux of gravitons-spin.

On the other hand, an observer located in all the space outside the poles (zone 1) is subjected to the proportion k_n of incident gravitons arriving from his side and which are not compensated by the same proportion k_n of incident gravitons arriving from the opposite side of the nucleus because they interact with the nucleus and are re-emitted in the form of gravitons-spin by the two poles of the nucleus. The resulting flux of the medium is considerable. It ensures the cohesion of the nucleus and corresponds to the strong force (strong acceleration of the flux of the medium) symbolized by the blue arrows (Fig. 2).

Figure 2 is rotationally symmetric around the axis of the nucleus (symbolized by a cylinder) passing through the two red arrows symbolizing the flux of gravitons-spin emitted by the two poles of the nucleus.

A. Acceleration of the flux of the medium outside the poles—Cohesion of the nucleus

The acceleration of the flux of the medium created by an atom nucleus is given by the **vector average** of the flux of gravitons,

$$\overrightarrow{\gamma_S} = \frac{1}{N_{\text{tot}}} \sum_{i=1}^{N_{c(3D)}} F_i \overrightarrow{V_{Gi}} = -\frac{F_G.N_c.k_n.V_G}{N_{\text{tot}}}\overrightarrow{u_r} \ , \tag{29}$$

where

- $F_G = \frac{N_G}{\Delta t}$ is the flux of gravitons in a given direction, that is to say the number of incident gravitons crossing the section of an elementary cone **per second** ($\Delta t = 1$ s) and moving towards the apex of the cone;
- N_c is the number of elementary cones intercepted by the nucleus;
- k_n is the proportion of gravitons having interacted with the nucleus and reemitted in the form of gravitons-spin in the two privileged directions that are the two poles of the nucleus; and
- V_G is the speed of the incident gravitons.

The explanation of formula (29) is as follows: the incident gravitons which arrive on the nucleus from the side opposite to the point M interact with the nucleus (in the small proportion k_n), are re-emitted in the form of gravitons-spin by the two poles of the nucleus, and do not reach the point M, which therefore only feels the equivalent proportion of incident gravitons arriving from its side with respect to the nucleus at the speed V_G.

The number of elementary cones intercepted by the section $N_n s_n$ of the N_n nucleons of the nucleus is

$$N_c = \frac{N_n s_n}{s_e} = \frac{N_n s_n}{\Omega_e . r^2} \quad . \tag{30}$$

Finally, the **acceleration of the flux of the medium** (outside the poles) created by an atomic nucleus composed of N_n nucleons is written as

$$\gamma_S = K \frac{N_n s_n}{r^2} \quad \text{with} \quad K = \frac{k_n}{4\pi} . V_G \quad . \tag{31}$$

In the theory of DMR, it is this acceleration that ensures the cohesion of the nucleons of an atomic nucleus.

B. Acceleration of the flux of gravitons-spin emitted by the poles of a nucleus

All the incident gravitons which move towards an atom nucleus, i.e., which arrive from $N_{c(3D)} = \frac{4\pi}{\Omega_e}$ directions of 3D space and which interact with a nucleus (in the very low proportion k_n), are re-emitted in the form of gravitons-spin by the two poles of the nucleus. Thus, the acceleration of the **flux of gravitons-spin** emitted by the two poles of the nucleus of an atom has the expression:

$$\gamma_{\text{Gspin(poles)}} = N_{c(3D)} F_G k_n V_{\text{Gspin}} \quad . \tag{32}$$

C. Acceleration of the mean flux of gravitons-spin emitted by a nucleus

To determine the mean flux of gravitons-spin emitted by a nucleus, the following two important points must be taken into consideration:

- In the proposed model, an atom nucleus spins on itself at high speed. Thus, the two jets of gravitons-spin emitted by the two poles sweep across 3D space, in all directions of space,
- The second essential point is that the gravitons-spin emitted by the two poles of the nucleus do not correspond only to the incident gravitons arriving in these two directions, but to the incident gravitons arriving from all directions of space and which interact with the nucleus (Fig. 3).

Note: given the extreme smallness of the gravitons, there are hardly ever any collisions between the incident gravitons and the gravitons-spin emitted by the two poles of the nucleus.

The nucleus being in rapid rotation, it is assumed that the jets of gravitons-spin emitted by the two poles of the

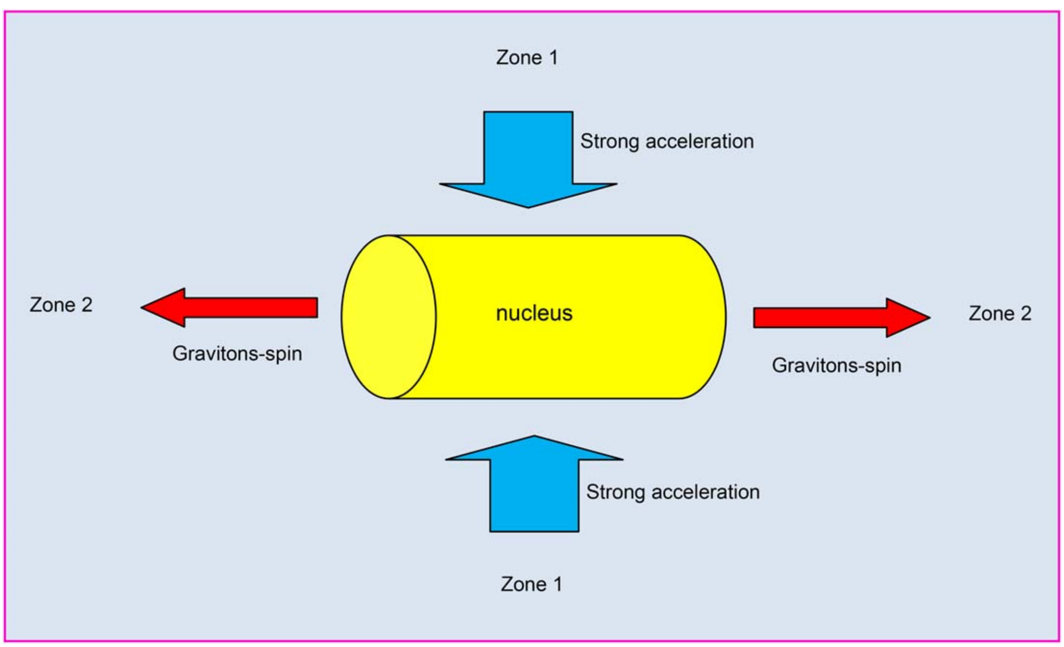

FIG. 2. (Color online) Strong force ensuring the cohesion of an atom nucleus.

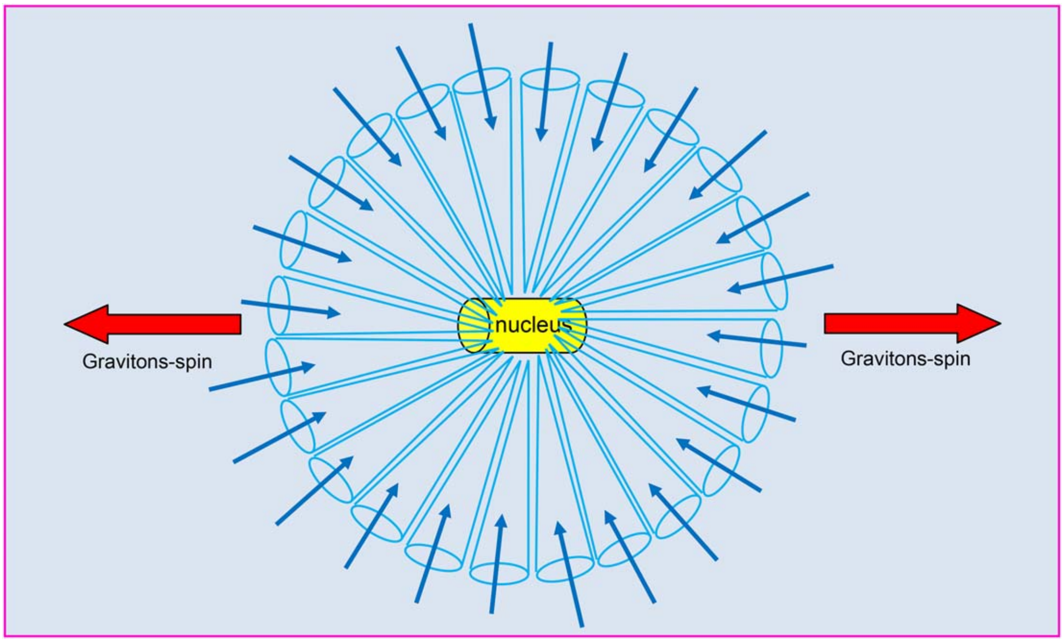

FIG. 3. (Color online) Flux of incident gravitons and flux of gravitons-spin emitted by a nucleus.

nucleus describe the $N_{C(3D)}$ directions of space in the period T, and therefore that a jet of gravitons-spin is found in a given direction (in the elementary cone of solid angle Ω_e) during the duration: $\tau = \frac{T}{N_{c(3D)}}$.

Thus, the acceleration of the flux of gravitons-spin emitted by the two poles of the nucleus of an atom, considered as a mean flux emitted continuously in all directions of space, has the expression,

$$\gamma_{\text{Gspin(mean)}} = \frac{\tau}{T}\gamma_{\text{Gspin(poles)}} = F_G k_n V_{\text{Gspin}}. \quad (33)$$

V. LINK BETWEEN THE MEAN FLUX OF GRAVITONS-SPIN EMITTED BY A NUCLEUS AND THE GRAVITATIONAL ACCELERATION

The acceleration of the **flux of the medium** created by an atom nucleus is given by the **vector average** of the flux of gravitons,

$$\overrightarrow{\gamma}_{\text{flux(nucleus)}} = \frac{1}{N_{\text{tot}}}\sum_{i=1}^{N_{c(3D)}} F_i \overrightarrow{V_{Gi}}$$
$$= \frac{1}{N_{\text{tot}}}\left(\overrightarrow{\gamma}_{\text{Gspin(mean)}} - \overrightarrow{\gamma}_{G(\text{standard})}\right) , \quad (34)$$

$$\overrightarrow{\gamma}_{\text{flux(nucleus)}} = \frac{F_G.k_n.V_{\text{Gspin}} - F_G.k_n.V_G}{N_{\text{tot}}}\overrightarrow{u_r} \ . \quad (35)$$

To make the connection between the acceleration of the flux of the medium created by an atom nucleus and the gravitational acceleration, we have to go from an atom to a material body made up of a very large number of atoms.

We consider a material body of surface S and thickness e (assumed constant to simplify calculations) seen by an observer located at point M.

The acceleration of the flux of the medium **generated** by the material body at a point M located at the distance r from the center of gravity of the material body has the formula

$$\overrightarrow{\gamma_{\text{flux}}} = \frac{1}{N_{\text{tot}}}\sum_{i=1}^{N_{c(3D)}} F_i \overrightarrow{V_{Gi}}$$
$$= (N_c.N_s.k_s).\left[\frac{F_G.k_n}{N_{\text{tot}}}.(V_{\text{Gspin}} - V_G)\overrightarrow{u_r}\right] , \quad (36)$$

where

- $N_c = \frac{S}{s_e} = \frac{S}{\Omega_e.r^2}$ is the number of elementary cones intercepted by the material body,
- $N_s = \frac{e}{d}$ is the number of elementary slices of thickness the interatomic distance d contained in the thickness e of the material body,
- $k_s = \frac{N_n.s_n}{d^2}$ is the proportion of gravitons for which an atom nucleus is in their path. So k_s is the ratio of the cross section of the nucleons constituting the nucleus of an atom and the interatomic section d,[2] and
- m_n is the mass of a nucleon, s_n is the section of a nucleon and N_n is the number of nucleons in a given atomic nucleus.

By taking into account the density of the material body $\rho = \frac{M}{V} = \frac{M}{S.e} = \frac{N_n m_n}{d^3}$, we have

$$N_c N_s k_s = \frac{S}{\Omega_e.r^2}\frac{e}{d}\frac{N_n.s_n}{d^2} = \frac{S.e}{d^3}\frac{N_n.s_n}{\Omega_e.r^2} = \frac{s_n}{m_n}\frac{M}{\Omega_e.r^2} \ ,$$

which makes it possible to obtain

$$\gamma_{\text{flux}} = G\frac{M}{r^2} \text{ with } G = \frac{1}{N_{\text{tot}}}\frac{F_G}{\Omega_e}k_n\frac{s_n}{m_n}(V_G - V_{\text{Gspin}}), \tag{37}$$

finally using $N_{\text{tot}} = \frac{4\pi N_G}{\Omega_e}$, we have

$$G = \frac{k_n}{4\pi}\frac{s_n}{m_n}(V_G - V_{\text{Gspin}}). \tag{38}$$

There is therefore a close link between the acceleration of the flux of gravitons-spin emitted by atomic nuclei and the acceleration of the flux of the medium created by a material body or gravitational acceleration.

VI. COMPARISON OF GRAVITATIONAL FORCE AND STRONG FORCE

In the theory of DMR, there is a very strong link between the gravitational force and the strong force because both are created by the nuclei of atoms, but the following differences should be highlighted:

- The strong force exists near an atomic nucleus outside the axis of the poles of the nucleus through which the gravitons-spin are emitted. The strong force ensures the cohesion of an atom nucleus.
- Gravitational force is created by a gigantic number of atomic nuclei (12 grams of carbon contain $N_A = 6 \times 10^{23}$ carbon atoms!). A gigantic number of nuclei emit gravitons-spin in all directions of space that must be taken into account to find the gravitational acceleration of a material body.

To compare the gravitational force and the strong force, we will take the case of a material particle of mass m and a nucleus of mass $N_n m_n$ and section $N_n s_n$ for which the two forces are expressed as follows:

$$F_G = m.\gamma_G = G\frac{m.(N_n m_n)}{r^2} \quad , \tag{39}$$

$$F_S = m.\gamma_S = K\frac{m.(N_n s_n)}{r^2} \quad . \tag{40}$$

The order of magnitude between the two forces is 10^{38} which gives

$$\frac{F_S}{F_G} = \frac{\gamma_S}{\gamma_G} = \frac{K}{G}\frac{s_n}{m_n} \approx \ 10^{38} \quad . \tag{41}$$

We deduce the order of magnitude of the constant K by assuming that the order of magnitude of the section of a nucleon is $s_n \approx (10^{-15})^2 \approx 10^{-30}$ m^2,

$$\begin{aligned} K &= G\left(\frac{\gamma_S}{\gamma_G}\right)\left(\frac{m_n}{s_n}\right) \\ &\approx 6.67 \times 10^{-11}.10^{38}.\frac{1.67 \times 10^{-27}}{10^{-30}} \\ &\approx 1.12 \times 10^{31} \text{ m s}^{-2}. \end{aligned} \tag{42}$$

It is possible to determine the speed of gravitons-spin using the gravitational acceleration and the strong acceleration of the medium given by the following expressions:

$$\gamma_G = G\frac{N_n m_n}{r^2} \quad \text{with} \quad G = \frac{k_n}{4\pi}\frac{s_n}{m_n}(V_G - V_{\text{Gspin}}),$$
$$\gamma_S = K\frac{N_n s_n}{r^2} \quad \text{with} \quad K = \frac{k_n}{4\pi}.V_G.$$

The ratio of the two accelerations gives us

$$\frac{\gamma_G}{\gamma_S} = \frac{G}{K}\frac{m_n}{s_n} = \frac{V_G - V_{\text{Gspin}}}{V_G} = \frac{\Delta V_G}{V_G}. \tag{43}$$

The speed difference $\Delta V_G = V_G - V_{\text{Gspin}}$ is therefore given by the following expression:

$$\Delta V_G = V_G\left(\frac{\gamma_G}{\gamma_S}\right) \quad . \tag{44}$$

In two previous articles,[1,3] we determined the speed of "standard" gravitons at around $V_G \approx 3 \times 10^{69}$ m/s.

We therefore deduce
$\Delta V_G \approx 3 \times 10^{69}.10^{-38} \approx 3 \times 10^{31}$m/s.

This provides the proof that $\Delta V_G \ll V_G$ as assumed in the article[3] « Explanation of the huge difference between vacuum energy and dark energy in the theory of the dynamic medium of reference ».

We also deduce the value of the proportion k_n: $k_n = 4\pi K.V_G^{-1} \approx 4.68 \times 10^{-38}$.

The following important points summarize what has just been seen:

- The gravitational force is proportional to the difference $\Delta V_G = V_G - V_{\text{Gspin}}$.
- The strong force is proportional to the speed of standard gravitons V_G.
- The proportion k_n of gravitons which interact with matter is very low.

VII. SPEED OF THE FLUX OF THE MEDIUM CREATED BY A NUCLEUS

Within the framework of the theory of the dynamic medium of reference, the strong field is the centripetal acceleration of the flux of the medium created by a nucleus,

$$\overrightarrow{\gamma_S} = -K\frac{N_n s_n}{r^2}\overrightarrow{u_r}. \tag{45}$$

The link between the acceleration and the speed of the flux of the medium is given by the following formula:

$$\gamma_{\text{flux}} = \frac{dV_{\text{flux}}}{dt} = \frac{dV_{\text{flux}}}{dr}\frac{dr}{dt} = \frac{dV_{\text{flux}}}{dr}V_{\text{flux}} = \frac{d}{dr}\left(\frac{V_{\text{flux}}^2}{2}\right). \tag{46}$$

The speed of the flux of the medium is therefore given by the following formula:

$$V_S^2 = \int 2\gamma_S dr = \int \left(-2K\frac{N_n s_n}{r^2}\right) dr = \frac{2KN_n s_n}{r} + C. \tag{47}$$

At an infinite distance from the nucleus, the speed of the flux of the medium is zero whence $C = 0$ and finally

$$V_S^2 = \frac{2KN_n s_n}{r}. \tag{48}$$

VIII. RADIUS CORRESPONDING TO A SPEED OF THE FLUX OF THE MEDIUM EQUAL TO THE SPEED OF LIGHT

A. Case of gravitation

The speed of the flux of the medium $V_G = \sqrt{\frac{2GM}{r}}$ is equal to the speed of light for $R_G = \frac{2GM}{c_0^2}$.

This formula gives the Schwarzschild radius achievable only for a black hole of mass M.

For a black hole of a solar mass, we have $R_G = 3000$ m.

B. Case of strong force

The speed of the flux of the medium $V_S = \sqrt{\frac{2KN_n s_n}{r}}$ is equal to the speed of light for

$$r_S = \frac{2KN_n s_n}{c_0^2}. \tag{49}$$

For a nucleus of 4 nucleons, this gives $r_S \approx 1$ fm.

This radius defines a sphere around the nucleus except the two poles of the nucleus.

It is important to note that the value found is on the order of magnitude of the size of an atomic nucleus.

IX. EFFECTS DUE TO THE STRONG ACCELERATION OF THE FLUX OF THE MEDIUM

All the effects which will be described below are due to the speed of the flux of the medium created by an atom nucleus in a region remaining (at least for a brief moment) **outside the poles of the nucleus**.

A. Slowing down of material clocks

Material clocks undergo a dilatation of their period according to the following formula:

$$T = T_0.K_S(r) \text{with } K_S(r) = \left(1 - \frac{V_S^2}{c_0^2}\right)^{-1/2} = \left(1 - \frac{2KN_n s_n}{c_0^2.r}\right)^{-1/2} = \left(1 - \frac{r_s}{r}\right)^{-1/2}. \tag{50}$$

B. Contraction of material rulers

Material rulers undergo a contraction of their length according to the following formula:

$$L = L_0/K_S(r) \text{with } K_S(r) = \left(1 - \frac{V_S^2}{c_0^2}\right)^{-1/2} = \left(1 - \frac{2KN_n s_n}{c_0^2.r}\right)^{-1/2} = \left(1 - \frac{r_s}{r}\right)^{-1/2}. \tag{51}$$

C. Slowing down of light

In the case of a radial trajectory of the light, we have the following simple expression:

$$c = \frac{c_0}{n(r)} = \frac{c_0}{K_S^2(r)}. \tag{52}$$

In the case of any trajectory, light is slowed down by a strong field, and the expression of its speed is

$$c = \frac{c_0}{K_S\sqrt{1 + \left(K_S^2 - 1\right)\cos^2\varphi}}. \tag{53}$$

We name $\varphi = \left(\overrightarrow{u_r}, \overrightarrow{c}\right)$ the angle between the unit radial vector $\overrightarrow{u_r}$ and the speed vector of light $\overrightarrow{c}$. The vector $\overrightarrow{c_0}$ represents the speed vector of light if there was not any nucleus.

D. Deflection of light by an atom nucleus

General relativity predicts the deflection of a ray of light by a massive body such as the Sun.

According to the theory of the dynamic medium of reference, a ray of light is also deflected by an atom nucleus.

The deflection of a ray of light by an atom nucleus would be similar to that obtained with a massive body, but whereas it is necessary to use the universal gravitational constant $G = 6.67 \times 10^{-11}$ m^3 s^{-2} kg^{-1} in the gravitational case, it is necessary to use the constant $K \approx 10^{31}$ m s^{-2} in the nuclear case.

The deflection in the gravitational case is due to the influence of a massive body of mass M with which the constant $R_G = \frac{2GM}{c_0^2}$ is associated and the deflection is given by the formula $\delta_G = \frac{4GM}{c_0^2.R_{\min}} = 2\frac{R_G}{R_{\min}}$ ($R_{\min}$ indicates the smallest distance of the light path to the center of gravity of the massive body), while in the nuclear case the deflection is due to the influence of an atom nucleus of N_n nucleons at which is associated the constant $r_S = \frac{2KN_n s_n}{c_0^2}$ and the deflection is given by the formula

$$\delta_S = \frac{4KN_n s_n}{c_0^2.r_{\min}} = 2\frac{r_S}{r_{\min}}. \tag{54}$$

Note: the expression $\delta_S = 2\frac{r_S}{r_{\min}}$ is valid for $r_{\min} \gg r_S$. Otherwise, further mathematical developments would have to be carried out.

E. Nuclear time delay of light

General relativity predicts a delay in the travel time of light or an electromagnetic signal passing near a massive body such as the Sun, relative to the same path taken without the presence of the massive body. This is called the time delay of light or Shapiro delay.

In the context of general relativity, the delay in travel time is due to the curvature of space–time created by the massive body.

In the context of the dynamic medium of reference theory, the delay in travel time is simply due to the fact that the light is slowed down by the massive body.

The dynamic medium of reference theory also predicts a delay in the travel time of light due to its slowing down by an atom nucleus. We can call it the nuclear time delay of light.

We will now establish the delay in the travel time of light due to an atom nucleus.

We consider the path of a ray of light going from point M_1 of Cartesian coordinates (x_1, y_1) to point M_2 of Cartesian coordinates (x_2, y_2) (Fig. 4).

The time taken by light to go from point M_1 to point M_2 is

$$\Delta t = \int_{M_1}^{M_2} \frac{dx}{c(r)}. \tag{55}$$

In the approximation where $r \gg r_S$, the speed of light is expressed as

$$c = \frac{c_0}{K_S\sqrt{1+\left(K_S^2-1\right)\cos^2\varphi}} \approx c_0\left(1-\frac{r_s}{2r}\right)\left[1-\frac{1}{2}\left(K_S^2-1\right)\cos^2\varphi\right],$$

with

$$K_S^2 - 1 = \frac{1}{1-\frac{r_S}{r}} - 1 = \frac{r}{r-r_S} - 1 = \frac{r_S}{r-r_S},$$

so we have

$$c \approx c_0\left(1-\frac{r_s}{2r}\right)\left[1-\frac{1}{2}\frac{r_S}{r-r_S}\cos^2\varphi\right] \approx c_0\left[1-\frac{r_s}{2r}-\frac{1}{2}\frac{r_S}{r-r_S}\cos^2\varphi+\frac{1}{4}\frac{r_S^2}{r(r-r_S)}\cos^2\varphi\right].$$

Thus, in the approximation where $r \gg r_S$, the speed of light is expressed as

$$c(r) \approx c_0\left[1-\frac{r_S}{2r}\left(1+\cos^2\varphi\right)\right]. \tag{56}$$

By using the formula $\cos\varphi = \frac{x}{r}$, we have

$$c(r) \approx c_0\left[1-\frac{r_S}{2r}-\frac{r_S.x^2}{2r^3}\right], \tag{57}$$

and therefore

$$\Delta t = \int_{M_1}^{M_2} \frac{dx}{c(r)} \approx \frac{1}{c_0}\int_{x_1}^{x_2} dx + \frac{r_S}{2c_0}\int_{x_1}^{x_2}\frac{dx}{r} + \frac{r_S}{2c_0}\int_{x_1}^{x_2}\frac{x^2}{r^3}dx.$$

$\Delta t_{\text{Newton}} = \frac{1}{c_0}\int_{x_1}^{x_2} dx = \frac{x_2-x_1}{c_0}$ represents the duration of the travel of the ray of light in the Newtonian case.

If we define $f(x) = \ln(x+r)$, then we have

$$f'(x) = \frac{df(x)}{dx} = \frac{1+\frac{dr}{dx}}{x+r} = \frac{1+\frac{d\sqrt{x^2+y^2}}{dx}}{x+r} = \frac{1+\frac{1}{2}\frac{2x}{\sqrt{x^2+y^2}}}{x+r} = \frac{1+\frac{x}{r}}{x+r} = \frac{1}{r}.$$

By writing $g(x) = \frac{x}{r}$, we have $g'(x) = \frac{1}{r} - x\frac{\frac{dr}{dx}}{r^2} = \frac{1}{r} - \frac{x^2}{r^3}$.
Finally, we have

$$\Delta t \approx \Delta t_{\text{Newton}} + \frac{r_S}{2c_0}\int_{x_1}^{x_2}\left(2f'(x)-g'(x)\right)dx,$$

$$\Delta t \approx \Delta t_{\text{Newton}} + \frac{r_S}{2c_0}\left[2f(x_2)-2f(x_1)-g(x_2)+g(x_1)\right],$$

$$\Delta t \approx \Delta t_{\text{Newton}} + \frac{r_S}{2c_0}\left[2\ln\left(\frac{x_2+r_2}{x_1+r_1}\right)-\frac{x_2}{r_2}+\frac{x_1}{r_1}\right]. \tag{58}$$

Using the fact that $(r_1+x_1)(r_1-x_1) = r_1^2 - x_1^2 = y_1^2$, the previous formula can also be written as

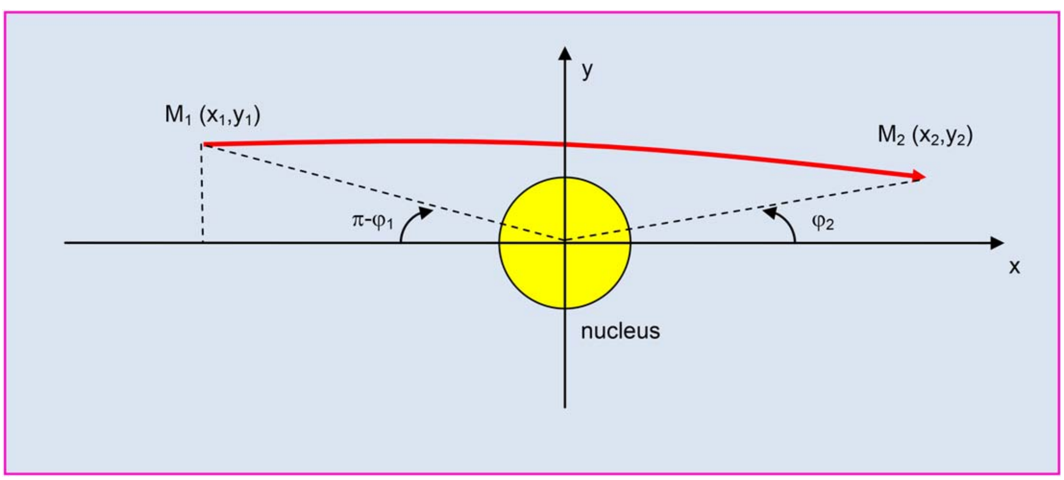

FIG. 4. (Color online) Slowdown of light due to a nucleus.

$$\Delta t \approx \Delta t_{\text{Newton}} + \frac{r_S}{2c_0}\left[2\ln\left(\frac{(r_2+x_2)(r_1-x_1)}{y_1^2}\right) - \frac{x_2}{r_2} + \frac{x_1}{r_1}\right]. \quad (59)$$

By using once again the relation $\cos\varphi = \frac{x}{r}$, we finally obtain

$$\Delta t \approx \Delta t_{\text{Newton}} + \frac{r_S}{2c_0}\left[2\ln\left(\frac{r_1 r_2}{y_1^2}(1-\cos\varphi_1)(1+\cos\varphi_2)\right) + \cos\varphi_1 - \cos\varphi_2\right]. \quad (60)$$

Case where $\varphi_1 \approx \pi$ and $\varphi_2 \approx 0$ (that is to say, $\cos\varphi_1 \approx -1$ and $\cos\varphi_2 \approx 1$):

By observing that $y_1 \approx r_{\min}$, we have

$$\Delta t \approx \Delta t_{\text{Newton}} + \frac{r_S}{c_0}\left[ln\left(4\frac{r_1 r_2}{r_{\min}^2}\right) - 1\right]. \quad (61)$$

X. PROPOSED EXPERIMENT

The experiment uses a source emitting photons one at a time. Each photon passes near an atom nucleus as shown in Fig. 5.

The choice of a source emitting photons one at a time allows to achieve high accuracy on the emission time, reception time, and position of arrival of the photon.

This experiment will make it possible to verify the two following phenomena:

- The nuclear deflection of light.
- The nuclear time delay of light.

A. Nuclear deflection of light

The deviation is given by the formula $\delta_S = \frac{4KN_n s_n}{c_0^2 \cdot r_{\min}} = 2\frac{r_S}{r_{\min}}$ with

- Speed of light: $c_0 = 299\,792\,458$ m/s,
- Strong constant: $K \approx 10^{31}$ m s^{-2},
- $s_n \approx 10^{-30}$ m^2.

We deduce the value of the deviation for an atom nucleus of $N_n = 4$ nucleons:

- $\boldsymbol{\delta_S} \approx 0.2$ radians $\approx 11°$ for $r_{\min} = 10$ fm.

The deflection of a photon passing 10 fm from an atomic nucleus of 4 nucleons is about 23 000 times greater than the deflection of the same photon passing near the surface of the Sun.

B. Nuclear time delay of light

In Table I, we give the results of the nuclear time delay of light by taking the following values:

- Speed of light: $c_0 = 299\,792\,458$ m/s,
- Strong constant: $K \approx 10^{31}$ m s^{-2},
- Mass of the nucleon : $m_n = 1.67 \times 10^{-27}$ kg,
- Number of nucleons in the nucleus: $N_n = 10$ whence $r_s \approx 2.5$ fm,
- $r_1 = r_2 = 5$ cm.

C. Discussion about the nuclear time delay of light

The delays in the duration of the light path are far too small to be measured even by the most accurate atomic clocks.

The following parameters can be optimized for the greatest possible effect:

- increase N_n, that is to say, use an atom nucleus of the greatest possible mass,
- decrease the radial distance $r_{\min}$ (but this has a reduced effect due to the natural logarithm).

This optimization of the parameters may not be sufficient. We therefore propose that the photons make a large number of round trips over a duration of T_{total}.

The number of round trips made by the photons during the duration T_{total} is given by the formula

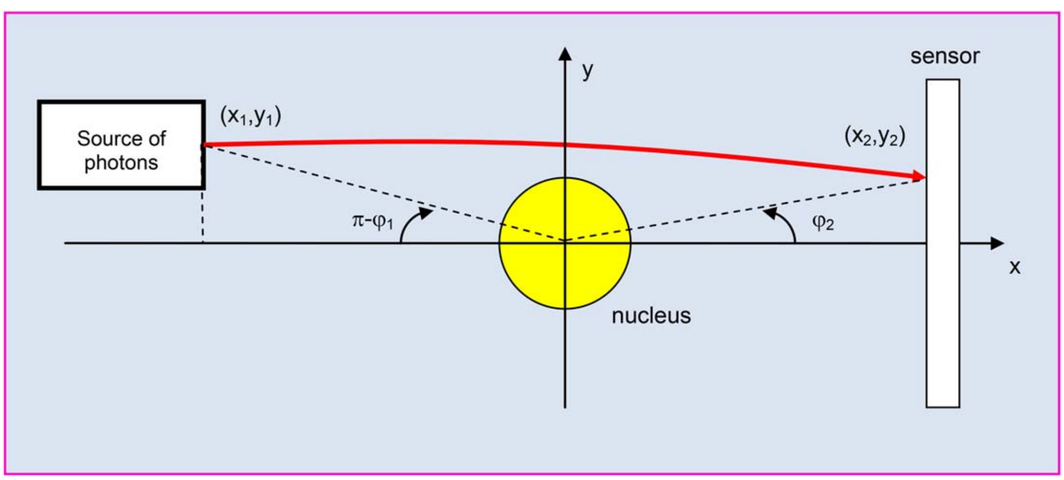

FIG. 5. (Color online) Proposed experiment.

TABLE I. Nuclear time delay of light as a function of the distance r_{min}.

r_{min} (m)	10^{-15}	10^{-14}	10^{-13}	10^{-12}	10^{-11}	10^{-10}	10^{-9}
$\Delta t - \Delta t_{Newton}$ (s)	5.2×10^{-22}	4.9×10^{-22}	4.5×10^{-22}	4.1×10^{-22}	3.7×10^{-22}	3.3×10^{-22}	3.0×10^{-22}

$$N = \frac{c_0.T_{total}}{x_2 - x_1} \approx \frac{c_0.T_{total}}{r_2 + r_1} \; . \tag{62}$$

For $T_{total} = 0.1$ s and $r_1 = r_2 = 5$ cm, $N = c_0 = 299\,792\,458$.

The delay effect will thus be multiplied by N, and the cumulative measured delay will be $N.(\Delta t - \Delta t_{Newton}) \approx 0.9 \times 10^{-13}$ s (for $r_{min} = 10^{-9}$ m) which is measurable by atomic clocks.

Finally, the experiment will require having good precision on the parameters participating in the delay formula, in particular, the distances.

XI. CONCLUSION

This article shows us that the "mechanism" of an atomic nucleus explains both the strong force (nuclear force ensuring the cohesion of the nucleus) and the gravitational force (due to the jets of gravitons-spin emitted by the two poles of the atom nuclei).

This therefore establishes a fundamental link between the nuclear domain and gravitation.

This article also proposes that the strong acceleration of the flux of the medium which is exerted in all the directions around a nucleus (except the two directions in the axis of the two poles of the nucleus) implies effects comparable to those due to the gravitational acceleration but with the constant K $\approx 10^{31}$ m s^{-2} much greater than the gravitational constant $G \approx 6.67 \times 10^{-11}$ m^3 s^{-2} kg^{-1}. These effects on light are a deflection of the trajectory as well as a slowing down (decrease in the speed of light) which implies a delay in the travel time which can be measured by an atomic clock if we consider a large number of round trips near an atom nucleus.

There remains a discussion to be conducted on the real existence of these effects on light depending on whether the photons pass near the nucleus avoiding the jets of gravitons-spin emitted by the two poles of the nucleus and thus undergo the strong acceleration of the flux of the medium described in part IV.A. ($\gamma_S = K \frac{N_n s_n}{r^2}$ with $K = \frac{k_n}{4\pi}.V_G$) or depending on whether the photons are subjected to the mean flux of gravitons-spin described in part IV.C. which leads only to gravitational acceleration.

Nuclei are made up of nucleons, material particles which therefore cannot go faster than light.

It is reasonable to think that there are some cases where, even if the nucleons located in the outer layer of the nucleus are close to the speed of light, the time that the poles of the nucleus describe all the directions of space, photons will have time to fly over the nucleus without being hit by the jets of gravitons-spin.

If this is the case, photons will be deflected by about 11° when passing at 10 fm from a nucleus of 4 nucleons and these same photons will experience an extra delay compared to the Newtonian prediction of about 3×10^{-22} s when passing at 1 nm from a nucleus of 10 nucleons.

Table I shows that the nuclear time delay of light decreases very slowly as a function of the distance r_{min}. Thus, it is not necessary for the photons to pass a few femtometers from the nucleus to be slowed down by it. They can pass within one or more nanometers of the nucleus, making it possible to use heavy nuclei.

In conclusion, the phenomena of deflection of light and slowing down of light (which implies a time delay of light) are of three different types caused by the following entities:

- Massive bodies (gravitation),
- Electrons (electronic cloud) of atoms (refractive index n),
- Nuclei of atoms (strong acceleration of the flux of the medium proposed by the theory of the dynamic medium of reference).

[1]O. Pignard, Phys. Essays **32**, 422 (2019).
[2]O. Pignard, Phys. Essays **33**, 395 (2020).
[3]O. Pignard, Phys. Essays **34**, 61 (2021).
[4]O. Pignard, Phys. Essays **34**, 279 (2021).
[5]H. Poincaré, *Science et Méthode* (Flammarion, 1908).