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Abstract: The theory of the Dynamic Medium of Reference has already been presented in several articles, in particular O. Pignard, "Dynamic Medium of Reference: A new theory of gravitation" [Phys. Essays **32**, 422 (2019)]. The objective of this article is to present a model of a massive particle within the framework of the Dynamic Medium of Reference theory. A concept of elementary wave on the subatomic level is introduced. An elementary wave is always identical to itself while being constantly renewed by new gravitons (entities that make up the medium of propagation of the wave). This elementary wave propagates in its medium (Dynamic Medium of Reference) at the speed of light, whatever its trajectory. A possible model of the elementary wave called vortex is presented in Appendix B. Then, the concept of line of vortices is introduced. The proposed model of a massive particle is then a set of lines of vortices. This model allows to explain that a massive particle has at the same time a wave aspect (because composed only of elementary waves) and a corpuscular aspect (since the elementary waves remain identical to themselves and that the massive particle remains delimited by the same volume). This model makes it possible to attribute to a massive particle a period $T = \gamma \cdot T_0 = T_0/\sin\vartheta$, a pulsation or angular velocity $\Omega = (\Omega_0/\gamma) = \Omega_0 \sin\vartheta$, an energy $E = \gamma \cdot m_0 c_0^2 = \gamma \cdot E_0 = (E_O/\sin\vartheta)$, and a momentum $p = \gamma \cdot m_0 V = (m_0 c_0/\tan\vartheta)$, where T_0, Ω_0, E_0, and m_0 are, respectively, the period, the pulsation, the energy, and the mass of the particle at rest in the Privileged Frame of Reference and ϑ designates the angle defined by the relation $\cos\vartheta = V/c_0$, where V is the speed of the particle relative to the Privileged Frame of Reference. This same model also makes it possible to attribute to the massive particle the de Broglie wavelength of expression $\lambda = (h/p) = \lambda_0 \tan\vartheta$ with $\lambda_0 = (h/m_0 c_0)$ and a frequency of expression $\nu = \sqrt{(c_0/\lambda)^2 + (c_0/\lambda_0)^2} = \gamma \cdot \nu_0 = (\nu_0/\sin\vartheta)$, where $\nu_0 = (c_0/\lambda_0) = (m_0 c_0^2/h)$ represents the frequency of stationary elementary waves making circular revolutions when the particle is at rest in the Privileged Frame of Reference. Two types of configuration are considered for the particles of matter. In the first type of configuration, the lines of vortices are radial with a spherical envelope. This corresponds to particles of matter free in space, without any field. In the second type of configuration, the lines of vortices are parallel with a cylindrical envelope. This corresponds to nucleons (protons, neutrons) confined in an atomic nucleus by the strong force. © *2024 Physics Essays Publication.*
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Résumé: La théorie du Milieu Dynamique de Référence a déjà été présentée dans plusieurs articles, en particulier "Dynamic Medium of Reference: A new theory of gravitation" (Phys. Essays **32**, 422, 2019). Le présent article a pour objectif de présenter un modèle de particule massive dans le cadre de la théorie DMR. Un concept d'onde élémentaire à l'échelle subatomique est introduit. Une onde élémentaire est toujours identique à elle-même tout en étant sans cesse renouvelée par de nouveaux gravitons (entités qui composent le milieu de propagation de l'onde). Cette onde élémentaire se propage dans son milieu (Milieu Dynamique de Référence) à la vitesse de la lumière quelle que soit sa trajectoire. Un modèle possible de l'onde élémentaire appelé vortex est présenté à l'annexe B. Ensuite le concept de file de vortex est introduit. Le modèle proposé d'une particule massive est alors un ensemble de lignes de vortex. Ce modèle permet d'expliquer qu'une particule massive possède **en même temps** un aspect ondulatoire (car composé uniquement d'ondes élémentaires) et un aspect corpusculaire (puisque les ondes élémentaires restent identiques à elles-mêmes et que la particule massive demeure délimitée par le même volume). Ce modèle permet d'attribuer à une particule massive, une période $T = \gamma.T_0 = T_0/\sin\vartheta$, une pulsation ou vitesse angulaire $\Omega = \frac{\Omega_0}{\gamma} = \Omega_0.\sin\vartheta$, une énergie $E = \gamma.m_0 c_0^2 = \gamma.E_0 = \frac{E_O}{\sin\vartheta}$, et une quantité de mouvement $p = \gamma.m_0 V = \frac{m_0 c_0}{\tan\vartheta}$ où T_0, Ω_0, E_0 et m_0 sont respectivement la période, la pulsation, l'énergie

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et la masse de la particule au repos dans le Référentiel Privilégié et ϑ désigne l'angle défini par la relation $\cos\vartheta = V/c_0$ où V est la vitesse de la particule par rapport au Référentiel Privilégié. Ce même modèle permet également d'attribuer à la particule massive la longueur d'onde de de Broglie d'expression $\lambda = \frac{h}{p} = \ \lambda_0 \tan\vartheta$ avec $\lambda_0 = \frac{h}{m_0 c_0}$ et une fréquence d'expression $\nu = \sqrt{\left(\frac{c_0}{\lambda}\right)^2 + \left(\frac{c_0}{\lambda_0}\right)^2} = \gamma.\nu_0 = \frac{\nu_0}{\sin\vartheta}$ où $\nu_0 = \frac{c_0}{\lambda_0} = \frac{m_0 c_0^2}{h}$ représente la fréquence des ondes élémentaires stationnaires effectuant des révolutions circulaires lorsque la particule est au repos dans le Référentiel Privilégié. Deux types de configuration sont considérés pour les particules de matière. Dans le premier type de configuration les lignes de vortex sont radiales avec une enveloppe sphérique. Cela correspond à des particules de matière libre dans l'espace, sans champ. Dans le second type de configuration les lignes de vortex sont parallèles avec une enveloppe cylindrique. Cela correspond à des nucléons (protons, neutrons) confinés dans un noyau atomique par la force forte.

Key words: Dynamic Medium of Reference; Gravitons Field; Model of A Massive Particle; Elementary Waves; Matter-Vortex; Wave-Corpuscle Duality; De Broglie Wavelength.

I. SUCCINCT 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).

The theory of the Dynamic Medium of Reference has already been presented in several articles,[1–8] in particular "Dynamic Medium of Reference: A new theory of gravitation,"[1] which it is strongly recommended to read.

The theory of the dynamic medium of reference[1] introduces a **dynamic nonmaterial** 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 $V_{\text{flux}} = \sqrt{\frac{2GM}{r}}$ and acceleration $\gamma_{\text{flux}} = \frac{GM}{r^2}$, 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 Preferred Frame of Reference (PFR) according to the formula:

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

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 Preferred Frame of Reference (PFR) according to the formula:

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

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]

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

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

The physical 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 physical 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 constitutes **a demonstration of 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]

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

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]

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

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

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

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:

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

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 $\varepsilon = \varepsilon_0 \cdot \varepsilon_r = \varepsilon_0(1 - \frac{2GM}{c_0^2 r})^{-1}$ and $\mu = \mu_0 . \mu_r = \mu_0(1 - \frac{2GM}{c_0^2 r})^{-1}$.

The refractive index is given by the formula $n = \sqrt{\varepsilon_r \mu_r} = (1 - \frac{2GM}{c_0^2 r})^{-1}$ with $\varepsilon_r = \varepsilon/\varepsilon_0 = (1 - \frac{2GM}{c_0^2 r})^{-1}$ and $\mu_r = \mu/\mu_0 = (1 - \frac{2GM}{c_0^2 r})^{-1}$.

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]

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

that we can write $\left(K^2 \frac{dr}{dt}\right)^2 + (Kr\frac{d\phi}{dt})^2 = c_0^2$

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

$$\frac{d^2u}{d\phi^2} + u = \frac{3GM}{c_0^2}u^2 \text{ with } u = 1/r.$$

This equation, which is exactly that provided by General Relativity,[9–13] 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, 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]

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

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

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

$$\frac{d^2u}{d\phi^2} + u = \frac{GM}{A^2} + \frac{3GM}{c_0^2}u^2 \text{ with } u = 1/r.$$

This equation, which is exactly that provided by General Relativity,[9–13] 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. MODEL OF A MASSIVE PARTICLE IN THE DMR THEORY

A. Elementary wave, matter-vortex

We distinguish two types of waves:

- The "macroscopic" wave which propagates and extends everywhere in space. This is the type of "classic" wave that we are used to considering. This wave is called macroscopic because it corresponds to what we observe at the macroscopic scale. However, with regard to the electromagnetic wave, it is in fact made up of a gigantic number of elementary waves.
- **The elementary wave** on the subatomic level which is always identical to itself while being constantly renewed by new gravitons (entities which make up the medium of propagation of the wave). This elementary wave propagates in its medium (Dynamic Medium of Reference) always at the speed of light whatever its trajectory (which is not necessarily straight).

A possible model of the elementary wave is a vortex and is presented in Appendix B.

In this model the axis of the vortex corresponds to the direction of the vector of the electric field and the direction of rotation of the vortex gives the orientation of the vector of the electric field.

B. Wave–particle duality

In the context of quantum mechanics, a massive particle can behave either like a wave or like a corpuscle. This is called wave–particle duality.

The DMR theory proposes a model in which the particle is at the same time:

- A complex grouping of elementary waves and therefore behaves globally like a wave,
- A quantum of energy determined by the sum of the energy of the elementary waves which constitute it. These quanta of energy are delimited by a certain volume, which remains identical over time and gives the impression of a corpuscle.

C. Line of matter-vortices

The behavior of the line of matter-vortices is different from that of the line of light-vortices[8] (a photon is made up of several parallel lines of light-vortices) although the vortices themselves retain the following fundamental characteristics:

- A matter-vortex is a wave,
- A matter-vortex propagates at the speed of light in the medium (DMR).

Note: in the model of the photon[8] all the lines of vortices are parallel to the velocity vector of the photon and the vortex axes are all perpendicular to the velocity vector of the photon.

On the other hand, for a line of matter-vortices, the direction of the axis of the vortex changes depending on the speed of the line of vortices:

- The axis of the vortices is parallel to that of the line when the line is at rest in the Preferred Frame of Reference as shown in Fig. 1,
- The axis of the vortices is almost perpendicular to that of the line when it approaches the speed of light as shown in Fig. 2.
- In the general case as shown in Fig. 3, the axis of the vortices makes an angle α with the axis of the line, the angle α being given by the formula $\sin\alpha = (V/c_0) = \cos\vartheta$, ϑ designating the angle between the speed vector of the vortex $\overrightarrow{c_0}$ and the speed vector of the line of vortices $\overrightarrow{V}$.

Thus, the trajectory of the vortices is as follows depending on the speed of the line:

- For a line of matter-vortices at rest in the Preferred Frame of Reference, the vortices have a circular trajectory around the axis of the line. The energy of the line of vortices is $E_{\text{line}} = m_{\text{line}} \cdot c_0^2 = N_V m_V c_0^2$, where m_V is the mass of a vortex and N_V the number of vortices in the line,
- For a line of vortices at speed V with regard to the Preferred Frame of Reference, the vortices have a helical trajectory, that is to say they describe a helix with an axis that of the line of vortices.

The axis of the vortices gradually orients itself from parallel to perpendicular to the direction of movement of the line when the speed of translation increases. This explains:

- That there is a contraction of the line of vortices and that it takes place parallel to the direction of movement. This phenomenon would be at the origin of what is called length contraction.

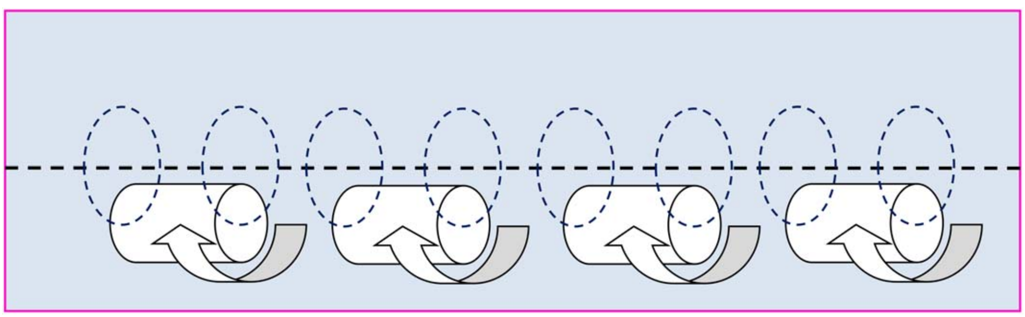

FIG. 1. (Color online) Line of matter-vortices at rest in the Preferred Frame of Reference.

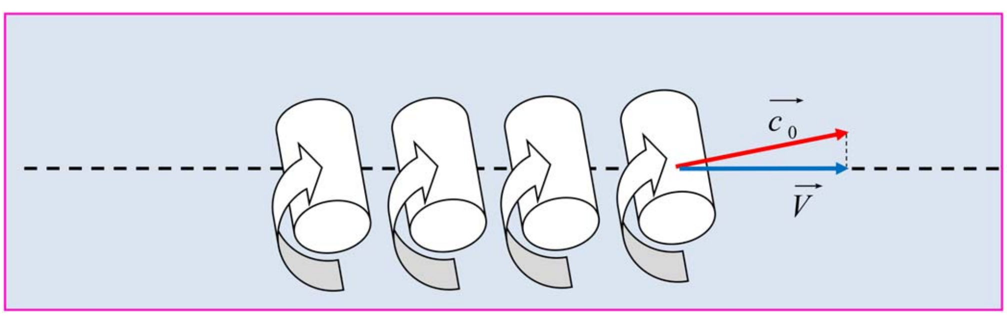

FIG. 2. (Color online) Line of matter-vortices at a speed close to c_0 with regard to the Preferred Frame of Reference.

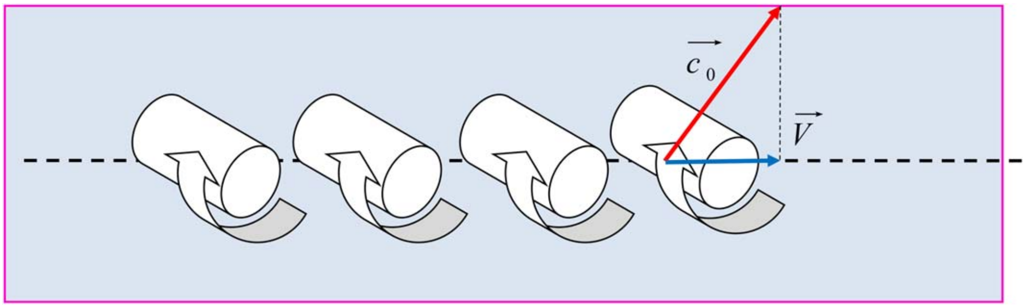

FIG. 3. (Color online) Line of matter-vortices at speed V with regard to the Preferred Frame of Reference.

- That the vortices, which always propagate at the speed of light c_0, take more time to complete a revolution around the axis of the line of vortices. Thus, the period T associated with a line of vortices will be greater as the speed of the line is greater with regard to the Privileged Frame of Reference. This phenomenon would be at the origin of what is called slowing down of clocks.

D. Length contraction, time dilation

1. First case: the line of vortices is at rest with regard to the Preferred Frame of Reference

In this case, the axis of the vortices is parallel to the axis of the line and they describe circles around the axis of the line as shown in Fig. 4:

- The length of a vortex is: L_{V0},
- The length of the line is $L_{\text{line}\,0} = N_V \cdot L_{V0}$ where N_V is the number of vortices constituting the line,
- The path traveled by a vortex when it makes a revolution is: $p_0 = 2 \cdot \pi \cdot r_0$, where r_0 is the radius of the circle traveled by the vortex,
- The speed of the vortex in the Preferred Frame of Reference is c_0.
- The angular speed of the vortex around the axis of the line is $\Omega_0 = \frac{c_0}{r_0}$.
- The period corresponding to one revolution made by the vortex is $T_0 = \frac{p_0}{c_0} = \frac{2\pi r_0}{c_0} = \frac{2\pi}{\Omega_0}$.

2. Second case: the line of vortices is moving with regard to the Preferred Frame of Reference

In this case, the line of vortices has the speed $\overrightarrow{V}$ with regard to the Preferred Frame of Reference.

The movement of the line of vortices with regard to the medium has the effect of tilting the axis of the vortices.

We note α the angle between the axis of the vortices and the axis of the line of vortices.

The speed vector of the vortices $\overrightarrow{c_0}$, which is always perpendicular to the axis of the vortices, makes an angle $\vartheta = (\pi/2) - \alpha$ with the axis of the line and, therefore, the speed vector $\overrightarrow{V}$.

Thus, we have the relationship $\cos\vartheta = (V/c_0) = \sin\alpha$ as well as the relationship $\sin\vartheta = \sqrt{1-(V^2/c_0^2)} = (1/\gamma) = \cos\alpha$.

In the $\mathbf{R_{line}}$ frame of reference, the vortices always describe a circle, but in the Preferred Frame of Reference, they describe a helix (as shown in Figs. 5–7).

Vortices have the following characteristics:

- The projection of the length of a vortex along the axis of the line is $L_V = L_{V0} \cdot \cos\alpha = L_{V0} \cdot \sin\theta = L_{V0}/\gamma$.
- The length of the line is $L_{\text{line}} = N_V \cdot L_V = N_V \cdot L_{V0}/\gamma = L_{\text{line}0}/\gamma$ (length contraction).
- The speed of the vortex in the Preferred Frame of Reference is c_0.
- The speed of rotation of the vortex around the axis of the line is $V_{\text{rot}} = c_0 \cdot \cos\alpha = c_0 \cdot \sin\theta = c_0/\gamma$.

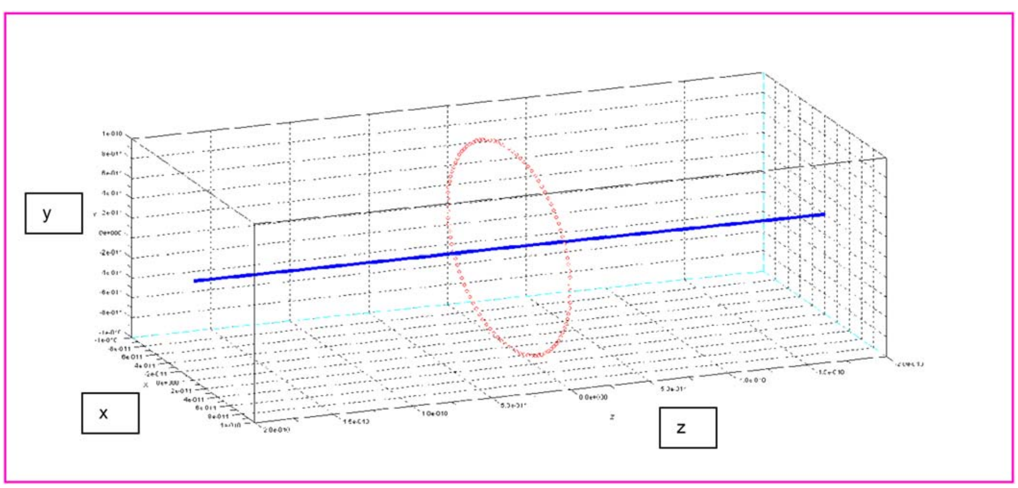

FIG. 4. (Color online) Trajectory of a matter-vortex of a line at rest in the Preferred Frame of Reference.

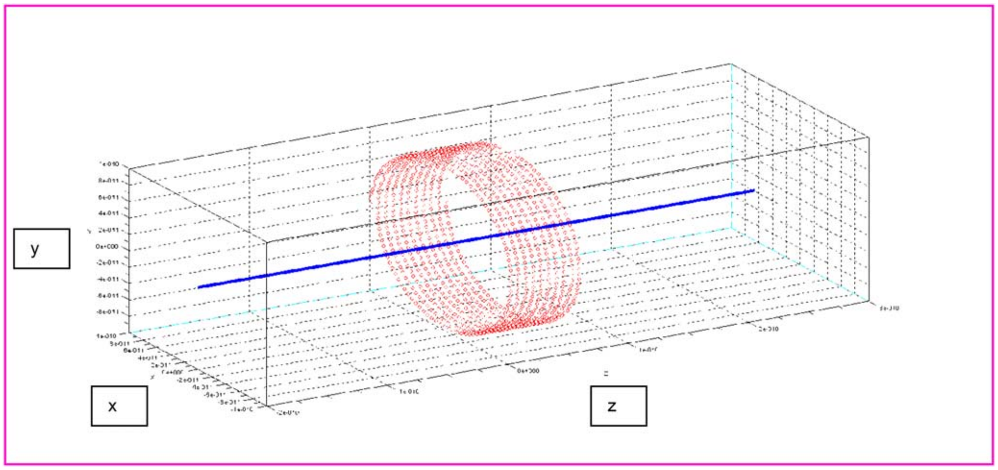

FIG. 5. (Color online) Trajectory of a matter-vortex at speed $V = 0.01c_0$ with regard to the PFR.

- The angular speed of the vortex around the axis of the line is $\Omega = \Omega_0/\gamma = c_0/(r_0 \cdot \gamma) = V_{\text{rot}}/r_0$.
- The distance traveled by a vortex in the Preferred Frame of Reference when it completes one helical turn (one revolution) is $p = 2 \cdot \pi \cdot r_0 \cdot \gamma = \gamma \cdot p_0 = c_0 \cdot T = 2\pi c_0/\Omega$.
- The period corresponding to one turn of the helix made by the vortex is: $T = (p/c_0) = (2\pi \cdot r_0 \cdot \gamma/c_0) = \gamma \cdot T_0$ (dilatation of the durations and periods of the clocks). This latter relationship can also be found by writing $T = (2\pi.r_0/V_{\text{rot}}) = (2\pi \cdot r_0/(c_0/\gamma)) = \gamma \cdot T_0$.

Another demonstration of obtaining the period T is given below.

The element of elementary length travelled by one of the vortices of the line during the duration dt can be broken down into two components, one perpendicular to the movement of the line and the other parallel,

$$dl^2 = dl_\perp^2 + dl_\parallel^2.$$

This expression can also be written as $(c_0 dt)^2 = (V_\perp dt)^2 + (V_\parallel dt)^2$ with $V_\perp = V_{\text{rot}}$ and $V_\parallel = V$. (Note that it was possible to start directly from equality: $c_0^2 = V_{\text{rot}}^2 + V^2$.)

This expression remaining true throughout the trajectory of the vortex, we can write

$$(c_0 T)^2 = (V_\perp T)^2 + (V_\parallel T)^2.$$

The quantity $V_\perp T$ represents the path travelled by a vortex on a revolution projected on a plane perpendicular to the line of vortices, that is to say, $V_\perp T = p_0 = 2 \cdot \pi \cdot r_0 = c_0 \cdot T_0$.

Thus, we have $(c_0 T)^2 = (c_0 T_0)^2 + (VT)^2$.

Finally, we get $T = \frac{c_0 T_0}{\sqrt{c_0^2 - V^2}} = \gamma T_0$.

The line of vortices progresses along the z axis.

To summarize, when the line of vortices is at rest in the Preferred Frame of Reference, the vortices complete a revolution of length $p_0 = 2\pi \cdot r_0$with the angular speed $\Omega_0 = c_0/r_0$ in a period $T_0 = p_0/c_0 = 2\pi \cdot r_0/c_0$ and the length of the line is $L_{\text{line0}} = N_V \cdot L_{V0}$ (we assume that the space between two consecutive vortices is negligible compared to the length of a vortex).

When the line of vortices is at speed $\overrightarrow{V}$, parallel to the line, the vortices complete a revolution of length $p = p_0 \cdot \gamma$ with angular speed $\Omega = \Omega_0/\gamma$ in a period $T = T_0 \cdot \gamma = p/c_0$ and the length of the line is $L_{\text{line}} = L_{\text{line0}}/\gamma$ because the

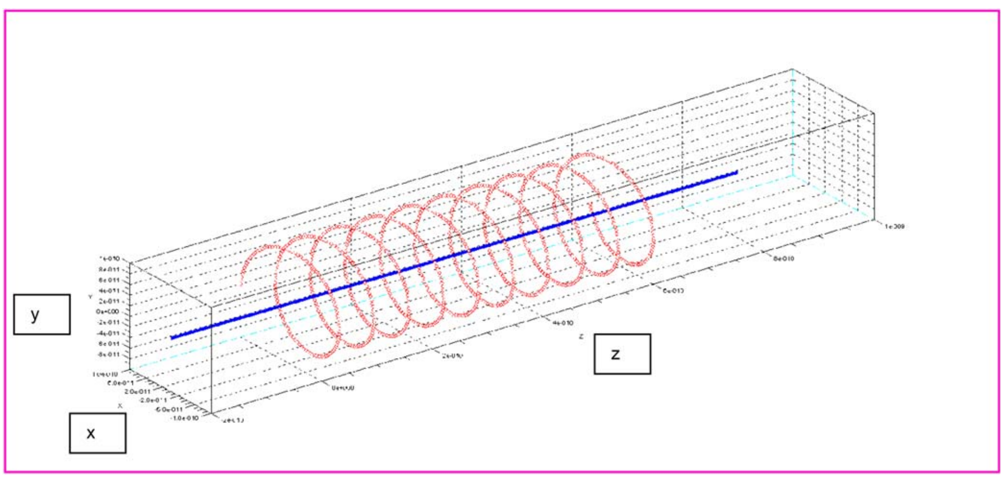

FIG. 6. (Color online) Trajectory of a matter-vortex at speed $V = 0.1c_0$ with regard to the PFR.

vortices are inclined by an angle α such that $\sin\alpha = (V/c_0) = \cos\vartheta$.

For a given reference duration T_{ref} in the Preferred Frame of Reference, the number of turns made by the vortices of a line when it is at rest in the PFR is

$$N_0 = \frac{T_{ref}}{T_0}.$$

The number of turns made by the vortices of a line when it is moving at speed V with regard to the PFR is

$$N = \frac{T_{\text{ref}}}{T} = \frac{T_{\text{ref}}}{\gamma \cdot T_0} = \frac{N_0}{\gamma}.$$

Thus, whatever the speed of the particle with regard to the PFR, we have

$$T_{\text{ref}} = N_0 \cdot T_0 = N.T.$$

The relationship $\mathbf{T_{ref} = N_0.T_0 = N.T}$ shows that it is possible to consider the existence of a privileged time or reference time. Indeed, the vortices constituting a fixed clock in the Preferred Frame of Reference will perform N_0 revolutions of period T_0, while the vortices constituting a clock moving at speed V with regard to the Preferred Frame of Reference will perform N revolutions of period T but we have always $N_0 T_0 = N \cdot T$.

Two observers, one linked to the Preferred Frame of Reference, the other going at speed V with regard to the Preferred Frame of Reference, are both in the same present time.

Fundamental note:

In the proposed theory, our Universe does not have a temporal dimension. Time is only a concept invented by Man who uses natural or artificial periodic movements to mark events.

Movement is "primary," time is only a concept based on movement.

In special relativity, space and time are linked and the faster a particle moves in space, the slower time passes for it and vice versa. Space and time are like communicating vessels.

In the proposed theory, for a particle at rest with regard to the Preferred Frame of Reference, all its vortices describe circles, this cyclical movement corresponding to the passing of time. If the particle has a certain speed with regard to the Preferred Frame of Reference, the vortices describe a helix traveling at the speed of light. Part of their movement (and their speed) contributes to the circular trajectory, the complementary part contributes to the movement of the particle in space. The higher the speed of the particle, the stronger the spatial contribution and the less important the circular contribution, which means a larger time period (it will take more time for the vortices to make a loop). For a particle close to the speed of light, almost all the vortex speed corresponds to the spatial movement of the particle, a very small part of the vortex speed is dedicated to circular movement which gives an enormous period (the time flows very slowly for the particle).

Finally, for vortices moving in a straight line at the speed of light (case of the photon[8]) the entire speed of the vortices is spatial, there is no longer any circular movement and therefore time no longer passes.

To summarize it is possible to give the following two equivalences:

- **Circular movement of vortices == time.**
- **Translational movement of vortices == space.**

E. Energy of a line of matter-vortices

The mechanism of a vortex (made up of gravitons) is that of a wave progressing in the medium, just as a wave (made up of water molecules) progresses on the surface of the ocean.

It is possible to apply the simple laws of classical mechanics to vortices, which are on a much finer scale than those of particles (electrons, nucleons, etc.), in their movement with regard to the Preferred Frame of Reference.

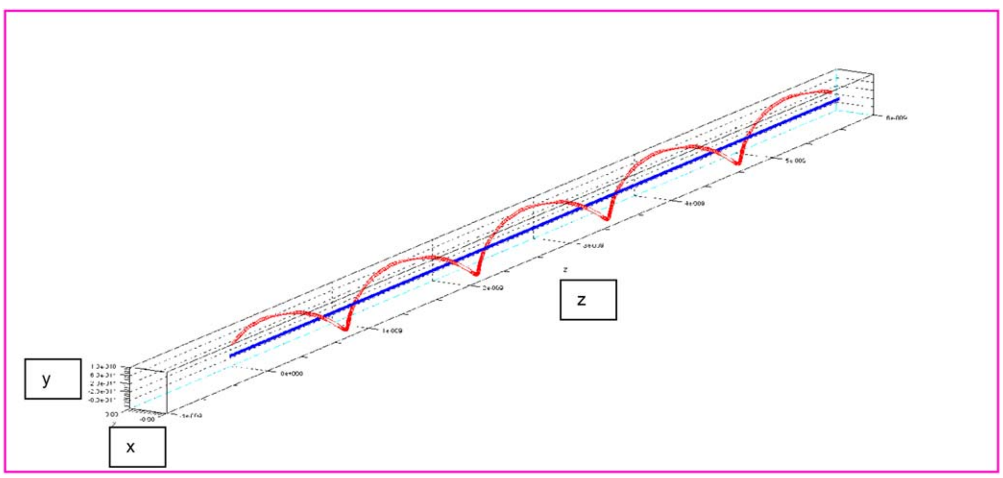

FIG. 7. (Color online) Trajectory of a matter-vortex at speed $V = 0.9c_0$ with regard to the PFR.

It is the movements of all the vortices which explain the laws established at the particle scale ($E = \gamma \cdot m_0 \cdot c_0^2$, $\overrightarrow{p} = \gamma \cdot m_0 \cdot \overrightarrow{V}$).

Let us now establish the formula for the energy of a vortex.

The position of the center of a vortex and its speed are given by the following expressions:

$$\overrightarrow{OM} = \left\{ \begin{array}{c} x = r_0 \cdot \cos(\Omega t) \\ y = r_0 \cdot \sin(\Omega t) \\ z = V \cdot t \end{array} \right\} \quad \overrightarrow{v} = \frac{d\overrightarrow{OM}}{dt}$$
$$= \left\{ \begin{array}{c} v_x = -r_0 \cdot \Omega \cdot \sin(\Omega t) \\ v_y = r_0 \cdot \Omega \cdot \cos(\Omega t) \\ v_z = V \end{array} \right\}.$$

The modulus of the velocity vector has the following expression:

$$v(t) = \sqrt{V^2 + r_0^2\Omega^2 \sin^2(\Omega t) + r_0^2\Omega^2 \sin^2(\Omega t)}$$
$$= \sqrt{V^2 + r_0^2\Omega^2}.$$

As the speed of the center of the vortex is c_0 with regard to the Privileged Frame of Reference, we obtain the following fundamental relation:

$$c_0^2 = V^2 + r_0^2\Omega^2.$$

This expression shows that the speed of a vortex c_0 is always composed of a translation speed V (which is that of the particle containing the vortex) and a rotation speed $r_0.\Omega$.

For a zero translation speed with regard to the Privileged Frame of Reference ($V = 0$), we have

$$c_0 = r_0\Omega_0 = \frac{2 \cdot \pi \cdot r_0}{T_0}.$$

The fundamental relationship can also be written $(V/c_0)^2 + (\Omega/\Omega_0)^2 = 1$.

Finally, it allows us to find the relationship between T and T_0,

$$\left(\frac{V}{c_0}\right)^2 + \left(\frac{T_0}{T}\right)^2 = 1 \text{ that is to say : } \frac{T_0}{T}$$
$$= \sqrt{1 - \frac{V^2}{c_0^2}} = \frac{1}{\gamma} \text{ or } T = \gamma \cdot T_0.$$

The energy of a vortex is given by the following formula:

$$E_V = \frac{\int_0^T m_V v^2(t) dt}{T_{\text{ref}}},$$

where T_{ref} represents a reference duration in the Privileged Frame of Reference.

The rest energy of the vortex in the Privileged Frame of Reference is then

$$E_{V0} = \frac{\int_0^{T_0} m_V v^2(t) dt}{T_{\text{ref}}} = m_V c_0^2 \frac{T_0}{T_{\text{ref}}}.$$

The energy of the vortex in the Galilean frame R moving at the speed $\overrightarrow{V}$ with regard to the Privileged Frame of Reference is

$$E_V = \frac{\int_0^{T} m_V v^2(t) dt}{T_{\text{ref}}} = m_V c_0^2 \frac{T}{T_{\text{ref}}}.$$

By choosing $T_{\text{ref}} = T_0$, we obtain the following important formulas:

$$E_{V0} = m_V c_0^2,$$

$$E_V = m_V c_0^2 \frac{T}{T_0} = \gamma m_V c_0^2,$$

$$\frac{E_V}{E_{V0}} = \frac{T}{T_0} = \gamma.$$

Note that this amounts to saying that the ratio of the vortex energy to the rotation period is constant whatever the speed $\overrightarrow{V}$,

$$\text{Power} = \frac{E_{V0}}{T_0} = \frac{E_V}{T} = \text{constant}.$$

The energy of the particle is given by

$$E = \sum_i E_{Vi} = \sum_i \gamma \cdot m_{Vi} \cdot c_0^2 = \gamma \cdot c_0^2 \cdot \sum_i m_{Vi}.$$

The mass of the particle being given by the relation $m_0 = \sum_i m_{Vi}$, we finally obtain

$$E = \gamma \cdot m_0 \cdot c_0^2.$$

For $V = 0$, we find Einstein's famous formula $E = m_0 \cdot c_0^2$.

Important note: in DMR theory, the rest energy of a particle is, therefore, explained by the fact that it is made up of entities (vortices) in circular motion at the speed of light c_0.

F. Momentum of a line of matter-vortices

The relationship between energy and momentum is as follows:

$$\frac{dE}{dt} = \overrightarrow{F} \cdot \overrightarrow{v} = \frac{\overrightarrow{dp}}{dt} \cdot \overrightarrow{v}.$$

We have $(dE/dt) = (d(\gamma \cdot m_0 c_0^2)/dt) = m_0 \cdot c_0^2 (d\gamma/dt)$ with

$$\frac{d\gamma}{dt} = \frac{d\left(\left(1 - \frac{V^2}{c_0^2}\right)^{-1/2}\right)}{dt} = \frac{-1}{2}\left(\frac{-2}{c_0^2} V \frac{dV}{dt}\right)\left(1 - \frac{V^2}{c_0^2}\right)^{-3/2}$$
$$= \frac{V}{c_0^2}\frac{dV}{dt}\gamma\left(1 - \frac{V^2}{c_0^2}\right)^{-1} = \frac{\gamma \cdot V}{c_0^2 - V^2}\frac{dV}{dt}$$

hence,

$$\frac{dE}{dt} = m_0 V \frac{dV}{dt}\gamma \frac{c_0^2}{c_0^2 - V^2} = m_0 V \frac{dV}{dt}\gamma \left(1 + \frac{V^2}{c_0^2 - V^2}\right)$$
$$= m_0 V \frac{dV}{dt}\gamma + m_0 V \frac{dV}{dt}\gamma \frac{V^2}{c_0^2 - V^2},$$

and finally,

$$\frac{dE}{dt} = m_0 V \left(\gamma \frac{dV}{dt} + V \frac{d\gamma}{dt}\right) \text{ and } = \frac{d\vec{p}}{dt} = m_0 \left(\gamma \frac{d\vec{V}}{dt} + \frac{d\gamma}{dt}\vec{V}\right).$$

By simple integration, knowing that the integration constant is zero because for $V = 0$, $p = 0$, we finally obtain: $\vec{p} = \gamma \cdot m_0 \vec{V}$.

G. Wavelength associated with a line of matter-vortices

To determine the wavelength associated with a line of vortices in DMR theory, we will use the following definition:

The wavelength λ associated with a line of vortices is **the length of the path traveled by an elementary wave** (vortex) of the line to pass from its position at time t_0 to its position at time t_1 which corresponds to the position that the neighboring vortex of the same line had at time t_0.

It is therefore a question of determining the length of a helix portion which is the trajectory of the vortex. To do this, we will reason only in the Privileged Frame of Reference.

Since the vortex propagates at the speed of light c_0 in the medium, the length of the helix portion is given quite simply by the formula,

$$L_{\text{helix}} = c_0(t_1 - t_0).$$

By calling L the distance separating the centers of two consecutive vortices when the particle moves at speed V relative to the Privileged Frame of Reference, we also have the following formula:

$$L = V(t_1 - t_0).$$

By calling L_0 the distance separating the centers of two consecutive vortices when the particle is at rest in the Privileged Frame of Reference, we have $L = L_0/\gamma = L_0 \cdot \sin\vartheta$.

We also have the equality $\cos\vartheta = V/c_0$.

Using all these relationships, we obtain

$$\lambda = L_{\text{helix}} = c_0(t_1 - t_0) = c_0 \frac{L}{V} = c_0 \frac{L_0}{\gamma \cdot V} = c_0 \frac{L_0 \sin\vartheta}{c_0 \cos\vartheta}.$$

Finally, we obtain the formula for wavelength

$$\lambda = L_0 \cdot \tan\vartheta$$

Note that we assume that the space between two consecutive vortices, when the line is at rest in the Privileged Frame of Reference, is negligible compared to the length of a vortex.

Therefore, the length L_0 is practically equal to the length of a vortex L_{V0}.

We will now determine the number of revolutions made by a vortex when it travels the distance λ and the line of vortices has traveled the distance L.

As we have already seen, the time necessary to cover the distance L separating the centers of two consecutive vortices when the particle moves at speed V relative to the Privileged Frame of Reference is

$$\Delta t = t_1 - t_0 = \frac{L}{V} = \frac{L_0/\gamma}{V}.$$

The number of revolutions made by the vortex is, therefore,

$$N = \frac{\Delta t}{T} = \frac{L}{V \cdot T} = \frac{L_0/\gamma}{(c_0 \cos\vartheta)\cdot(T_0\gamma)} = \frac{L_0}{c_0 T_0}\frac{\sin^2\vartheta}{\cos\vartheta}.$$

Now, as we will see in part 1.7, we have $p_0 = 2\pi r_0 = c_0 T_0 = L_0$, which finally gives us,

$$N = \sin\vartheta \cdot \tan\vartheta.$$

It is remarkable that this number of revolutions does not depend on the dimensions of the vortex, nor on its trajectory, but only on the speed V (nonzero) of the particle.

When the speed V of the particle is small compared to the speed of light c_0, we have

$$N = \frac{1 - \cos^2\vartheta}{\cos\vartheta} = \frac{1}{\cos\vartheta} - \cos\vartheta \approx \frac{1}{\cos\vartheta} = \frac{c_0}{V}.$$

For $\cos\vartheta = V/c_0 = 0.01$, we have $\vartheta = 89.4°$ and $N \approx 100$.

For $\cos\vartheta = V/c_0 = 0.1$, we have $\vartheta = 84.3°$ and $N \approx 10$ (see Fig. 8).

For $\cos\vartheta = \mathrm{V}/\mathrm{c}_0 = 0.5$, we have $\vartheta = 60°$ and $\mathrm{N} \approx 1.5$.

H. Wavelength associated with a massive particle

We will now establish the formula for the wavelength associated with a massive particle as a function of the angle ϑ.

Louis de Broglie proposed in his 1924 thesis that each particle is associated with a wave of wavelength: $\lambda = h/p$.

It is possible to express this relationship using the angle ϑ (the one which links V to c_0 by the formula $V = c_0 \cdot \cos\vartheta$),

$$\lambda = \frac{h}{p} = \frac{h}{\gamma \cdot m_0 \cdot V} = \frac{h}{(1/\sin\vartheta)\cdot m_0 \cdot (c_0\cos\vartheta)}$$
$$= \frac{h}{m_0 \cdot c_0}\tan\vartheta.$$

We finally find $\lambda = \lambda_0 \cdot \tan\vartheta$ with $\lambda_0 = (h/m_0 c_0)$.

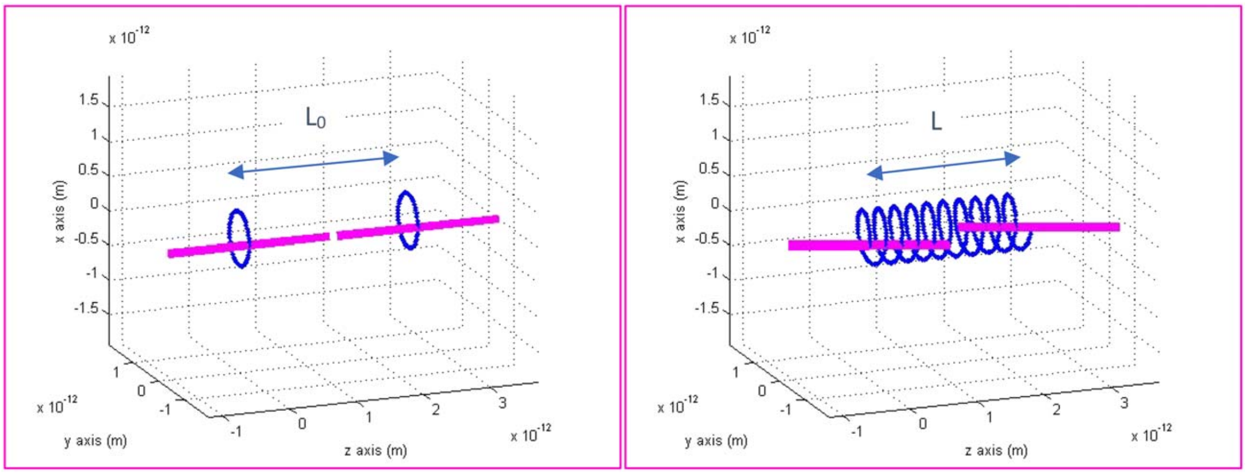

FIG. 8. (Color online) Vortex-matter when the particle is at rest then in motion relative to the Privileged Frame of Reference.

We note that the formula proposed by Louis de Broglie for a massive particle and that provided by the DMR theory for a line of vortices are identical if we pose,

$$L_0 = \lambda_0 = \frac{h}{m_0 c_0}.$$

I. Frequency associated with a massive particle

To determine the frequency associated with a massive particle we will use the following formulas:

$$E^2 = p^2 c_0^2 + m_0^2 c_0^4,$$

$$E = h \cdot \nu,$$

$$p = h/\lambda.$$

By replacing E and p by their expressions in the first formula, we obtain

$$h^2 \nu^2 = \frac{h^2 c_0^2}{\lambda^2} + m_0^2 c_0^4.$$

This gives us

$$\nu^2 = \left(\frac{c_0}{\lambda}\right)^2 + \left(\frac{m_0 c_0^2}{h}\right)^2.$$

Using the formula $\lambda_0 = (h/m_0 c_0)$, we obtain

$$\left(\frac{\nu}{c_0}\right)^2 = \left(\frac{1}{\lambda}\right)^2 + \left(\frac{1}{\lambda_0}\right)^2.$$

Using the formula $\lambda = \lambda_0 \cdot \tan\vartheta$, we obtain

$$\left(\frac{\nu}{c_0}\right)^2 = \frac{1}{\lambda_0^2}\left(\tan^{-2}\vartheta + 1\right) = \frac{1}{\lambda_0^2 \cdot \sin^2\vartheta}.$$

This finally gives us the formula

$$\nu = \frac{\nu_0}{\sin\vartheta} = \gamma \cdot \nu_0 \text{ with } \quad \nu_0 = \frac{c_0}{\lambda_0} = \frac{m_0 c_0^2}{h}.$$

Note that we obtain this last formula directly by using the two expressions:

$$E = \gamma m_0 c_0^2 = \frac{m_0 c_0^2}{\sin\vartheta} \quad \text{and} \quad E = h \cdot \nu.$$

When the particle is at rest in the Privileged Frame of Reference, then the wavelength λ tends towards infinity and we obtain $\nu_0 = (c_0/\lambda_0) = (m_0 c_0^2/h)$. This frequency corresponds to that of the vortices making circles around the axis of the line to which they belong. The frequency υ_0 corresponds to stationary waves making circular revolutions.

When the particle is at any speed V relative to the Privileged Frame of Reference, the frequency ν corresponds to progressive waves whose component of the speed along z is equal to the speed V of the particle.

When the particle is at a speed close to that of light, then the wavelength λ tends towards 0 and we obtain $\nu \approx c_0/\lambda$. This formula is close to that of a photon because the matter-vortices have a trajectory close to that of the light-vortices.[8]

When the particle is at rest in the Privileged Frame of Reference, we found

$$T_0 = \frac{p_0}{c_0} = \frac{2 \cdot \pi \cdot r_0}{c_0}.$$

We therefore have $T_0 = (2\pi r_0/c_0) = (1/\nu_0) = (h/m_0 c_0^2)$, which gives us the radius of the circle traveled by the vortices,

$$r_0 = \frac{\hbar}{m_0 c_0} = \frac{\lambda_0}{2\pi}.$$

Summarizing this part and the previous one, we have the following important equalities,

$$p_0 = 2\pi r_0 = \frac{2\pi c_0}{\Omega_0} = c_0 T_0 = L_0 = \lambda_0 = \frac{c_0}{\nu_0} = \frac{h}{m_0 c_0}.$$

For the electron, we have $\lambda_0 \approx 2.4 \times 10^{-12}$ m and $\upsilon_0 \approx 1.25 \times 10^{20}$ Hz.

For the proton, we have $\lambda_0 \approx 1.3 \times 10^{-15}$ m and $\upsilon_0 \approx 2.3 \times 10^{23}$ Hz.

The values of the wavelength λ_0 seem large (especially for the electron), but they give an order of magnitude of the extension of the elementary waves (vortices) constituting the particle.

We will see in the section on the Schrödinger wave packet that the particle itself seems localized in a much smaller spatial volume.

J. Schrödinger equation

We previously showed the following relationships for a particle

- $E_0 = m_0 c_0^2 = h \cdot \nu_0$ with $\nu_0 = \frac{m_0 c_0^2}{h}$,
- $E = \gamma m_0 c_0^2 = h\nu = \hbar\omega$ with $\nu = \gamma \cdot \nu_0$,
- $\overrightarrow{p} = (h/\lambda)\overrightarrow{u} = \hbar\overrightarrow{k}$ with $\overrightarrow{k} = (2\pi/\lambda)\overrightarrow{u}$.

In the proposed model, any particle of energy E and momentum $\overrightarrow{p}$ **can also be seen as a complex assembly of elementary waves** (vortex) to which we can assign the frequency ν, the wave vector $\overrightarrow{k}$ as well as the wave function,

$$\Psi(\overrightarrow{r}, t) = A \cdot \exp\left(i\overrightarrow{k}.\overrightarrow{r} - i\omega t\right) = A \cdot \exp\left(\frac{i}{\hbar}\left(\overrightarrow{p}.\overrightarrow{r} - Et\right)\right).$$

We have the following derivatives:

$$\frac{\partial \Psi}{\partial \overrightarrow{r}} = \nabla\Psi = \frac{i}{\hbar}(p_x\Psi + p_y\Psi + p_z\Psi),$$

$$\frac{\partial^2 \Psi}{\partial \overrightarrow{r}^2} = \nabla^2\Psi = \frac{\partial^2\Psi}{\partial x^2} + \frac{\partial^2\Psi}{\partial y^2} + \frac{\partial^2\Psi}{\partial z^2} = \left(\frac{i}{\hbar}\right)^2\left(p_x^2\Psi + p_y^2\Psi + p_z^2\Psi\right) = -\frac{\overrightarrow{p}^2}{\hbar^2}\Psi.$$

From where we have $\overrightarrow{p}^2\Psi = -\hbar^2\nabla^2\Psi$,

$$\frac{\partial\Psi}{\partial t} = -\frac{i}{\hbar}E\Psi \quad \text{whence} \quad E\Psi = \mathrm{i}\hbar\frac{\partial\Psi}{\partial t}.$$

For a nonrelativistic free particle, the Hamilton function is purely kinetic and equal to the total mechanical energy, i.e.,

$$H = E = \frac{1}{2}mv^2 = \frac{p^2}{2m}.$$

Using this relationship with the wave function Ψ, we obtain:

$$\frac{1}{2m}\overrightarrow{p}^2\Psi = \mathrm{E}\Psi.$$

This is the Schrödinger equation for a free particle, which is written in the following form:

$$-\frac{\hbar^2}{2m}\nabla^2\Psi = \mathrm{i}\hbar\frac{\partial\Psi}{\partial t}.$$

The Schrödinger equation is the law of evolution of the particle modeled in this article.

The proposed model, therefore, makes it possible to find the Schrödinger equation and thus make a link with quantum mechanics.

K. Particle of matter

For particles of matter, two types of configuration are considered:

- **First type of configuration**: the lines of vortices are arranged radially in three dimensions relative to the center of the particle. This type of configuration would correspond to that of the electron and that of the proton and neutron "alone" in space (that is to say not confined in a nucleus by the strong force),
- **Second type of configuration**: the lines of vortices are arranged in a parallel manner in three dimensions inside a cylindrical envelope. This type of configuration would correspond to that of the proton and neutron when they are confined in an atomic nucleus by the strong force.

The proposed model of the particle is such that, whatever the configuration of the particle, whatever the line of vortices considered, for a given velocity vector $\overrightarrow{V}$ of the particle relative to the Preferred Frame of Reference, **all the vortices have the same angular velocity**:

- Ω_0 when the particle is at rest relative to the Preferred Frame of Reference.
- $\Omega = \Omega_0/\gamma$ when the particle is at speed $\overrightarrow{V}$ relative to the Preferred Frame of Reference.

The following equalities are equivalent, knowing of course that Ω and T are positive,

$$\Omega = \frac{\Omega_0}{\gamma} \iff c_0^2 = (r_0\Omega)^2 + V^2 \iff \left(\frac{V}{c_0}\right)^2 + \left(\frac{\Omega}{\Omega_0}\right)^2 = 1 \iff T = \gamma T_0.$$

1. First type of configuration

The first type of configuration corresponds to particles of matter made up of radial lines of matter-vortices.

The simplest shape of the envelope of these lines of matter-vortices is a sphere as shown in Fig. 9.

Since the lines of vortices are radial, most of them are not collinear with the velocity vector $\overrightarrow{V}$ of the particle.

We must, therefore, establish in the general case the relationships already obtained in the case of a line of vortices parallel to the velocity vector $\overrightarrow{V}$.

a. Dilation of the period of vortices, of the particle, of a clock

For the particle to maintain coherence when it is moving at speed $\overrightarrow{V}$ relative to the Privileged Frame of Reference, all the vortices that compose it must have the same angular speed,

$$\Omega = \frac{\Omega_0}{\gamma} \quad \text{with} \quad \Omega_0 = \frac{c_0}{r_0}.$$

We have seen that this relationship can also be written

$$\left(\frac{V}{c_0}\right)^2 + \left(\frac{\Omega}{\Omega_0}\right)^2 = 1.$$

As we also have $T_0 = (2\pi/\Omega_0)$ and $T = (2\pi/\Omega)$, we deduce that

$$T = \gamma \cdot T_0.$$

This result is very important: whatever the line of vortices chosen, whatever its orientation, all the vortices in this line complete one revolution in the period T.

It is, therefore, entirely justified to attribute the period T to the entire particle moving at speed $\overrightarrow{V}$ with regard to the Privileged Frame of Reference.

Matter being made up of atoms themselves made up of particles (electrons, protons, neutrons), a material clock moving at speed $\overrightarrow{V}$ with regard to the Privileged Frame of Reference has its period dilated according to the formula $T = \gamma \cdot T_0$ where T_0 designates the period of the clock when it is at rest in the Privileged Frame of Reference.

This is consistent with the Lorentz–Poincaré theory.

b. Length contraction

According to Lorentz theory, a particle having a spherical shape when it is at rest in the Privileged Frame of Reference, takes the shape of an ellipsoid when it is in motion relative to the Privileged Frame of Reference.

Indeed, the particle, which is a sphere of radius L_{line0} when the particle is at rest, is crushed when it is in motion and becomes an ellipsoid whose major axes perpendicular to the movement keep the length L_{line0} while the minor axis is contracted in the direction of the movement and has the length L_{line0}/γ.

This ellipsoid has the Cartesian equation,

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1,$$

or as parameterized equations,

$$\left\{\begin{array}{c} x = a \cdot \cos\varphi \cdot \cos\psi \\ y = b \cdot \cos\varphi \cdot \sin\psi \\ z = c \cdot \sin\varphi \end{array}\right\} \quad \textit{with}$$
$$\left\{\begin{array}{c} a = L_{\text{line0}} = N_V L_{V0} \\ b = L_{\text{line0}} = N_V L_{V0} \\ c = L_{\text{line}\ z} = N_V L_V = N_V L_{V0}/\gamma \end{array}\right\}.$$

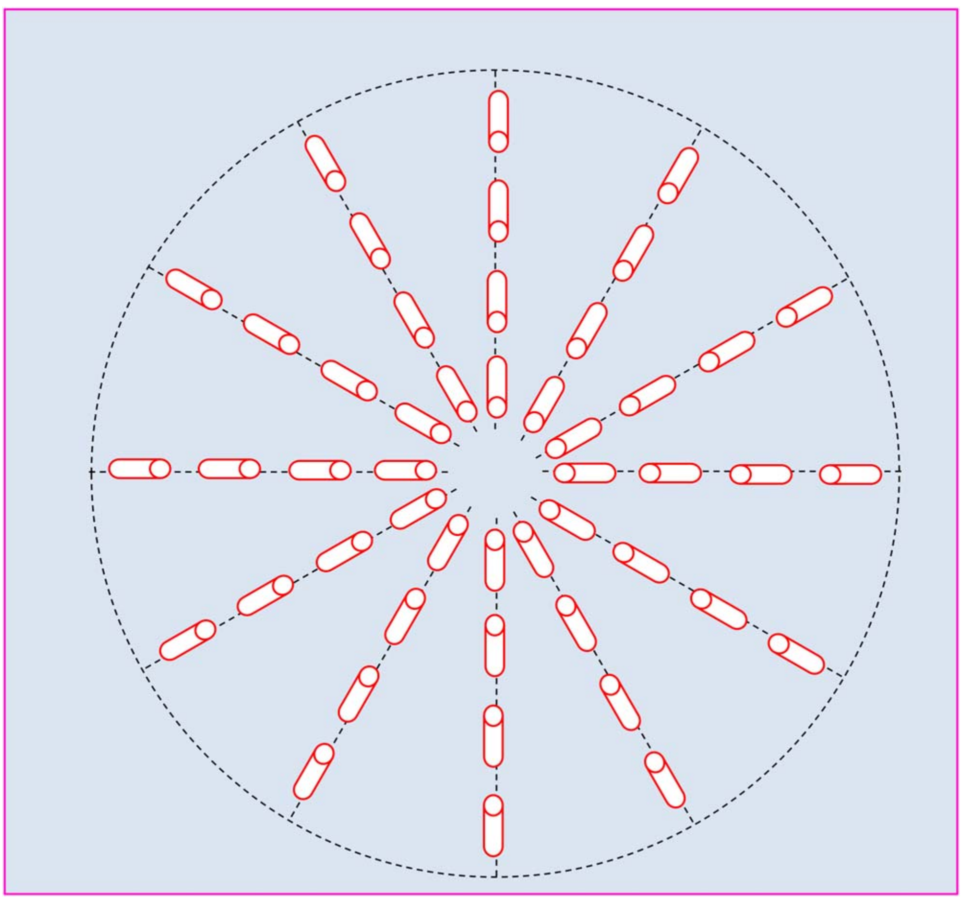

FIG. 9. (Color online) Particle of matter made up of lines of matter-vortices.

This ellipsoid is of revolution (because $a = b$), also called spheroid, and it is called oblate (because $a = b > c$).

If we consider the point M designating the end of any line of vortices and O the center of the ellipsoid, we have

$$OM = N_V L_{V0}\sqrt{\cos^2\varphi\cos^2\psi + \cos^2\varphi\sin^2\psi + \sin^2\varphi/\gamma^2},$$

$$OM = N_V L_{V0}\sqrt{\cos^2\varphi + \sin^2\varphi/\gamma^2}.$$

We call α the angle that the axis of the vortices makes with the axis of the line to which they belong. We, therefore, have $OM = L_{\mathrm{line}} = N_V L_{V0} \cdot \cos\alpha$.

Thus, we finally have $\cos\alpha = \sqrt{\cos^2\varphi + \sin^2\varphi/\gamma^2}$.

For $\gamma = 1$, $\cos\alpha = \sqrt{\cos^2\varphi + \sin^2\varphi} = 1$ and, therefore, $\alpha = 0$ which is normal because when the particle is at rest in the Privileged Frame of Reference, the axis of each vortex is parallel to the axis of the line to which it belongs.

For γ tending towards infinity, we have $\cos\alpha \approx \cos\varphi$, which means that the axis of the vortices makes the same angle with the line to which they belong as the line with the abscissa axis Ox.

For a line of vortices perpendicular to the movement of the particle, we have $\varphi = 0$, which gives us $\cos\alpha = 1$, that is to say, $\alpha = 0$. The vortex axis is parallel to the line of vortices, which, therefore, does not change in length compared to its value L_{line0} when the particle is at rest in the Privileged Frame of Reference.

Figure 10 shows a massive particle at rest then at speed $V = 0.9\,c_0$ and finally at speed $V = 0.99\,c_0$ relative to the Privileged Frame of Reference, the speed vector $\vec{V}$ of the particle being parallel to the Oz axis.

The particle is invariant under a symmetry of revolution with axis Oz.

c. Energy of the particle

For a line of vortices at rest in the Privileged Frame of Reference and whose axis coincides with the Oz axis, the position of the center of a vortex in the line is given by

$$\overrightarrow{OM} = \left\{\begin{matrix} x = r_0 \cdot \cos(\Omega_0 t) \\ y = r_0 \cdot \sin(\Omega_0 t) \\ z = 0 \end{matrix}\right\}.$$

To obtain a line of vortices in the plane (Ozy) and making an angle φ with the axis Oz, we can apply the rotation of axis Ox and angle φ : $Rot(Ox, \varphi) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\varphi & -\sin\varphi \\ 0 & \sin\varphi & \cos\varphi \end{pmatrix}$ to the vector $\overrightarrow{OM}$, which gives

$$\begin{aligned}\overrightarrow{OM'} &= Rot(0x, \varphi).\overrightarrow{OM} \\ &= \left\{\begin{matrix} x' = r_0 \cdot \cos(\Omega_0 t) \\ y' = \cos\varphi \cdot r_0 \cdot \sin(\Omega_0 t) \\ z' = \sin\varphi \cdot r_0 \cdot \sin(\Omega_0 t) \end{matrix}\right\}.\end{aligned}$$

Finally, when the line is no longer at rest with regard to the Privileged Frame of Reference but experiences the speed $\vec{V}$ of the particle, the angular speed of the vortex becomes Ω and the center of a vortex of the line has the position,

$$\begin{aligned}\overrightarrow{OM''} &= \overrightarrow{OM'} + \mathrm{Trans}\left(\vec{V}t\right) \\ &= Rot(0x, \varphi) \cdot \overrightarrow{OM} + \mathrm{Trans}\left(\vec{V}t\right) \\ &= \left\{\begin{matrix} x'' = r_0 \cdot \cos(\Omega t) \\ y'' = \cos\varphi \cdot r_0 \cdot \sin(\Omega t) \\ z'' = \sin\varphi \cdot r_0 \cdot \sin(\Omega t) + V \cdot t \end{matrix}\right\}.\end{aligned}$$

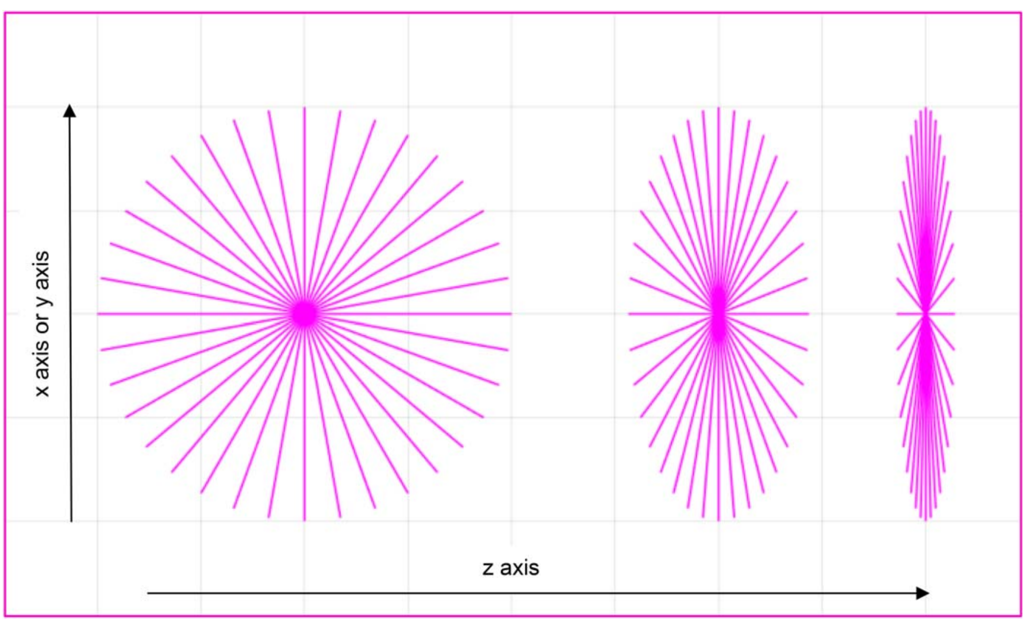

FIG. 10. (Color online) Massive particle at different speeds with regard to the Privileged Frame of Reference.

The velocity vector of the vortex has the following expression:

$$\overrightarrow{v''} = \frac{d\overrightarrow{OM''}}{dt} = \left\{ \begin{array}{c} -r_0 \cdot \Omega \cdot \sin(\Omega t) \\ r_0 \cdot \Omega \cdot \cos\varphi \cdot \cos(\Omega t) \\ r_0 \cdot \Omega \cdot \sin\varphi \cdot \cos(\Omega t) + V \end{array} \right\}.$$

The square of the modulus of the velocity vector of the vortex has the following expression:

$$\|\overrightarrow{v''}\|^2 = r_0^2\Omega^2 \sin^2(\Omega t) + r_0^2\Omega^2 \cos^2\varphi \cdot \cos^2(\Omega t) + \left(r_0 \cdot \Omega \cdot \sin\varphi \cdot \cos(\Omega t) + V\right)^2,$$

$$\|\overrightarrow{v''}\|^2 = r_0^2\Omega^2 \sin^2(\Omega t) + r_0^2\Omega^2 \cos^2(\Omega t) + V^2 + 2V \cdot r_0 \cdot \Omega \cdot \sin\varphi \cdot \cos(\Omega t),$$

$$\|\overrightarrow{v''}\|^2 = r_0^2\Omega^2 + V^2 + 2V \cdot r_0 \cdot \Omega \cdot \sin\varphi \cdot \cos(\Omega t).$$

Now, we saw in the section on the dilation of the period of the vortices that all vortices have the same angular speed, $\Omega = \frac{\Omega_0}{\gamma} = \frac{c_0}{\gamma \cdot r_0}$ formula we can write $c_0^2 = V^2 + r_0^2 \cdot \Omega^2$.
In addition, we have the following two relationships: $V = c_0 \cdot \cos\vartheta$ and $r_0 \cdot \Omega = \frac{c_0}{\gamma} = c_0 \cdot \sin\vartheta$.
Using the last three formulas, we obtain the final expression for the square of the vortex speed:

$$\|\overrightarrow{v''}\|^2 = c_0^2 + 2c_0^2 \cdot \cos\vartheta \cdot \sin\vartheta \cdot \sin\varphi \cdot \cos(\Omega t),$$

$$\|\overrightarrow{v''}\|^2 = c_0^2\left[1 + \sin(2\vartheta) \cdot \sin\varphi \cdot \cos(\Omega t)\right].$$

We notice that the speed of the vortex fluctuates around the value c_0. This is considered to be due to fluctuations of the medium in the vicinity of the vortices due to the movement of the particle in the medium.

Furthermore, we have $\int_0^T v''^2(t)dt/T = c_0^2 + c_0^2 \sin(2\vartheta) \cdot \sin\varphi \int_0^T \cos(\Omega t)dt = c_0^2$.

This means that the average of the quadratic speed of the vortex over a revolution of period T is constant and equal to the square of c_0.

The energy of the vortex in the Privileged Frame of Reference is

$$E_V = \frac{\int_0^T m_V v''^2(t)dt}{T_{\text{ref}}} = m_V c_0^2 \frac{T}{T_{\text{ref}}}.$$

Taking again $T_{\text{ref}} = T_0$, we obtain

$$E_V = m_V c_0^2 \frac{T}{T_0} = \gamma m_V c_0^2.$$

The energy of the particle is given by

$$E = \sum_i E_{Vi} = \sum_i \gamma \cdot m_{Vi} \cdot c_0^2 = \gamma \cdot c_0^2 \cdot \sum_i m_{Vi} = \gamma \cdot m_0 \cdot c_0^2.$$

General case of any line of vortices

To deal with the case of any line of vortices of the particle, after the rotation of axis Ox and angle φ, we apply a rotation of axis Oy and angle ψ $Rot(Oy, \psi) = \begin{pmatrix} \cos\psi & 0 & -\sin\psi \\ 0 & 1 & 0 \\ \sin\psi & 0 & \cos\psi \end{pmatrix}$ to the vector $\overrightarrow{OM'}$, which gives

$$\overrightarrow{OM''} = Rot(0y, \psi).\overrightarrow{OM'} = \left\{ \begin{array}{c} x'' = r_0 \cdot \cos\psi \cdot \cos(\Omega_0 t) - \sin\varphi \cdot r_0 \cdot \sin\psi \cdot \sin(\Omega_0 t) \\ y'' = \cos\varphi \cdot r_0 \cdot \sin(\Omega_0 t) \\ z'' = r_0 \cdot \sin\psi \cdot \cos(\Omega_0 t) + \sin\varphi \cdot r_0 \cdot \cos\psi \cdot \sin(\Omega_0 t) \end{array} \right\}.$$

When the line is no longer at rest with regard to the Privileged Frame of Reference but experiences the speed $\overrightarrow{V}$ of the particle, the angular speed of the vortex becomes Ω and the center of a vortex of the line has the position,

$$\overrightarrow{OM'''} = \overrightarrow{OM''} + \text{Trans}\left(\overrightarrow{V}t\right) = \left\{ \begin{array}{c} x''' = r_0 \cdot \cos\psi \cdot \cos(\Omega t) - \sin\varphi \cdot r_0 \cdot \sin\psi \cdot \sin(\Omega t) \\ y''' = \cos\varphi \cdot r_0 \cdot \sin(\Omega t) \\ z''' = r_0 \cdot \sin\psi \cdot \cos(\Omega t) + \sin\varphi \cdot r_0 \cdot \cos\psi \cdot \sin(\Omega t) + V \cdot t \end{array} \right\}.$$

The velocity vector of the vortex has the following expression:

$$\overrightarrow{v'''} = \frac{d\overrightarrow{OM'''}}{dt} = \left\{ \begin{array}{c} -r_0 \cdot \Omega \cdot \cos\psi \cdot \sin(\Omega t) - r_0 \cdot \Omega \cdot \sin\varphi \cdot \sin\psi \cdot \cos(\Omega t) = v_{x1} + v_{x2} \\ r_0 \cdot \Omega \cdot \cos\varphi \cdot \cos(\Omega t) = v_y \\ -r_0 \cdot \Omega \cdot \sin\psi \cdot \sin(\Omega t) + r_0 \cdot \Omega \cdot \sin\varphi \cdot \cos\psi \cdot \cos(\Omega t) + V = v_{z1} + v_{z2} + V \end{array} \right\}.$$

The square of the modulus of the velocity vector of the vortex has the expression:

$$\| \overrightarrow{v'''} \|^2 = v_{x1}^2 + v_{x2}^2 + 2v_{x1}v_{x2} + v_y^2 + v_{z1}^2 + v_{z2}^2 + V^2 + 2v_{z1}v_{z2} + 2V(v_{z1} + v_{z2}).$$

We have $v_{x2}^2 + v_{z2}^2 = r_0^2\Omega^2 \sin^2\varphi \cdot \cos^2(\Omega t)$ and, therefore,

$$(v_{x2}^2 + v_{z2}^2) + v_y^2 = r_0^2\Omega^2 \cdot \cos^2(\Omega t).$$

Furthermore, we have $v_{x1}^2 + v_{z1}^2 = r_0^2\Omega^2 \cdot \sin^2(\Omega t)$ and, therefore,

$$\left(v_{x2}^2 + v_{z2}^2 + v_y^2\right) + \left(v_{x1}^2 + v_{z1}^2\right) = r_0^2\Omega^2.$$

Finally, we have $2v_{x1}v_{x2} + 2v_{z1}v_{z2} = 0$; hence, the square of the module of the speed vector of the vortex,

$$\| \overrightarrow{v'''} \|^2 = r_0^2\Omega^2 + V^2 + 2Vr_0\Omega\left[-\sin\psi \cdot \sin(\Omega t) + \sin\varphi \cdot \cos\psi \cdot \cos(\Omega t)\right].$$

Using the formulas, $c_0^2 = V^2 + r_0^2 \cdot \Omega^2$, $V = c_0 \cdot \cos\vartheta$ and $r_0.\Omega = \frac{c_0}{\gamma} = c_0 \cdot \sin\vartheta$, we obtain

$$\| \overrightarrow{v'''} \|^2 = c_0^2 + 2c_0^2 \cos\vartheta \sin\vartheta\left[-\sin\psi \cdot \sin(\Omega t) + \sin\varphi \cdot \cos\psi \cdot \cos(\Omega t)\right],$$

$$\| \overrightarrow{v'''} \|^2 = c_0^2 + c_0^2 \sin(2\vartheta)\left[-\sin\psi \cdot \sin(\Omega t) + \sin\varphi \cdot \cos\psi \cdot \cos(\Omega t)\right].$$

In addition, we have $\int_0^T \cos(\Omega t)dt = 0$ and $\int_0^T \sin(\Omega t)dt = 0$; hence, the result $\int^T v'''^2(t)dt/T = c_0^2$.

We find the fact that the average of the quadratic speed of the vortex over a revθlution of period T is constant and equal to the square of c_0.

We also find the energy of a vortex,

$$E_V = m_V c_0^2 \frac{T}{T_0} = \gamma m_V c_0^2.$$

The energy of the particle,

$$E = \sum_i E_{Vi} = \sum_i \gamma \cdot m_{Vi} \cdot c_0^2 = \gamma \cdot c_0^2 \cdot \sum_i m_{Vi} = \gamma \cdot m_0 \cdot c_0^2.$$

d. Spin of the particle

The spin of the particle, or intrinsic angular momentum, can be explained by the rotation of the vortices that make up the particle.

Let us first notice that, the particle being rotationally symmetrical with respect to any axis passing through its center, whatever the projection axis chosen this will give the same value for the spin.

We will establish the expression for the spin of a particle in its own frame of reference, in which all the vortices have a circular trajectory.

We take any direction $\overrightarrow{u}$ to establish the expression of the spin along this axis.

We start by treating a vortex belonging to a line whose axis is parallel to the direction $\overrightarrow{u}$.

The spin of this vortex, whose circular trajectory is in a plane P perpendicular to the direction $\overrightarrow{u}$, has the expression,

$$\overrightarrow{J_V} = \overrightarrow{OM} \wedge \overrightarrow{p_V} = m_V \overrightarrow{r_0} \wedge \overrightarrow{V_V}.$$

The vectors $\overrightarrow{r_0}$ and $\overrightarrow{V_V} = \overrightarrow{c_0}$ being perpendicular to each other and in the plane P, we obtain

$$\overrightarrow{J_V} = m_V r_0 c_0 \overrightarrow{u}.$$

Now, we have $r_0 = (\lambda_0/2\pi)$ with $\lambda_0 = (h/m_0 c_0)$ and $m_0 = N_{V\text{tot}} \cdot m_V$, where $N_{V\text{tot}}$ is the total number of vortices constituting the particle.

The final expression for the spin of the vortex is, therefore,

$$\overrightarrow{J_V} = \frac{h}{2\pi N_{V\text{tot}}} \overrightarrow{u} = \frac{\hbar}{N_{V\text{tot}}} \overrightarrow{u}.$$

The spin of the particle would then be

$$\overrightarrow{J} = \sum_{i=1}^{N_{V\text{tot}}} \overrightarrow{J_{Vi}} = \hbar \left(\frac{1}{N_{V\text{tot}}} \sum_{i=1}^{N_{V\text{tot}}} \overrightarrow{u_i} \right).$$

However, we cannot describe a particle by giving the direction of its intrinsic angular momentum, but only by giving **the component of the intrinsic angular momentum along a certain direction**.

We must therefore add up the spins of all the vortices of the particle projected onto the axis of direction $\overrightarrow{u}$, which gives the following expression:

$$\overrightarrow{J\overrightarrow{u}} = \hbar \left(\frac{1}{N_{V\text{tot}}} \sum_{i=1}^{N_{V\text{tot}}} |\cos(\varphi_i)| \right) \overrightarrow{u} \quad \text{with}$$

$$\varphi_i = (\overrightarrow{u_i}, \overrightarrow{u}).$$

The quantity $(1/N_{V\text{tot}}) \sum_{i=1}^{N_{V\text{tot}}} |\cos(\varphi_i)|$ is a scalar that must be determined for each particle according to the value of $N_{V\text{tot}}$ and the distribution of the vortices of the particle.

2. Second type of configuration

The second type of configuration corresponds to particles of matter made up of **parallel** lines of matter-vortices.

The simplest shape regarding the envelope of these lines of matter-vortices is a **cylinder** as shown in Fig. 11.

The lines of vortices, whose axes are spaced an equal distance apart, fill the entire cylinder.

This second type of configuration would correspond to the **nucleons** constituting the nuclei of atoms.

Indeed, the cohesion of an atom nucleus is ensured by the strong force which, in DMR theory, corresponds to fluxes of the medium of high acceleration[5] as shown in Fig. 12.

These fluxes of the medium have a speed V_{flux} very close to the speed of light c_0.

This explains that the lines of vortices constituting the nucleons are very tight on the axis of the particle which is perpendicular to the fluxes of the medium.

Indeed, due to the application of the equivalence principle (see part 2.14), the shape of the nucleons is very close to that of the particle on the right in Fig. 10.

The difference compared to Fig. 10 is that when a particle is in a Galilean frame of reference at speed V relative to the Privileged Frame of Reference, the flux of the medium only takes place in one direction (by placing itself in the Galilean frame of reference of the particle).

In the case of nucleons in an atomic nucleus, the strong fluxes of the medium take place along the entire cylindrical surface of the nucleus (see Fig. 12) and this implies that the lines of vortices constituting the nucleons are folded along the axis of the nucleons of cylindrical envelope.

The particle is invariant by a symmetry of revolution **of axis Ox,** which is the axis of the particle and of the cylindrical envelope.

If the dimensions of the nucleon are L_{x0}, L_{y0}, L_{z0} (the envelope is a sphere of radius R_0) when it is "free," far from any field (gravitational, strong) and at rest in the Privileged Frame of Reference, then its dimensions become $L_x = L_{x0}$, $L_y = L_{y0}/K$, and $L_z = L_{z0}/K$ with $K = (1 - (V_{\text{flux}}^2/c_0^2))^{-1/2}$ when it is within an atom nucleus, if we consider that the axis of the nucleon and the nucleus is the axis Ox (the envelope of the nucleon is a cylinder of radius $R = R_0/K$ and base $L_x = L_{x0} = 2R_0$).

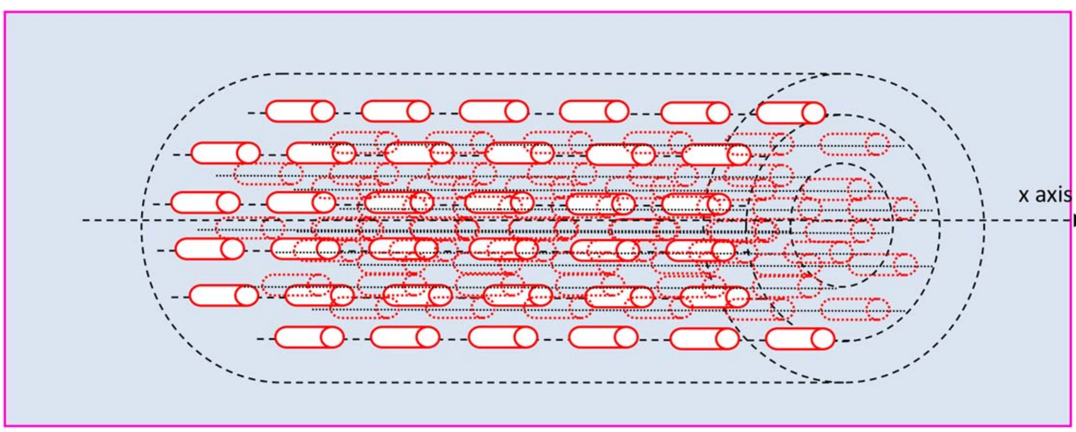

FIG. 11. (Color online) Particle of matter made up of parallel lines of matter-vortices.

To understand graviton-spin jets, refer to Appendix B.

a. Energy of the second type configuration particle

A velocity vector $\overrightarrow{V}$ of any direction (in 3D) with respect to the all parallel lines of vortices of the particle is equivalent to a given velocity vector and consider a line of vortices of any 3D orientation, which has already been treated in the general case of Section II K 1 c.

We can therefore affirm here again that:

The average of the quadratic speed of the vortex over a revolution of period T is constant and equal to the square of c_0 and that the energy of the particle is $E = \gamma \cdot m_0 \cdot c_0^2$.

b. Reflections on inertia

The following two points are fundamental:

- A change in the **modulus** of the velocity vector of a massive particle will correspond to a change in orientation of the vortices themselves (by calling α the angle between the axis of the vortices and the lines of vortices, the sine of this angle is proportional to the modulus of the velocity vector of the particle: $\sin \alpha = V/c$).
In the frame of reference of the particle this corresponds to a change in **modulus** of the velocity vector of the flux of the medium.
- A change in **direction** of the velocity vector of the particle will correspond to a modification of the angle between the line of vortices and the velocity vector of the particle and, therefore, of the axis of the vortices themselves with the velocity vector of the particle.

In the frame of reference of the particle this corresponds to a change in **direction** of the velocity vector of the flux of the medium.

These two points are linked to the force of inertia and the centrifugal force in the following way:

- Any change in module of the velocity vector of the particle expressed in the Privileged Frame of Reference gives rise to **the inertia force**,
- Any change in direction of the velocity vector of the particle expressed in the Privileged Frame of Reference gives rise to **the centrifugal force**.

This description of massive particles, nucleons, nucleus of an atom and therefore of matter allows us to draw fundamental lessons on inertia.

L. Louis de Broglie pilot wave versus Schrödinger wave packet

In 1905, Einstein associated the wave aspect of light with a particle aspect, the quantum of light called photon.

Later, in 1924, Louis de Broglie maintained that any particle can be associated with a matter wave.

It remains to give a physical interpretation to this matter wave. The two best-known interpretations which give a **concrete physical existence** to this matter wave are the following:

- That of Louis de Broglie who introduced the concept of pilot wave which guides the particle,
- That of Erwin Schrödinger who represents a corpuscle as a set of waves of different wavelengths which he calls "wave packet."

The theory of elementary waves (vortices) is very close to Schrödinger's vision in the sense that **matter is only**

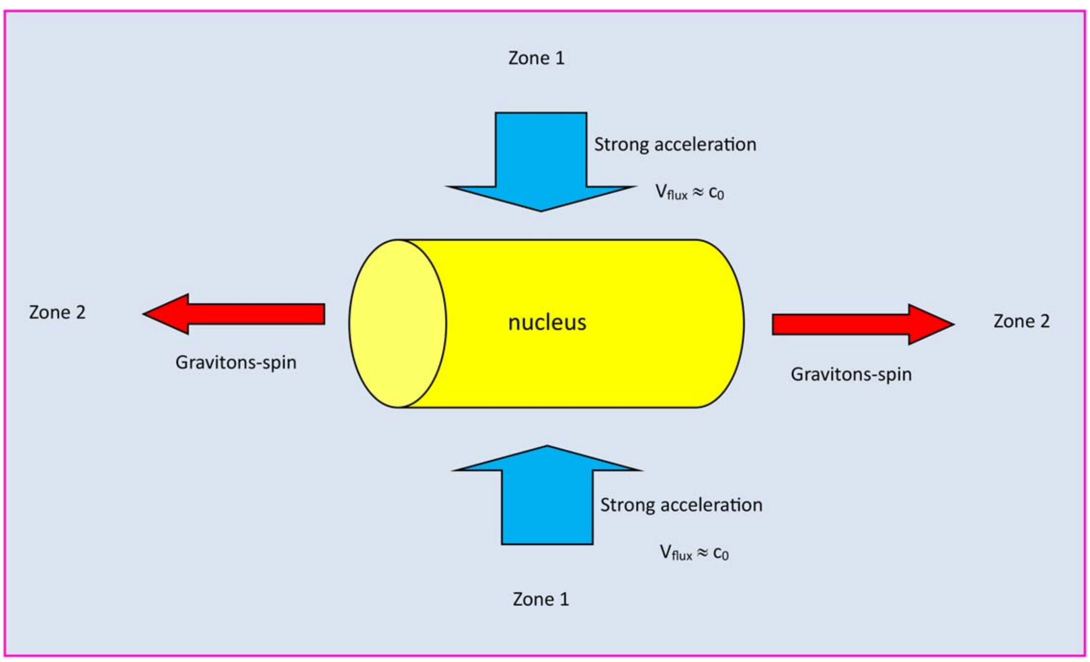

FIG. 12. (Color online) Strong force ensuring the cohesion of an atom nucleus.

made of waves. In this theory, there is no coexistence of a particle and a wave as in Louis de Broglie's vision.

If we follow the thesis of Louis de Broglie and his subsequent work, we must introduce the concept of pilot wave. The idea is relatively simple in principle: the wave acts as a guide for the particle, a bit like a boat sailing on the swell. This hypothesis has the advantage of retaining both aspects of duality, but is not based on any real physical evidence. Schrödinger offers another interpretation. Determined to definitively abandon the corpuscular aspect and the quantum leaps that go with it, he represents a corpuscle as a set of waves of different wavelengths which he calls a **wave packet**. According to his theory, what we believe to be a particle, an electron for example, is in reality a packet of waves adding to each other. Mathematically, we can show that this sum leads to very strongly attenuating the oscillations in certain regions of space and to amplifying them in a well-localized region, thus forming a peak. **This peak, for Schrödinger, is the representation of a particle**.

We can draw a parallel between Schrödinger's wave packet and lines of matter-vortices of different wavelengths constituting the material particle as shown in Fig. 13.

This image is interesting, because it allows us to find Heisenberg's uncertainty principle with a wave approach. Remember that this principle prohibits the simultaneous determination with great precision of two conjugated physical quantities which are, for example, the position and the speed of a particle. Transposed to a wave vision, the principle is expressed using the wave packet. For the position of a particle to be known precisely, it is important that the peak of the wave packet be very localized. This implies that a large number of different wavelengths constitute the wave packet. However, the momentum of a particle, which is by definition its speed multiplied by its mass, is linked to the wavelength by a relationship established by Louis de Broglie. Therefore, the momentum of a very localized particle is highly uncertain. Conversely, a very defined momentum implies the presence of very few wavelengths in the wave packet. This results in a significant spreading of the peak representing the position of the particle. This spreading means that the particle is very poorly localized. Conceptually, these conclusions are analogous to those reached by Heisenberg in the demonstration of his uncertainty principle.

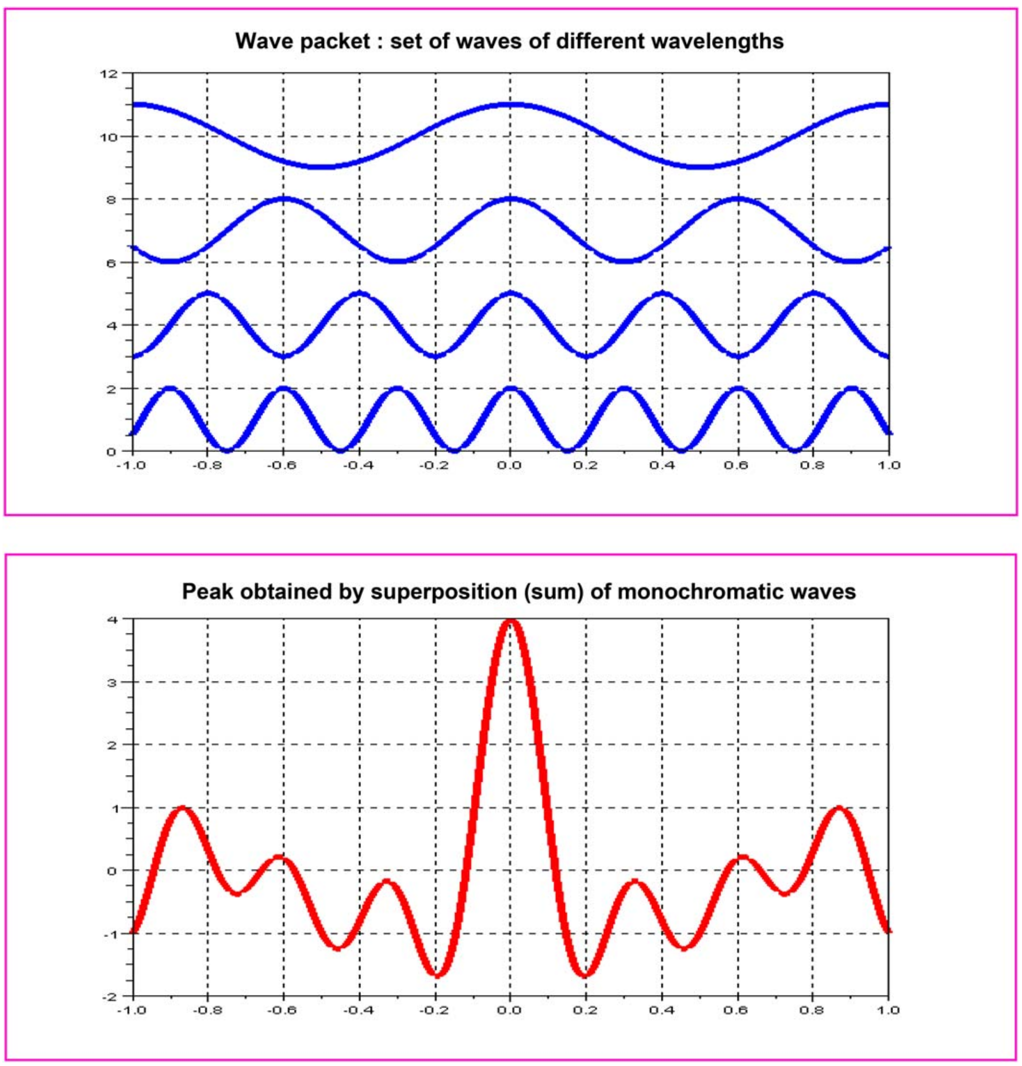

FIG. 13. (Color online) Schrödinger wave packet interpreted by vortex theory.

To be more precise on the formula of the uncertainty principle, we will take up the words of Louis de Broglie during conferences whose title was "Corpuscules, wave and wave mechanics:"

> Let us now arrive at the uncertainty relations due to Mr. Heisenberg which precisely set the limit of quantum uncertainties. Consider a corpuscle associated with a wave ψ. In general, the wave ψ will form a limited wave train represented by a superposition of monochromatic waves.

Note that it can be demonstrated, using the Fourier series or integral analogy, that a wave train of limited dimensions can always be represented by the superposition (the sum) of a finite or infinite number of monochromatic plane waves of various wavelengths and propagation directions. This superposition of plane waves must be chosen so that at each instant the component waves are destroyed by interference outside the region occupied by the train of waves and, on the contrary, gives an exact representation of this train of waves within the region it occupies. The analysis of this representation of wave trains leads to the following essential result: the more restricted a wave train is, the more it is necessary, to represent it exactly, to superimpose monochromatic plane waves belonging to an extended domain of wavelengths. A train of waves of infinite dimensions can be represented by a monochromatic plane wave while the representation of a train of waves of very small dimensions, almost point-like, will involve monochromatic waves of all wavelengths.

If we take into account, just to simplify, what concerns an axis, the x axis for example, the wave ψ will be written in the form: $\psi = \sum_i \alpha_i \exp\left[2\pi j\left(v_i t - \frac{x}{\lambda_i}\right)\right]$.

Now, we have seen that if Δl designates the length of the wave train ψ along the x axis, the λ_i appearing in the expression for ψ occupy a fairly large interval in the wavelength scale so that we always have: $\Delta l \cdot \Delta(1/\lambda) \geq 1$.

This is a result of the general theory of waves, therefore, independent of Wave Mechanics.

Let us now introduce the relationship between wave and corpuscle postulated by Wave Mechanics by positing the formula: $\lambda = h/p$.

It is enough to multiply both sides of the inequality above by the constant h to obtain the Heisenberg uncertainty relation: $\Delta l \cdot \Delta p \geq h$.

Note that the definitive relationship established by Heisenberg is $\Delta l \cdot \Delta p \cdot \geq \hbar/2$.

M. Material particle in a gravitational field

Let us consider a line of vortices near a massive body (for example, the Earth) which is assumed to be immobile with regard to the Privileged Frame of Reference.

This massive body will create a gravitational field which will have similar consequences on the line of vortices if it is moving relative to the Privileged Frame of Reference.

Relative to a frame of reference linked to the massive body, the vortices describe circles.

However, the massive body creates a centripetal flux of the medium of velocity $V_{flux} = \sqrt{2GM/r}$ (see Fig. 14).

The medium allows us to define the Privileged Frame of Reference (without gravitational field) or Reference (with gravitational field).

Relative to this Reference the line of vortices moves at the speed $V_{line} = \sqrt{2GM/r}$ and the vortices describe helices (see Fig. 14). Therefore, seen from the Reference, a clock made up of lines of vortices, placed on the surface of the massive body, will beat more slowly with a period $T = \gamma \cdot T_0$, where $\gamma = (1 - (V_{\text{clock}}^2/c_0^2))^{-1/2}$ and T_0 represents the period of the clock, at rest with regard to the Privileged Frame of Reference and without the presence of a gravitational field. The speed of the clock and the lines of

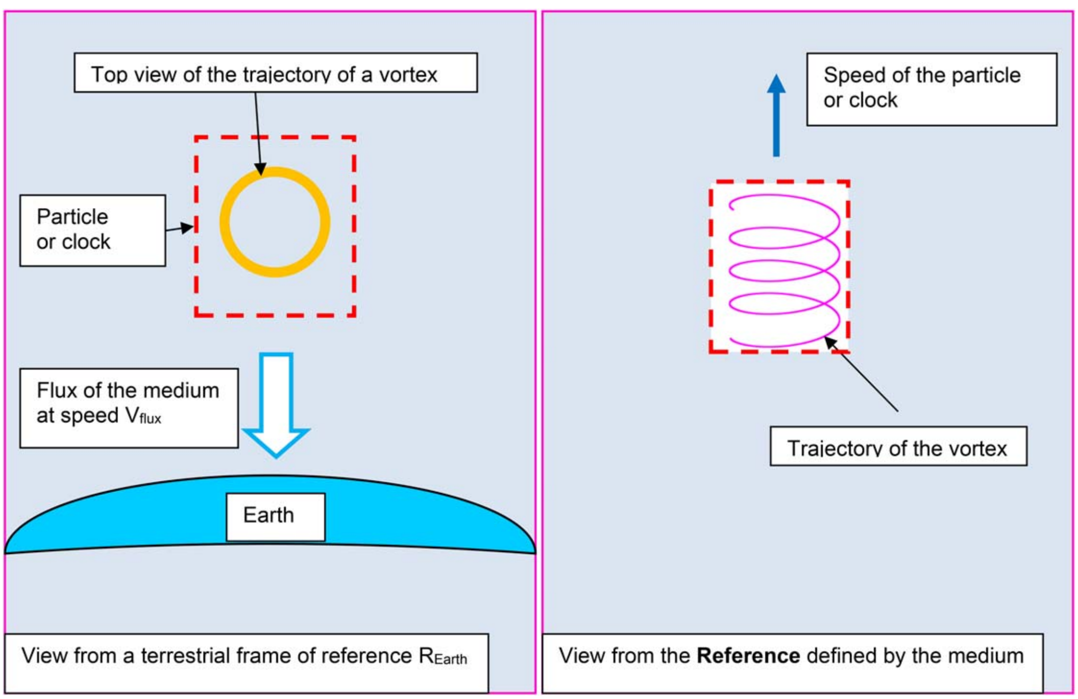

FIG. 14. (Color online) Trajectory of a vortex seen from R_{Earth} then seen from the Reference.

vortices being $V_{\text{clock}} = \sqrt{2GM/r}$ relative to the Reference, finally the period of the clock in the gravitational field created by the massive body is given by the following formula:

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

N. Principle of equivalence

The article "Dynamic Medium of Reference: A new theory of gravitation"[1] provides a justification for the principle of equivalence based on the fact that, in all cases, it is the **relative movement of the material clock and ruler with regard to the medium (which is the reference), which creates the effects (dilatation of the period of the material clock and contraction of the length of the material ruler).**

This means that the same effects are obtained in the following two cases:

- A material clock sees its period expand in the ratio $\gamma = (1 - (V^2/c_0^2))^{-1/2}$ and a material ruler sees its length contract in the same ratio γ when they are moving at speed V relative to the medium which is the Reference.
- A material clock sees its period expand in the ratio $K = (1 - (V_{\text{flux}}^2/c_0^2))^{-1/2} = (1 - (2GM/c_0^2 r))^{-1/2}$ and a material ruler sees its length contract in the same ratio K when they are placed in the gravitational field created by a massive body of mass M generating centripetal fluxes of the medium with speed $V_{\text{flux}} = \sqrt{2GM/r}$.

This article explores this further by asserting that:

- A material clock moving at speed V relative to the medium (which allows to define the Privileged Frame of Reference) is composed of elementary waves (vortices) which have a helical trajectory of period $T = \gamma \cdot T_0$, where T_0 is the period of the vortices which describe circles when the clock is at rest with regard to the Privileged Frame of Reference.
- A material clock placed in a gravitational field is composed of elementary waves (vortices) which have a helical trajectory of period $T = \gamma \cdot T_0$, where T_0 is the period of the vortices which describe circles when the clock is at an infinite distance from the source of the gravitational field.

The principle of equivalence within the framework of DMR theory also states that there is equivalence between:

- The size, dimensions of a massive particle and the configuration of the vortices and the lines of vortices constituting the particle, when the particle is in a Galilean frame of reference at speed V relative to the Privileged Frame of Reference. The characteristics of the massive particle depend on the coefficient $\gamma = (1 - (V^2/c_0^2))^{-1/2}$.
- The size, dimensions of a massive particle and the configuration of the vortices and the lines of vortices constituting the particle, when the particle is in a gravitational field, for example that of a black hole of mass M. The characteristics of the massive particle depend on the coefficient $K = (1 - (V_{\text{flux}}^2/c_0^2))^{-1/2} = (1 - (2GM/c_0^2 r))^{-1/2}$ the speed of the flux of the medium being $V_{flux} = \sqrt{2GM/r}$. As a reminder, the speed of the flux of the medium is exactly equal to the speed of light at the Schwarzschild sphere of radius $r_S = (2GM/c_0^2)$.

O. Gravitation

In the article "Dynamic Medium of Reference: A new theory of gravitation,"[1] a gravitational field generated by a massive body of mass M was explained by the deformation of a medium in the form of centripetal fluxes of speed $V_{\text{flux}} = \sqrt{2GM/r}$ and acceleration $\gamma_{\text{flux}} = (GM/r^2)$.

This article as well as the article on the model of the photon[8] brings the following fundamental point: all particles (photons and massive particles) are made up of elementary waves of which the DMR (Dynamic Medium of Reference) is precisely the propagation medium.

This gives an explanation of the fact that any deformation of the medium, for example by the presence of a massive body which creates a gravitational field, will have an impact on all the particles because they are made up of elementary waves propagating in the medium.

P. Charged particle of matter

We now consider a charged particle moving at speed $\vec{V} = V\vec{u_z}$ with regard to the Privileged Frame of Reference.

In the reference frame R_0 linked to the particle its dimensions are (L_x, L_y, L_z) and the electric field $\vec{E}\ (E_x,\ E_y,\ E_z)$.

In the Privileged Frame of Reference the dimensions and the electric field of the charged particle have the following expressions:

$$\left\{\begin{array}{c} L'_x = L_x \\ L'_y = L_y \\ L'_z = L_z/\gamma \end{array}\right\} \qquad \left\{\begin{array}{c} E'_x = \gamma E_x \\ E'_y = \gamma E_y \\ E'_z = E_z \end{array}\right\}.$$

So, when the speed of the particle approaches the speed of light:

- The charged particle is contracted in its longitudinal dimension (by the factor γ),
- The electric field is expanded transversely (by the factor γ). This means that the field lines are concentrated in the transverse directions.

This result can be linked to the invariance of the electric charge in changes of frame of reference.

Indeed, let us consider in the frame of reference R_0 a cylinder with an axis parallel to Oz of length L_z and whose section perpendicular to Oz has a surface $S_{xy} = L_x L_y$.

In accordance with Gauss' theorem, the electric flux through this closed cylindrical surface has the value in R_0,

$$\int \vec{E} \cdot \vec{dS} = \frac{q}{\varepsilon_0}.$$

In the Privileged Frame of Reference,

$$\int \overrightarrow{E'} \cdot \overrightarrow{dS'} = \frac{q}{\varepsilon_0}.$$

The electric charge being invariant in changes of frame of reference, the electric flux is therefore invariant in changes of frame of reference.

Now, in such a change of frame of reference, $S'_{xy} = S_{xy}$ hence $E'_z = E_z$.

On the other hand, $L'_z = L_z/\gamma$, which implies $S'_{yz} = S_{yz}/\gamma$ and $S'_{xz} = S_{xz}/\gamma$, which implies $E'_x = \gamma \cdot E_x$ and $E'_y = \gamma \cdot E_y$.

We clearly find the previous expressions, which result in an increase in the amplitude of the electric field and its tightening in the direction transverse to the movement.

Figure 15 shows the electric field of a charged particle at rest, then at speed $V = 0.9\ c_0$ and finally at speed $V = 0.98\ c_0$ with regard to the Privileged Frame of Reference, the speed vector $\overrightarrow{V}$ of the particle being parallel to the Oz axis.

The electric field and the particle are invariant under a symmetry of revolution, of axis Oz.

Return to the contraction of lengths in the case of a material object[14]

Any material object, a standard ruler for example, is made up of atoms, each of which is made up of a positively charged central nucleus around which negatively charged peripheral electrons revolve. The cohesion and stability of these atoms and the aggregates that they form between them to create objects are due to the electromagnetic forces of attraction exerted between electron and nucleus and to the forces of repulsion exerted between electrons. For example, the points where the atoms of a crystal are placed are those where these forces are balanced. By applying the laws of electromagnetism we show that the potential and the electric field of a charged particle at rest have spherical symmetry, and at a distance r from a charge q the potential has the value $\varphi = q/r$.

On the other hand, when this same particle is in uniform motion with speed V relative to the medium, Lorentz demonstrated that the potential and the electric field created by this particle no longer have spherical symmetry. Each equipotential surface which was a sphere of radius R when the particle is at rest is then crushed when it is in motion, and becomes an ellipsoid whose major axes perpendicular to the movement keep the length R while the minor axis is contracted in the direction of movement and has the length R/γ.

It is the same for the potentials created by all the particles of an object and consequently the overall figure of the equipotentials is itself contracted in the direction of movement with the ratio $1/\gamma$ and this contraction, which only depends on the nature of electric forces, is the same for all objects, regardless of their nature, whether for example iron or rubber.

Finally, we note that the dimensions of objects perpendicular to the movement are not affected by this contraction phenomenon and remain unchanged.

Q. Comparison of the proton and the neutron

As has already been explained, a charged particle is made up of lines of vortices all rotating in the same direction

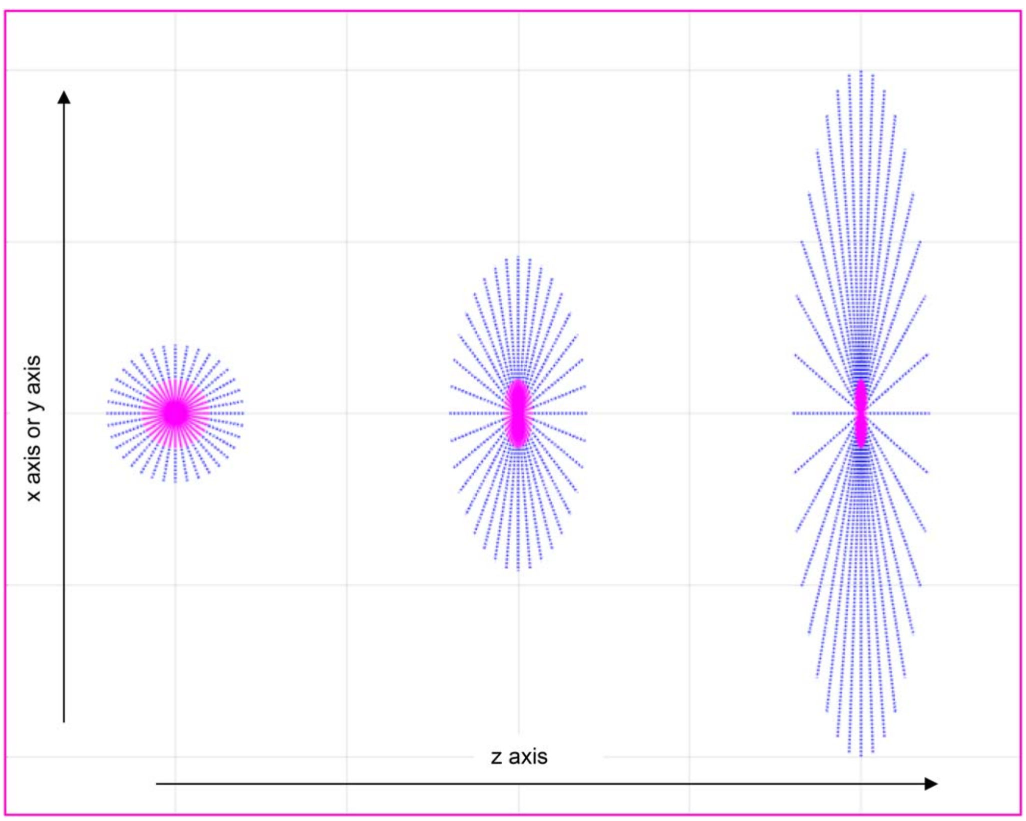

FIG. 15. (Color online) Electric field of a charged particle (blue dotted line).

and which emit gravitons-spin all rotating in the same direction which creates the electric field.

It is assumed that the neutron is made up of lines of vortices rotating alternately in one direction and in the other direction. Thus, for two adjacent lines of vortices, the vortices of the first line rotate in the positive direction emitting gravitons-spin rotating in the positive direction, and the vortices of the second line rotate in the negative direction emitting gravitons-spin rotating in the negative direction.

Thus, a neutron emits as many gravitons-spin rotating in the positive direction as gravitons-spin rotating in the negative direction, which guarantees it overall electrical neutrality.

R. Comparison of the proton and the electron

We consider a proton and an electron at rest in the privileged frame of reference and free in space, that is to say, that the two particles have the configuration of the first type described in II K 1.

For the proton we adopt the following notations:

- R_p designates the radius of its spherical envelope,
- L_{lp} designates the length of the lines of vortices. We have: $L_{lp} = R_p$,
- N_{lp} designates the number of lines of vortices constituting the proton,
- N_{vp} designates the number of vortices per line,
- $L_{0p} = \lambda_{0p}$ designates the distance separating the centers of two consecutive vortices when the particle is at rest in the Privileged Frame of Reference,
- $N_{\mathrm{vtotp}} = N_{lp}.N_{VP}$ designates the total number of vortices constituting the proton,
- $m_{0p} = N_{\mathrm{vtotp}} \cdot m_V = N_{lp} \cdot N_{VP} \cdot m_V$ designates the mass of the proton at rest in the Privileged Frame of Reference.

For the electron, we adopt the following notations:

- R_e designates the radius of its spherical envelope,
- L_{le} designates the length of the lines of vortices. We have: $L_{le} = R_e$,
- N_{le} designates the number of lines of vortices constituting the electron,
- N_{ve} designates the number of vortices per line,
- $L_{0e} = \lambda_{0e}$ designates the distance separating the centers of two consecutive vortices when the particle is at rest in the Privileged Frame of Reference,
- $N_{\mathrm{vtote}} = N_{le} \cdot N_{Ve}$ designates the total number of vortices constituting the electron,
- $m_{0e} = N_{\mathrm{vtote}} \cdot m_V = N_{le} \cdot N_{Ve} \cdot m_V$ designates the mass of the electron at rest in the Privileged Frame of Reference.

For the proton, we can write

$$R_p = L_{lp} = L_{0p}.N_{Vp} = \lambda_{0p}.N_{Vp} = \frac{h}{c_0}\frac{N_{Vp}}{m_{0p}} = \frac{h}{c_0 m_V}\frac{1}{N_{lp}}.$$

For the electron, we can write

$$R_e = L_{le} = L_{0e} \cdot N_{Ve} = \lambda_{0e} \cdot N_{Ve} = \frac{h}{c_0}\frac{N_{Ve}}{m_{0e}} = \frac{h}{c_0 m_V}\frac{1}{N_{le}}.$$

We can, therefore, write the following equivalences:

$$R_p = L_{lp} = R_e = L_{le} \iff N_{lp} = N_{le} \iff \frac{N_{Vp}}{m_{0p}} = \frac{N_{Ve}}{m_{0e}}.$$

Knowing that the proton and the electron have exactly the same charge in absolute value and that they generate exactly the same electric field in absolute value, the model of the particle proposes that the number of lines of vortices of the proton is equal to the number of lines of vortices of the electron so that the number of gravitons-spin rotating in the positive direction emitted by the proton is equal to the number of gravitons-spin rotating in the negative direction emitted by the electron. We, therefore, have the following equalities:

$$N_{lp} = N_{le} \text{ and } R_p = L_{lp} = R_e = L_{le} \text{ and } \frac{N_{Vp}}{m_{0p}} = \frac{N_{Ve}}{m_{0e}}.$$

The model of the proton and that of the electron, therefore, have the following characteristics:

- The radius of the spherical envelope of the proton is the same as that of the electron $R_p = R_e$.
- The length of the lines of vortices is the same for the proton and the electron $L_{lp} = L_{le}$.
- The number of lines of vortices is the same for the proton and the electron $N_{lp} = N_{le}$.
- The number of vortices per file is in the same ratio as the masses $(N_{Vp}/N_{Ve}) = (m_{0p}/m_{0e})$.

Note: it is not the set of all the vortices of the charged particle that contribute to the electric field, otherwise the proton would have an electric field approximately 1836 times greater than that of the electron in absolute value. Indeed, we have $(N_{\mathrm{vtotp}}/N_{\mathrm{vtote}}) = (m_{0p}/m_{0e}) \approx 1836$.

The model of the charged particle proposes that it is only the vortices at the extremity of the lines emitting gravitons-spin outwards that generate the electric field.

This confirms the fact that the number of lines of vortices of the proton must be equal to the number of lines of vortices of the electron $(N_{lp} = N_{le})$ so that the electric field generated by the proton is equal to the electric field generated by the electron in absolute value.

S. Antimatter

In the proposed theory, the model of the antiparticle is identical to the model of its associated particle except for the fact that all the vortices that make up the antiparticle are in inverse rotation to the vortices that make up the associated particle.

Thus, the characteristics of an antiparticle in relation to its associated particle are as follows:

- An antiparticle has the same radius of its spherical envelope as its associated particle.
- An antiparticle is made up of lines of vortices of the same length as its associated particle,
- An antiparticle has the same number of lines of vortices as its associated particle.
- An antiparticle has the same number of vortices per file as its associated particle.
- The previous propositions imply that an antiparticle has the same total number of vortices as its associated particle.
- The previous propositions imply that an antiparticle has the same mass and the same spin as its associated particle.
- An antiparticle has the same distance separating consecutive vortices as its associated particle.
- An antiparticle has the same wavelength and the same frequency as its associated particle (see parts II H and II I).
- **On the other hand, all the vortices of an antiparticle rotate in the opposite direction to the vortices constituting its associated particle.**
- **This last characteristic implies that an antiparticle has an opposite charge and an opposite electric field to those of its associated particle.**

Finally, during their collision, a particle and its antiparticle, all of whose vortices rotate in opposite directions, annihilate each other, decomposing to give lines of free vortices which correspond to high energy photons (gamma photons with a frequency greater than 30.10^{18} Hz. The frequency υ_0 provided for the electron and the proton in part II I is well above this frequency threshold).

These lines of free vortices correspond well to the model of the photon proposed by the DMR theory.[8]

III. CONCLUSION

The proposed model of a massive particle is a set of lines of elementary waves called vortices.

An elementary wave on the subatomic level is always identical to itself while being constantly renewed by new gravitons (entities which make up the medium of propagation of the wave). The elementary wave propagates in the medium always at the speed of light whatever its trajectory (which is not necessarily straight).

The model of the massive particle explains wave–particle duality.

Indeed, instead of a wave–particle duality involving the observation either of the wave aspect or of the corpuscular aspect, **the proposed model of the particle has both properties simultaneously**: the particle has the wave aspect because it is composed only of elementary waves, and it has the corpuscular aspect since the elementary waves remain identical to themselves and the particle remains delimited by the same volume which does not increase (the impact of a particle on a screen gives therefore a localized trace).

The model of the massive particle makes it possible to attribute to a massive particle, a period $T = \gamma \cdot T_0 = T_0/\sin\vartheta$, a pulsation or angular velocity $\Omega = (\Omega_0/\gamma) = \Omega_0 \cdot \sin\vartheta$, an energy $E = \gamma \cdot m_0 c_0^2 = \gamma \cdot E_0 = (E_O/\sin\vartheta)$, and a momentum $p = \gamma \cdot m_0 V = (m_0 c_0/\tan\vartheta)$, where T_0,Ω_0,E_0 and m_0 are, respectively, the period, the pulsation, the energy and the mass of the particle at rest in the Privileged Frame of Reference and ϑ designates the angle defined by the relation $\cos\vartheta = \mathrm{V}/\mathrm{c}_0$ where V is the speed of the particle relative to the Privileged Frame of Reference.

This same model also makes it possible to attribute to the massive particle the de Broglie wavelength of expression $\lambda = (h/p) = \lambda_0 \tan\vartheta$ with $\lambda_0 = (h/m_0 c_0)$ and a frequency of expression $\nu = \sqrt{(c_0/\lambda)^2 + (c_0/\lambda_0)^2} = \gamma \cdot \nu_0 = \frac{\nu_0}{\sin\vartheta}$, where $\nu_0 = (c_0/\lambda_0) = (m_0 c_0^2/h)$ represents the frequency of stationary elementary waves making circular revolutions when the particle is at rest in the Privileged Frame of Reference.

This article has exposed two types of configuration for the particles of matter.

In the first type of configuration the lines of vortices are radial with a spherical envelope. This corresponds to particles of matter free in space, without any field.

In the second type of configuration the lines of vortices are parallel with a cylindrical envelope. This corresponds to nucleons (protons, neutrons) confined in an atomic nucleus by the strong force.

APPENDIX A: A POSSIBLE DESCRIPTION OF THE DYNAMIC MEDIUM OF REFERENCE

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.[15] 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.***[16]

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 us 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 **nonmaterial** and constitute a **medium**.
- The total energy of an entity is the sum of its kinetic energy of translation $E_{\text{translation}}$ and of its kinetic energy of rotation about itself E_{rotation}.
- Fundamental law: conservation of the total energy of an entity: **the total energy of one entity remains constant**: $E_{\text{total}} = E_{\text{translation}} + E_{\text{rotation}} = \text{ constant}$.

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[16] 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's 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),

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

Definition of the Preferred Frame of Reference based on the entities constituting the medium:

Let's 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 $\overrightarrow{V_{G/R}}$.

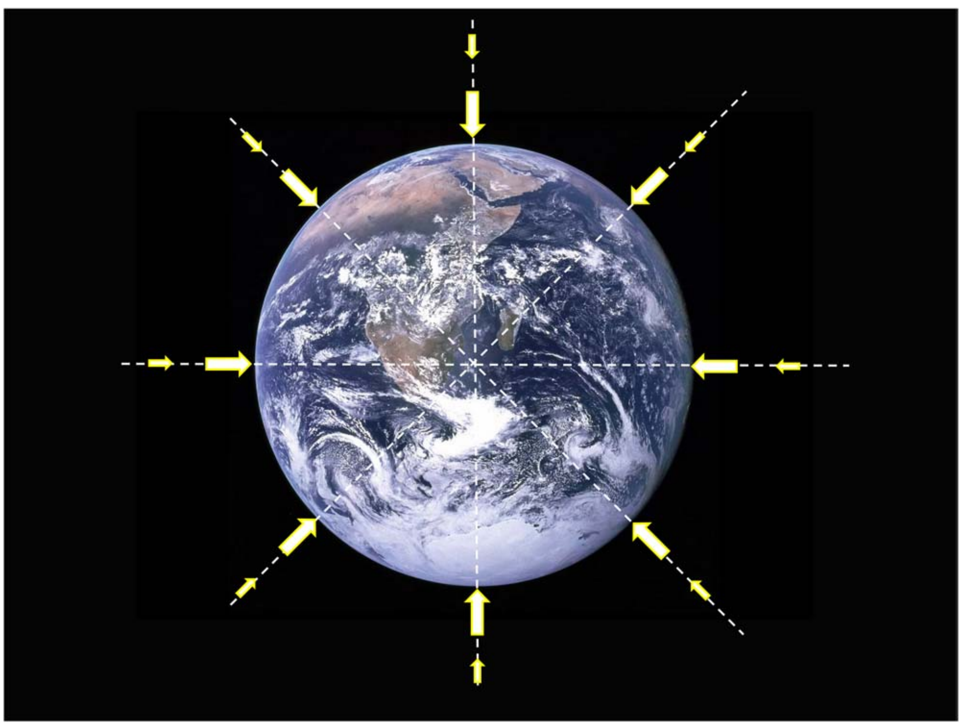

FIG. 16. (Color online) Flux of the medium due to the Earth.

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 Preferred Frame of Reference (PFR) is to define it as the unique referential for which, at any point M in space, we have

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

N_G is the number of gravitons contained in an elementary volume centered on point M.

Figure 16 shows the flux 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 magnitude 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.

APPENDIX B: INTRODUCTION TO THE VORTEX

The gravitons, like winds swirling in all directions, give rise to **vortices** a kind of agglomerates of gravitons taking the form of whirlpools, tornadoes on the subatomic scale, by analogy with natural whirlpools (see Fig. 17).

The vortex would be the basic brick of light and matter and it is from it that all the known laws of modern physics would apply: limit speed of light, laws of relativity, laws of quantum mechanics.

The functioning of a vortex is somewhat comparable to that of a wave which progresses. The vortex absorbs on average as many gravitons as it rejects. It is thus constantly renewed by new gravitons, even if, like the wave, it gives the appearance, the illusion of the same entity in motion, always identical to itself.

We can model a vortex by a rotating cylinder which would absorb the gravitons arriving by its cylindrical surface (imaginary surface delimiting the vortex) and would re-emit the gravitons by the two bases of the cylinder according to directions close to the axis of the cylinder (all the directions are included in a cone same axis as that of the cylinder) (see Fig. 18).

During the time they are part of the vortex, the gravitons lose some of their translational kinetic energy and their rotational kinetic energy increases to the same extent.

The gravitons come out of the vortex having been transformed into gravitons-spin.

It is considered that the **gravitons field** constitutes **the medium of propagation of the vortices**.

A single or free vortex moves spontaneously at the speed of light in the "gravitons field" whatever its direction of propagation, similar to a wave propagating on the surface of a volume of water which suffered a disturbance.

All particles in the Universe would be made up of vortices. A particle would be an edifice, a complex and well-ordered arrangement of vortices maintained by the gravitons

FIG. 17. (Color online) Examples of tornadoes, natural vortices.

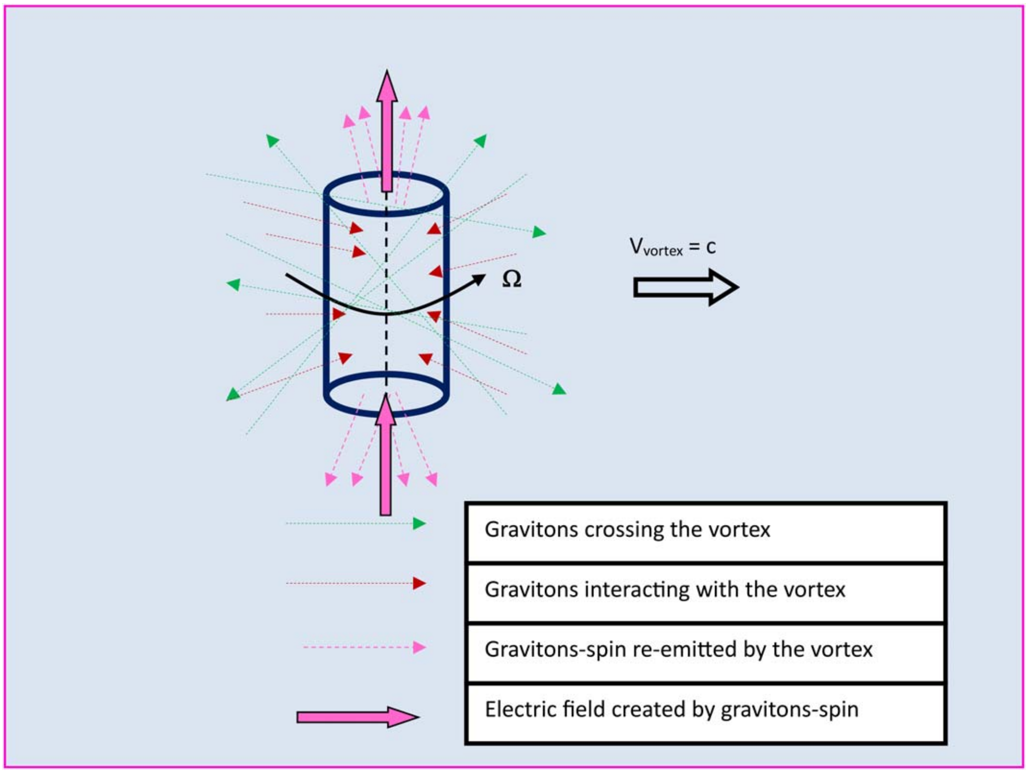

FIG. 18. (Color online) Propagation of a VORTEX in the gravitons field.

field itself. The vortices forming a kind of agglomerate, screen the gravitons, which helps maintain the structure of the particle.

This would explain that a particle of matter, a stable agglomerate of vortices, can be seen as a corpuscle but fundamentally has a wave behavior because it is composed of vortices which are elementary waves constantly renewed.

It is assumed that all the gravitons-spin emitted by the same vortex have the same direction of rotation and that the axis of this rotation is the same as that of the axis of the cylinder.

In the present theory, it is proposed that it is the gravitons-spin which create the electric field:

- If the gravitons-spin rotate in the counter clockwise direction with respect to the axis of the cylinder which would be oriented "from bottom to top" the electric field will be oriented **from bottom to top**.
- If the gravitons-spin turn clockwise with respect to the axis of the cylinder which would be oriented from bottom to top the electric field will be oriented "**from top to bottom**."

The electric field corresponds to the flux of gravitons-spin emitted by the vortex according to its two bases.

The electric field of a charged particle corresponds to the fluxes of gravitons-spin emitted by the vortices making up the particle and the direction of rotation of the gravitons-spin is determined by the sign of the charge of the particle.

It is important to note that the electric field vector moves at the same speed as the particle, but that the effect of the electric field operates at the speed of gravitons-spin, i.e., at a speed well above the speed of light.

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