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Spacetime: An emergent abstraction from the dynamics of an energetic medium

The power of a formalism can sometimes obscure the simplicity of the reality it describes. This may be one of the reasons for the current conceptual impasse, where mathematical coherence advances faster than physical intuition.

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1 Introduction

Can part of modern physics be reformulated in terms of the dynamics of a continuous energetic medium, without losing contact with experiment or contradicting established results? This question is the starting point of the pages that follow. It proceeds neither from a rejection of existing theories nor from a desire for rupture, but from a methodical examination: what happens if one attempts to describe certain fundamental phenomena from a more explicitly mechanical and causal standpoint?

As an electronics engineer who graduated from ENSEA, after preparatory classes at the Lycée Frédéric-Mistral in Avignon, I work in a profession situated at the interface between theory and reality: designing, measuring, testing, and correcting until a system is robust enough to withstand experimental scrutiny. This culture of iteration, confrontation with measurements, and questioning also structures my relationship to physics. I claim neither an academic position nor institutional authority in theoretical physics. The reflections presented here are those of an engineer who seeks to examine the internal consistency, physical scope, and measurable consequences of a given conceptual framework.

I am interested in models capable of articulating a formalism with effectively observable quantities, and I favour hypotheses that clearly expose their conditions of validity as well as their criteria for refutation. These notes are part of this approach: to propose a deliberately physical and testable reading of certain phenomena, by making the assumed hypotheses explicit and accepting that they may prove insufficient.

The luminiferous aether, long central to 19th-century debates, was largely abandoned after the emergence of relativity. Einstein's theory, through its coherence and predictive power, profoundly transformed our understanding of space and time. It remains today a framework of remarkable effectiveness. However, like any theoretical construction, it leaves certain areas of tension: the complete unification with quantum physics remains unfinished, and at the cosmological scale, dark matter and dark energy are introduced to account for observations whose interpretation remains open.

In this context, it may be heuristic to provisionally suspend the geometric interpretation of general relativity and adopt, as much as possible, a viewpoint closer to that of a pre-relativistic physicist. The aim is neither to ignore a century of experimental confirmations nor to contest established results, but to examine whether a more explicitly dynamic and mechanical description can at least partially reproduce the observed phenomena.

The proposed approach is articulated around a central hypothesis: the effects usually grouped under the notions of relativity, electromagnetism, and gravitation could be reformulated as manifestations of a continuous energetic medium, characterised locally by an energy density, stresses, and fluxes. The term aether is used here in a strictly operational sense. It does not denote a material fluid composed of particles or an asserted ontological entity, but a conceptual tool intended to structure a dynamics.

The starting point is deliberately minimal. One assumes the existence of a medium possessing an inertia of energetic origin and properties assimilable to elasticity, governed by local conservation laws. The velocity introduced within this framework does not correspond to a transport of matter, but to an energetic flux velocity describing the propagation and redistribution of energy. The initial challenge is not to propose a competing formalism, but to determine how far such a framework allows the reconstruction of phenomena considered fundamental.

In a first stage, the dynamic equations of this medium are established, and it is shown how electromagnetism can emerge as a compact writing of this dynamics under controlled hypotheses. Fields and potentials then appear as effective variables describing the energetic state of the medium. This basis makes it possible to address concrete phenomena, such as the optics of moving media and the Fresnel drag coefficient, serving as an experimental test bench.

On this basis, certain classical results are re-examined in order to evaluate whether the contraction of lengths and the slowing of clocks can be interpreted as dynamic effects linked to the finite propagation of interactions and to the energetic inertia of the medium. The objective is not to replace the relativistic formalism, but to explore whether it can receive a more explicitly causal reading.

The second part introduces the hypothesis of gravitation described as a radial flux of the energetic medium, whose local velocity would be related to the gravitational potential. This representation makes it possible to examine, in the weak-field regime, the emergence of well-established results: gravitational time dilation, spectral redshift, Shapiro delay, deflection of light rays, and corrections used in satellite navigation.

These proposals remain hypothetical. Their interest does not lie in an assertion of authority, but in their capacity to produce quantitative relations, to clarify certain mechanisms, and to expose their own limits. The ambition of these pages is not to convince, but to propose a coherent intellectual journey, sufficiently explicit for each reader to examine its solidity and test its sensitive points.

2 The dynamic equations of the aether

2.1 Framework and hypotheses

The aether is modelled as a continuous energetic medium, capable of storing, transporting, and redistributing energy. It is not a material fluid made up of particles, but an energetic medium endowed with dynamic and elastic properties. Its local state is described by energy densities, internal stresses, and fluxes.

The medium possesses its own dynamics independent of any material structure. Any form of viscosity is neglected. The medium is assumed to be perfect in the dissipative sense. This dynamics is conservative and governed by the local conservation of energy as well as by the internal elastic response of the energetic medium.

Within this framework, the aether exhibits mixed behaviour:

- fluid-type behaviour: transport and redistribution of energy
- elastic behaviour: ability to store energy in the form of internal stresses

Shear-type deformations correspond to transverse redistributions of energy. They can be excited by a local electrical coupling and are responsible for the propagation of electromagnetic perturbations.

The model involves:

- an energetic pressure P, reflecting the longitudinal variations of the medium and its quasi-incompressible character
- an electric field $\vec{E}$, describing the local polarisation state of the energetic medium and characterised by an electrical coupling parameter ρ_e
- a velocity field $\vec{v}$, representing the dynamics of the energetic flux and the mechanisms of energy redistribution, associated with a volumetric energy density of the medium ρ_m

Notations and parameters. The following notations are adopted:

- P: energetic pressure
- χ_e: effective energetic compressibility coefficient of the medium
- $\vec{v}$: velocity field of the energetic flux
- $\vec{E}$: electric field
- ρ_m: volumetric energy density of the medium
- ρ_e: electrical coupling parameter of the medium

The quantity $\vec{v}$ does not represent a velocity of matter transport, but the local velocity of energy flux within the energetic medium.

Status of the constants ρ_m and ρ_e. The energetic medium possesses neither material mass nor intrinsic electrical charge in the corpuscular sense. It is characterised by its own dynamic properties, independent of any localised structure.

The quantities ρ_m and ρ_e do not represent densities associated with a particle or a material volume. They constitute fundamental coupling constants of the energetic medium.

The constant ρ_m intervenes in the dynamics of the energetic flux and characterises the response of the medium to variations in the velocity of the field $\vec{v}$. It corresponds to a volumetric energy density intrinsic to the medium, fixing the effective inertial scale of perturbations, without however representing a localised mass density.

The constant ρ_e characterises the electrical coupling of the medium. It intervenes in the relation between the energetic polarisation state and the electric field $\vec{E}$, without representing a charge density in the classical sense.

Within this theoretical framework, observable mass and charge are not identified with ρ_m or ρ_e. They emerge from particular dynamic configurations of the energetic field. The constants ρ_m and ρ_e describe solely the structural properties of the medium itself.

2.2 Linearised dynamics of the energetic flux

The dynamics of the medium is governed by a momentum equation applied to the energetic flux. Expressed per unit volume, it reads:

$$\boxed{\rho_m \left(\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla)\vec{v} \right) = -\nabla P - \rho_e \vec{E}} \tag{1}$$

Placing oneself in an Eulerian description (laboratory frame) and considering a linear regime where the convective effects of the flux are negligible compared to local variations:

$$(\vec{v} \cdot \nabla)\vec{v} \approx 0 \tag{2}$$

The equation reduces to:

$$\boxed{\rho_m \frac{\partial \vec{v}}{\partial t} = -\nabla P - \rho_e \vec{E}} \tag{3}$$

This equation expresses that the local temporal variation of the energetic velocity field is determined by the gradients of energetic pressure and by the electrical coupling of the medium to the field $\vec{E}$.

2.3 Conservation of energy and quasi-incompressibility

As the aether is conceived as an energetic medium, the fundamental law applicable to it is that of local energy conservation. In the absence of dissipation, the variations of the energy density of the medium are determined by the energetic fluxes and the internal stresses.

In the quasi-incompressible approximation, it is assumed that the medium has very low energetic compressibility. The coefficient χ_e is then small in absolute value, which means that large pressure variations produce only small relative variations in energy density.

It follows that the volumetric energy density of the medium remains practically constant at large scales, exhibiting only small deviations around a dominant mean value, in keeping with the adopted framework.

Local variations of the energy density are related to pressure variations by an effective compressibility relation serving as an equation of state:

$$\frac{1}{\rho_m}\frac{D\rho_m}{Dt} = \chi_e \frac{DP}{Dt} \tag{4}$$

where D/Dt denotes the material derivative along the energetic flux.

At quasi-incompressible order, one obtains the relation:

$$\nabla \cdot (\rho_m \vec{v}) + \rho_m \chi_e \frac{DP}{Dt} = 0 \tag{5}$$

In the linear regime, this relation becomes:

$$\boxed{\nabla \cdot (\rho_m \vec{v}) + \rho_m \chi_e \frac{\partial P}{\partial t} = 0} \tag{6}$$

This equation expresses the local conservation of the medium's energy in the form of fluxes and longitudinal stresses.

2.4 Dictionary "energetic aether to electromagnetic potentials"

A formal dictionary is now introduced relating the dynamic variables of the energetic medium to the electromagnetic potentials:

$$\boxed{\vec{A} \equiv \frac{\rho_m}{\rho_e}\,\vec{v} + \vec{A}_0 \qquad V \equiv \frac{1}{\rho_e}\,P + V_0} \tag{7}$$

These definitions do not introduce new physical entities. They constitute a reformulation of the dynamic variables of the medium, chosen to highlight the mathematical structure of the electromagnetic equations.

The constants ρ_m and ρ_e are structural parameters of the energetic medium. The constant ρ_m corresponds to a volumetric energy density intrinsic to the medium and fixes its dynamic inertial scale. The constant ρ_e characterises the fundamental electrical coupling of the medium. Their ratio defines an intrinsic scale factor relating the velocity of the energetic flux to the vector potential.

Thus, the coefficient relating $\vec{A}$ to $\vec{v}$ is governed by a factor fixed by the fundamental properties of the medium, independent of any particular material structure.

The fields $(\vec{A}, V)$ are defined up to a constant. The constants $(\vec{A}_0, V_0)$ carry no dynamic content and are fixed by a boundary condition, typically $\vec{A} \to \vec{0}$ and $V \to 0$ as $r \to \infty$.

A formal identification of the model parameters with the constants of electromagnetism is then carried out:

$$\boxed{\chi_e \leftrightarrow \varepsilon_0 \qquad \rho_m \leftrightarrow \mu_0} \tag{8}$$

These identifications should be understood as scale choices enabling the standard form of Maxwell's equations to be recovered, without introducing fields independent of the underlying energetic medium.

2.5 Field–potential relation and Lorenz gauge

Starting from the equation of motion (3), dividing by ρ_e and using the dictionary (7), one obtains:

$$\frac{\partial \vec{A}}{\partial t} = -\nabla V - \vec{E} \tag{9}$$

One then obtains the expression for the electric field:

$$\boxed{\vec{E} = -\nabla V - \frac{\partial \vec{A}}{\partial t}} \tag{10}$$

The quasi-incompressibility condition (6) is then rewritten using the dictionary:

$$\nabla \cdot \vec{A} + \rho_m \chi_e \frac{\partial V}{\partial t} = 0 \tag{11}$$

Identifying $\rho_m \chi_e$ with $\mu_0 \varepsilon_0$, one obtains the Lorenz gauge:

$$\boxed{\nabla \cdot \vec{A} + \mu_0 \varepsilon_0 \frac{\partial V}{\partial t} = 0} \tag{12}$$

2.6 Magnetic field and two immediate Maxwell equations

The magnetic field is defined as a quantity derived from the vector potential, itself arising from the dynamics of the energetic flux:

$$\boxed{\vec{B} \equiv \nabla \times \vec{A}} \tag{13}$$

This definition expresses that the magnetic field corresponds to a vorticity of the potential associated with the transverse energetic flux of the medium.

From this definition, the following identity immediately follows:

$$\boxed{\nabla \cdot \vec{B} = 0} \tag{14}$$

which reflects the absence of sources or sinks of the magnetic field, interpreted here as the absence of vorticity singularities of the energetic flux.

Taking the curl of the expression for the electric field (10), one obtains:

$$\nabla \times \vec{E} = -\nabla \times (\nabla V) - \frac{\partial}{\partial t}(\nabla \times \vec{A}) \tag{15}$$

The first term vanishes identically, giving:

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \tag{16}$$

that is, Faraday's equation:

$$\boxed{\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}} \tag{17}$$

This equation expresses the dynamic conversion between temporal variations of the vorticity of the energetic flux and the induced electric field.

2.7 Current, charge conservation, and the Maxwell–Ampère equation

A current density is introduced, that is, the quantity of charge crossing a surface per unit time and per unit area, defined by:

$$\boxed{\vec{J} \equiv \rho_q \, \vec{u}} \tag{18}$$

where $\vec{u}$ is the mean velocity of charge carriers in the energetic medium. This velocity is distinguished from the velocity $\vec{v}$ associated with the flux of the energetic medium. The density ρ_q denotes the local material charge density, associated with the organised structure.

The local conservation of charge is then written:

$$\boxed{\frac{\partial \rho_q}{\partial t} + \nabla \cdot \vec{J} = 0} \tag{19}$$

Starting from the vector identity:

$$\nabla \times \vec{B} = \nabla \times (\nabla \times \vec{A}) = \nabla(\nabla \cdot \vec{A}) - \nabla^2 \vec{A} \tag{20}$$

where ∇^2 denotes the Laplacian applied component by component.

From the Lorenz gauge (12), one has:

$$\nabla(\nabla \cdot \vec{A}) = -\mu_0 \varepsilon_0 \, \nabla \frac{\partial V}{\partial t} \tag{21}$$

Now, differentiating the expression for the electric field (10) with respect to time gives:

$$\frac{\partial \vec{E}}{\partial t} = -\nabla \frac{\partial V}{\partial t} - \frac{\partial^2 \vec{A}}{\partial t^2} \tag{22}$$

hence:

$$-\nabla \frac{\partial V}{\partial t} = \frac{\partial \vec{E}}{\partial t} + \frac{\partial^2 \vec{A}}{\partial t^2} \tag{23}$$

Combining these relations gives:

$$\nabla(\nabla \cdot \vec{A}) = \mu_0 \varepsilon_0 \left(\frac{\partial \vec{E}}{\partial t} + \frac{\partial^2 \vec{A}}{\partial t^2} \right) \tag{24}$$

Substituting into (20), one obtains:

$$\nabla \times \vec{B} = \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \mu_0 \varepsilon_0 \frac{\partial^2 \vec{A}}{\partial t^2} - \nabla^2 \vec{A} \tag{25}$$

In order to ensure correspondence with the observed magnetostatic regime, it is imposed that, in the stationary limit, the vector potential satisfies the vector Poisson equation:

$$\boxed{-\nabla^2 \vec{A} = \mu_0 \, \vec{J}} \tag{26}$$

The dynamic generalisation compatible with the Maxwell–Ampère equation and the Lorenz gauge condition then naturally leads to positing the forced wave equation for the vector potential:

$$\boxed{-\nabla^2 \vec{A} + \mu_0 \varepsilon_0 \frac{\partial^2 \vec{A}}{\partial t^2} = \mu_0 \, \vec{J}} \tag{27}$$

Substituting (27) into (25), one immediately obtains:

$$\boxed{\nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}} \tag{28}$$

which corresponds to the Maxwell–Ampère equation.

2.8 Maxwell–Gauss equation via the scalar potential

Taking the divergence of the expression for the electric field (10), one obtains:

$$\nabla \cdot \vec{E} = -\nabla \cdot (\nabla V) - \frac{\partial}{\partial t}(\nabla \cdot \vec{A}) \tag{29}$$

that is:

$$\nabla \cdot \vec{E} = -\nabla^2 V - \frac{\partial}{\partial t}(\nabla \cdot \vec{A}) \tag{30}$$

Using the Lorenz gauge (12), one has:

$$-\frac{\partial}{\partial t}(\nabla \cdot \vec{A}) = \mu_0 \varepsilon_0 \frac{\partial^2 V}{\partial t^2} \tag{31}$$

One obtains from the dynamics of the medium and the gauge condition:

$$\nabla \cdot \vec{E} = -\nabla^2 V + \mu_0 \varepsilon_0 \frac{\partial^2 V}{\partial t^2} \tag{32}$$

In order to ensure correspondence with the observed electrostatic regime, it is imposed that, in the stationary limit, the scalar potential satisfies the Poisson equation:

$$\boxed{-\nabla^2 V = \frac{\rho_q}{\varepsilon_0}} \tag{33}$$

The dynamic generalisation compatible with the preceding expression of $\nabla \cdot \vec{E}$ then naturally leads to positing the forced wave equation:

$$\boxed{-\nabla^2 V + \mu_0 \varepsilon_0 \frac{\partial^2 V}{\partial t^2} = \frac{\rho_q}{\varepsilon_0}} \tag{34}$$

Substituting (34) into (32), one immediately obtains:

$$\boxed{\nabla \cdot \vec{E} = \frac{\rho_q}{\varepsilon_0}} \tag{35}$$

which corresponds to the Maxwell–Gauss equation.

Charge as a local condition on the pressure field. In the stationary regime, an electric charge does not correspond to a permanent transport of the energetic medium, but to a static pressure configuration.

According to the established dictionary:

$$V \equiv \frac{1}{\rho_e} P + V_0 \tag{36}$$

The electrostatic potential appears as the scalar description of the pressure field of the medium. The presence of a charge density then locally imposes a constraint on P, which manifests as a spatial variation of the electric potential.

The sign of the charge specifies the nature of this constraint:

- A positive charge corresponds to a locally stabilised overpressure.
- A negative charge corresponds to a locally stabilised underpressure.

The electrostatic field $\vec{E} = -\nabla V$ describes how this constraint is distributed in the surrounding space. As long as the configuration remains stationary, there is no net flux of the medium. A flux only appears when the configuration evolves in time.

2.9 Definition of the propagation velocity of electromagnetic waves

The wave equations (27) and (34) show that electromagnetic perturbations propagate at a finite velocity in the energetic medium. This velocity is given by:

$$\boxed{c \equiv \frac{1}{\sqrt{\mu_0 \, \varepsilon_0}}} \tag{37}$$

The parameters of the energetic medium are formally identified with those of electromagnetism:

$$\mu_0 \leftrightarrow \rho_m \qquad \varepsilon_0 \leftrightarrow \chi_e \tag{38}$$

So that the propagation velocity can also be written:

$$\boxed{c = \frac{1}{\sqrt{\rho_m \, \chi_e}}} \tag{39}$$

The constant c thus appears as a wave velocity intrinsic to the energetic medium, determined by its volumetric energy density ρ_m and its energetic compressibility χ_e. It does not constitute a fundamental kinematic postulate, but results directly from the dynamic properties of the medium.

This velocity corresponds to the isotropic propagation of electromagnetic perturbations in the local frame co-moving with the energetic medium. Any possible anisotropy in the measured speed of light would arise from a relative motion between the observer and the energetic flux, without implying any intrinsic modification of c.

Throughout the remainder, the constant c designates exclusively the propagation velocity of electromagnetic waves in the local frame co-moving with the energetic medium, that is, in the frame in which the local velocity of the energetic flux is zero.

2.10 Kinematic emergence of the Lorentz force

The dynamics of a charge q in motion in the energetic medium is now examined.

Recalling the fields from the potentials:

$$\vec{E} = -\nabla V - \frac{\partial \vec{A}}{\partial t} \tag{40}$$

$$\vec{B} = \nabla \times \vec{A} \tag{41}$$

For a charge moving at velocity $\vec{u}$, the relevant temporal variation of the vector potential along the trajectory is not the partial derivative, valid for a fixed point in space, but the material derivative incorporating the convective term:

$$\frac{d\vec{A}}{dt} = \frac{\partial \vec{A}}{\partial t} + (\vec{u} \cdot \nabla)\vec{A} \tag{42}$$

The second term reflects the transport of the vector potential by the motion of the singularity through the energetic medium. It corresponds to the non-linear contribution present in the full dynamic equation (1) and becomes essential as soon as the charge has a finite velocity.

The effective electric field experienced by the charge is then written:

$$\vec{E}_{\text{eff}} = -\nabla V - \frac{d\vec{A}}{dt} \tag{43}$$

Substituting the definition of the electric field gives:

$$\vec{E}_{\text{eff}} = \vec{E} - (\vec{u} \cdot \nabla)\vec{A} \tag{44}$$

Using the vector identity:

$$\vec{u} \times (\nabla \times \vec{A}) = \nabla(\vec{u} \cdot \vec{A}) - (\vec{u} \cdot \nabla)\vec{A} \tag{45}$$

which allows one to write:

$$(\vec{u} \cdot \nabla)\vec{A} = \nabla(\vec{u} \cdot \vec{A}) - \vec{u} \times \vec{B} \tag{46}$$

One deduces:

$$\vec{E}_{\text{eff}} = \vec{E} - \nabla(\vec{u} \cdot \vec{A}) + \vec{u} \times \vec{B} \tag{47}$$

The gradient-type term can be absorbed into a redefinition of the scalar potential by introducing:

$$V^{\star} = V + \vec{u} \cdot \vec{A} \tag{48}$$

This transformation corresponds to a gauge redefinition of the potentials. It modifies neither the electric field nor the magnetic field, which depend only on the spatial and temporal derivatives of the potentials. The gradient term therefore introduces no additional physically measurable contribution.

One finally obtains:

$$\boxed{\vec{E}_{\text{eff}} = \vec{E} + \vec{u} \times \vec{B}} \tag{49}$$

The force exerted on a charge q is then written:

$$\boxed{\vec{F} = q(\vec{E} + \vec{u} \times \vec{B})} \tag{50}$$

The structure of the Lorentz force thus appears as a kinematic consequence of the material derivative applied to the vector potential.

The field $\vec{B} = \nabla \times \vec{A}$ represents the local vorticity of the energetic flux of the medium. The term $\vec{u} \times \vec{B}$ then describes the interaction between the velocity of the charge and this vorticity.

This structure is formally analogous to the Magnus-type force in fluid mechanics, where an object moving in a vortical fluid experiences a transverse force proportional to the cross product between its velocity and the local vorticity.

The magnetic component of the Lorentz force can thus be interpreted as a gyroscopic force resulting from the vortical structure of the energetic medium.

2.11 Operational status of the fields $\vec{E}$ and $\vec{A}$

In the preceding construction, neither the electric field $\vec{E}$ nor the vector potential $\vec{A}$ constitute primitive dynamic variables of the energetic medium. They appear as quantities describing the electrical coupling of the medium to a charge, this coupling being fixed by the structural constant ρ_e.

The fundamental dynamics of the medium brings in the term $\rho_e \vec{E}$, which represents the exchange of momentum between a charge and the energetic medium. The field $\vec{E}$ is therefore not defined independently, but through its mechanical action on a charge via the coupling ρ_e.

Likewise, the vector potential $\vec{A}$ has no autonomous operational meaning. It intervenes in the description of the dynamic coupling between a moving charge and the medium. Its role becomes physically identifiable only through the measurable effects produced on a test charge.

Thus, the fields $\vec{E}$ and $\vec{A}$ acquire experimental meaning only in the presence of a material charge that locally probes the state of the medium and reveals its mechanical effects.

The vacuum, from an electromagnetic standpoint, does not correspond to the absence of dynamics of the energetic medium, but to the absence of effective electrical interaction with a charge. The dynamics of the medium in vacuum can be described directly by the fundamental variables of the medium, in particular the energetic pressure P and the velocity field of the flux $\vec{v}$. The quantities $\vec{E}$ and $\vec{A}$ then appear as derived variables, introduced to describe in a compact manner the interaction between the medium and a charged material structure.

2.12 Summary: Maxwell's equations

From the potentials, the fields are introduced according to:

$$\vec{E} = -\nabla V - \frac{\partial \vec{A}}{\partial t}, \qquad \vec{B} = \nabla \times \vec{A} \tag{51}$$

Under the Lorenz gauge condition:

$$\nabla \cdot \vec{A} + \mu_0 \varepsilon_0 \frac{\partial V}{\partial t} = 0 \tag{52}$$

and using the forced wave equations satisfied by V and $\vec{A}$, the full set of Maxwell's equations is obtained:

$$\nabla \cdot \vec{B} = 0, \qquad \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \tag{53}$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}, \qquad \nabla \cdot \vec{E} = \frac{\rho_e}{\varepsilon_0} \tag{54}$$

Furthermore, the analysis in the non-linear regime, based on the material derivative of the vector potential along the trajectory of a moving singularity, leads to the expression of the force exerted on a charge q moving at velocity $\vec{u}$:

$$\vec{F} = q(\vec{E} + \vec{u} \times \vec{B}) \tag{55}$$

The Lorentz force thus appears as a kinematic consequence of the dynamics of the medium, and not as an independent postulate added to Maxwell's equations.

2.13 Conclusion

Within this framework, electromagnetic phenomena appear as the direct manifestation of the dynamics of a continuous energetic medium. The fields $\vec{E}$ and $\vec{B}$ are not introduced as independent fundamental entities, but as derived quantities, constructed from the dynamic variables of the medium (energetic pressure P, flux $\vec{v}$, and coupling constants) via the potentials $(V, \vec{A})$.

The energetic medium supports and transmits electromagnetic interactions: wave propagation, effects associated with charge distributions and currents, interactions between material structures. Electromagnetism thus appears as a compact reformulation of the dynamic equations of the energetic medium. The usual quantities $\vec{E}$ and $\vec{B}$ then describe particular modes of organisation and propagation of perturbations within this medium.

3 The Fresnel Drag Coefficient

3.1 Historical origin

It is essential to clarify from the outset the status of Fresnel's theory in what follows. Fresnel's original wave theory, based on a mechanical aether endowed with a material density, is not the one developed in these notes. It has today been abandoned as a fundamental framework. However, the central idea it introduced, as well as the quantitative result to which it leads, are retained here as experimentally established physical facts.

In Fresnel's approach, the propagation velocity of light depends on the quantity of aether contained in the traversed medium.

- In vacuum, the aether has a reference density ρ and the propagation velocity is c.
- In a transparent medium of optical index n, Fresnel assumes the medium contains a greater quantity of aether. In order to account for the reduced velocity $c' = \frac{c}{n}$, he postulates an effective density $\rho' = n^2 \rho$.

When a transparent body moves at velocity v relative to the supposedly stationary aether, Fresnel shows that the aether contained in the medium is not entirely dragged by the motion of the body. It only moves at a fraction of this velocity, which can be written as:

$$v_{\text{ether}} = f\, v \tag{56}$$

where the partial drag coefficient is given by:

$$f = 1 - \frac{1}{n^2} \tag{57}$$

It follows that the speed of light measured in the aether frame is written:

$$\boxed{V = \frac{c}{n} \pm v\left(1 - \frac{1}{n^2}\right)} \tag{58}$$

This result has two immediate and coherent limiting cases:

- for $n = 1$ (vacuum), $f = 0$ and there is no dragging
- for very large index, $f \simeq 1$ and the dragging becomes nearly total

An experimental result preserved beyond the theory. The fundamental point is not the original mechanical interpretation proposed by Fresnel, but the fact that this drag coefficient was confirmed experimentally with great precision. Fizeau's experiment (1851), which measures the speed of light in moving water, unambiguously shows that light propagation does not obey a simple Galilean addition of velocities $\frac{c}{n} \pm v$, but follows exactly Fresnel's law.

This result constitutes a robust experimental fact. It indicates that the propagation of light in a moving medium depends on the internal properties of the medium and its dynamic interaction with the wave, and not on elementary relative kinematics. It is this fact, and this alone, that is retained in what follows, independently of the historical theoretical framework in which it was initially formulated.

3.2 Electromagnetic description derived from the dynamics of the energetic medium

At the microscopic scale, the distance between molecules or between atoms within the atomic lattices of refracting media is of the order of 0.1 to 0.3 nm. This scale is far smaller than the wavelength of visible light, typically of the order of 500 nm. The electromagnetic wave therefore cannot spatially resolve the individual constituents of the medium and only couples to their collective response.

In a transparent material, electrons are set into oscillation by the incident electric field and re-emit the wave without net absorption. The wave traverses the medium, but its propagation is slowed by the energetic response time associated with the collective polarisation of the charges.

In an opaque material, two mechanisms dominate:

- electrons absorb the energy of the wave and convert it into heat
- in the case of metals, free electrons re-emit the wave immediately at the surface, producing reflection

Transparency thus corresponds to a coherent transmission of the energetic oscillation through the medium, without net dissipation, while opacity reflects either an irreversible conversion of this energy into internal agitation (absorption), or a quasi-instantaneous re-emission towards the exterior (reflection).

When light penetrates matter, it therefore does not interact with isolated atoms, but with the refracting medium as a collective system. The electromagnetic wave couples its energy to the medium via the coordinated oscillation of electronic charges. This collective response results in a polarisation of the medium, which locally modifies the energy stored in the fields and, consequently, the propagation velocity of the wave. The phenomena of refraction and dispersion thus appear as direct manifestations of the energetic dynamics of the medium.

In this description, the refracting medium is modelled as a continuum of polarisable charges. When a wave traverses it, it induces a collective dipole moment per unit volume. The macroscopic response of the medium is then characterised by the polarisation vector $\vec{P}$, which describes the energetic excitation state induced by the wave.

Consider a refracting medium moving at constant velocity $\vec{u}$ relative to the local frame co-moving with the energetic medium. According to relation (49), the bound charges of the medium, advected by this motion, do not probe the field at a fixed point but along their trajectory. They therefore experience an effective electric field of the form:

$$\vec{E}' = \vec{E} + \vec{u} \times \vec{B} \tag{59}$$

The polarisation, defined as the dipole moment per unit volume, is proportional to this effective field:

$$\vec{P} = (\varepsilon - \varepsilon_0)\, \vec{E}' \tag{60}$$

that is, explicitly:

$$\vec{P} = (\varepsilon - \varepsilon_0)\, (\vec{E} + \vec{u} \times \vec{B}) \tag{61}$$

When the medium is in motion, the temporal and spatial variation of the polarisation generates a total current in the fixed frame, denoted $\vec{j}_{\text{pol}}$:

$$\vec{j}_{\text{pol}} = \frac{\partial \vec{P}}{\partial t} + \text{rot}(\vec{P} \times \vec{u}) \tag{62}$$

The second term, $\text{rot}(\vec{P} \times \vec{u})$, corresponds to the convection current of dipoles, also called the Röntgen current.

Using the Maxwell–Ampère equation in the fixed frame:

$$\text{rot}\, \vec{B} = \mu_0 \left(\varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \vec{j}_{\text{pol}} \right) \tag{63}$$

and substituting the expression for $\vec{j}_{\text{pol}}$ and $\vec{P}$, one obtains:

$$\text{rot}\, \vec{B} = \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \mu_0(\varepsilon - \varepsilon_0) \frac{\partial}{\partial t}(\vec{E} + \vec{u} \times \vec{B}) + \mu_0(\varepsilon - \varepsilon_0)\, \text{rot}(\vec{E} \times \vec{u}) \tag{64}$$

Using the relation $n^2 = \varepsilon/\varepsilon_0$ and the identity $\mu_0 \varepsilon_0 = 1/c^2$, and limiting oneself to first order in $\vec{u}$, this equation simplifies to:

$$\text{rot}\, \vec{B} = \frac{n^2}{c^2} \frac{\partial \vec{E}}{\partial t} + \frac{n^2 - 1}{c^2} \frac{\partial}{\partial t}(\vec{u} \times \vec{B}) + \frac{n^2 - 1}{c^2}\, \text{rot}(\vec{E} \times \vec{u}) \tag{65}$$

This equation is combined with Faraday's equation:

$$\text{rot}\, \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

Taking the curl of $\vec{E}$ and injecting the preceding expressions, one obtains a propagation equation for a plane wave propagating along the x axis at velocity W:

$$\frac{\partial^2 \vec{E}}{\partial x^2} - \frac{n^2}{c^2} \frac{\partial^2 \vec{E}}{\partial t^2} - 2\, \frac{n^2 - 1}{c^2}\, vu\, \frac{\partial^2 \vec{E}}{\partial x\, \partial t} = 0 \tag{66}$$

A plane wave solution of the form:

$$\vec{E} = \vec{E}_0\, f(x - Wt) \tag{67}$$

The derivatives are then written:

$$\frac{\partial^2 \vec{E}}{\partial x^2} = \vec{E}_0 \, f'' \tag{68}$$

$$\frac{\partial^2 \vec{E}}{\partial t^2} = W^2 \, \vec{E}_0 \, f'' \tag{69}$$

$$\frac{\partial^2 \vec{E}}{\partial x \, \partial t} = -W \, \vec{E}_0 \, f'' \tag{70}$$

The propagation equation becomes:

$$1 - \frac{n^2 W^2}{c^2} + 2 \, \frac{n^2 - 1}{c^2} \, u \, W = 0 \tag{71}$$

Multiplying by c^2 and rearranging gives:

$$n^2 W^2 - 2(n^2 - 1) u W - c^2 = 0 \tag{72}$$

This quadratic equation yields the exact solution:

$$\boxed{W = \frac{(n^2 - 1)u \pm \sqrt{(n^2 - 1)^2 u^2 + n^2 c^2}}{n^2}} \tag{73}$$

To obtain the first-order approximation in u, we set:

$$W = \frac{c}{n} + \delta \tag{74}$$

and neglect terms of order u^2/c^2 and δ^2. This leads to:

$$\boxed{W \approx \frac{c}{n} + u \left(1 - \frac{1}{n^2}\right)} \tag{75}$$

The factor $\left(1 - \frac{1}{n^2}\right)$ is the Fresnel coefficient. This result shows that the effective propagation velocity does not arise from a simple kinematic addition of velocities, but from the dynamic interaction between the electromagnetic wave and the charges of the medium. These charges, set into oscillation by the field while being advected by the energetic flux, modify the phase of the re-emitted wave. The observed drag thus appears as a collective effect linked to the energetic response of the medium, and not as an intrinsic property of light itself.

It is essential to clarify that the velocity u appearing in this expression is defined relative to the local frame co-moving with the energetic aether. It measures the degree of non-co-mobility of the material medium with the energetic flux supporting electromagnetic propagation. The Fresnel coefficient therefore does not reflect a purely relative property between observers, but the dynamic effect of a refracting medium traversed by a non-co-moving energetic flux. This distinction constitutes a major conceptual difference from the relativistic interpretation, in which only the relative velocity between frames is considered physically relevant.

In this perspective, the linear term in u arising from Fresnel's analysis corresponds to a first-order effect. It is proportional to the velocity of the apparatus and does not depend on a quadratic term in v/c. Yet experimental history shows that virtually all classical devices, from Fizeau to Michelson–Morley via Hoek, were designed in such a way as to systematically cancel any first-order contribution. The symmetries of the optical paths and the compensation of travel times eliminate precisely the terms proportional to v, leaving only second-order corrections.

It follows that the absence of observed effect in these experiments does not constitute direct proof of the non-existence of a privileged reference frame or an underlying energetic flux, but the consequence of the fact that the setups make any global non-co-mobility experimentally invisible. In other words, relativity to the co-moving frame is built into the very structure of the experimental protocols.

If a device were to isolate a shift proportional to v, even when the source, the medium, and the detector are carried together, it would reveal a first-order effect irreducible to a simple reference frame transformation. Such a result would constitute an experimental criterion capable of distinguishing a strictly relativistic description, based on the complete equivalence of inertial frames, from a description resting on the existence of a structuring energetic flux.

A development of this question, as well as an analysis of the experimental conditions necessary to make this non-co-mobility visible, has been presented in my document entitled *When light exposes the reality we do not see*, to which the reader is invited to refer for a deeper exploration of this issue.

4 Length Contraction

If one accepts that electromagnetic interaction is not transmitted instantaneously, but propagates at finite velocity c in the energetic medium, then the motion of a charge imposes a dynamic reorganisation of the energy carried by the field. The field associated with a moving charge can no longer establish itself isotropically: it is constrained by the retarded propagation of perturbations in the medium and by the energetic inertia associated with the field itself.

In the reference frame co-moving with the energetic medium, a moving charge therefore deforms its own field: instead of being spherical, the field contracts in the direction of motion and strengthens transversally. This deformation is classically known as the Heaviside field and constitutes the starting point of the electromagnetic mechanism of length contraction.

Retarded field. For a charge at rest in the frame of the energetic medium, the electric field at distance R is determined by the instantaneous position of the charge. On the other hand, when a charge moves at velocity u relative to this frame, the field observed at time t corresponds to the state of the charge at an earlier time t', called the retarded time.

The geometric condition is that the electromagnetic perturbation, propagated in the energetic medium at velocity c, travels exactly the distance separating the position occupied by the charge at time t' and the observation point. This retarded propagation imposes an intrinsic anisotropy in the spatial distribution of the field's energy.

Why the scalar potential alone is insufficient. Correctly describing the field associated with a moving charge requires introducing, in addition to the scalar potential V, the vector potential $\vec{A}$. In electromagnetism formulated as a dynamics of the energetic medium, the electric field results from two complementary contributions:

$$\vec{E} = -\nabla V - \frac{\partial \vec{A}}{\partial t} \tag{76}$$

- the term $-\nabla V$ corresponds to a quasi-electrostatic contribution, associated with the instantaneous spatial distribution of electrical energy
- the term $-\frac{\partial \vec{A}}{\partial t}$ reflects the dynamics of the energetic flux: a moving charge is equivalent to a current, which induces a vector potential $\vec{A}$ whose temporal variation contributes directly to the field

In this reading, the vector potential encodes the energetic inertia of the field: it accounts for the fact that the energy carried by the field cannot reorganise itself instantaneously when the charge moves.

Anisotropy of the field. The dynamic contribution associated with the vector potential modifies the angular distribution of the electric field:

- **Transversally** ($\theta = 90°$): the term $-\frac{\partial \vec{A}}{\partial t}$ adds to the contribution from V. The field energy is pushed laterally, resulting in a strengthening of the field in directions perpendicular to the motion.

- **Along the axis of motion** ($\theta = 0°$ or $180°$): the dynamic term acts in opposition to $-\nabla V$. The accumulation of field energy ahead and behind is slowed, leading to longitudinal weakening.

The vector potential can thus be interpreted as a manifestation of the energetic inertia of the field: the energy carried by the medium resists compression in the direction of motion and redistributes preferentially in the transverse directions.

Field expression for uniform motion. For a charge q moving uniformly at velocity u relative to the frame co-moving with the energetic aether, the amplitude of the field depends on the angle θ measured relative to the direction of motion. The field is no longer spherical and reads, in the radial direction $\vec{u}_r$:

$$\boxed{\vec{E} = \frac{q}{4\pi\varepsilon_0\, r^2} \frac{1 - \dfrac{u^2}{c^2}}{\left(1 - \dfrac{u^2}{c^2}\sin^2\theta\right)^{3/2}} \vec{u}_r} \tag{77}$$

It follows that:

- for $\theta = 0°$ (forward and backward of the motion), the field is reduced by a factor $1 - \dfrac{u^2}{c^2}$;
- for $\theta = 90°$ (transverse directions), the field is enhanced by a factor $\dfrac{1}{\sqrt{1 - \dfrac{u^2}{c^2}}}$.

This anisotropy directly reflects the spatial redistribution of the field's energy imposed by the finite propagation of interactions in the energetic medium.

Connection with Lorentz contraction. Lorentz had formulated the decisive argument, which can be reformulated in the framework of the energetic medium:

1. the cohesion of matter rests primarily on electromagnetic interactions, which are mediated by the energetic medium
2. when the field of a moving charge becomes anisotropic, the interaction forces between constituents are no longer isotropic
3. in order to maintain a stable energetic and dynamic equilibrium, the internal equilibrium distances must readjust
4. this readjustment results in a contraction of lengths in the direction of motion relative to the energetic medium

Central idea. The finite propagation at velocity c of electromagnetic interactions imposes a spatial redistribution of the field's energy. This redistribution, governed by the energetic inertia of the medium, leads to longitudinal weakening and transverse strengthening of the field. At second order (in v^2/c^2), this mechanism provides a physical explanation for length contraction of an object in motion in the energetic medium, without resorting to an a priori geometric interpretation.

5 Mass and Inertia

5.1 A founding principle on the conservation of energy

Within the framework of the energetic medium, the inertia of a charged object cannot be attributed to an abstract point-like support. It necessarily results from the energy stored in the associated electromagnetic fields and from the way in which this energy dynamically interacts with the energetic medium.

Lorentz and Abraham were the first to formulate this idea under the name of electromagnetic mass: accelerating a charge amounts to accelerating an extended configuration of energy carried by the field, which requires additional work and manifests as a resistance to acceleration.

Energy and momentum of the field. The electromagnetic field carries energy and momentum. The electromagnetic energy density is given by:

$$u = \frac{1}{2}\left(\varepsilon_0 E^2 + \frac{1}{\mu_0} B^2\right) \tag{78}$$

The energy flux is described by the Poynting vector:

$$\vec{S} = \frac{1}{\mu_0}\,\vec{E} \times \vec{B} \tag{79}$$

In classical electromagnetism, the momentum density associated with the field is related to this flux by:

$$\vec{g} = \frac{\vec{S}}{c^2} \tag{80}$$

This relation expresses the fundamental fact that electromagnetic energy possesses its own inertia: any variation of the field implies a transport and redistribution of momentum in the energetic medium.

Field of a charge and dynamic anisotropy. For a charge at rest in the frame comoving with the energetic aether, the field is isotropic and the electromagnetic energy is distributed spherically. The volume integral of the momentum density is then zero.

When a charge moves at velocity $\vec{u}$ relative to this frame, its field becomes anisotropic. The electric and magnetic components couple, generating an energy flux directed globally in the direction of motion. The field then carries a non-zero momentum.

Directional definition of inertia. For any distribution of momentum density $\vec{g}(\vec{r})$, the total momentum is:

$$\vec{P} \equiv \int \vec{g}\, dV \tag{81}$$

In classical mechanics, if one wishes to associate an effective inertia to the motion in the direction of $\vec{u}$, one defines the scalar m_{em} by the identity:

$$\vec{u} \cdot \vec{P} \equiv m_{\text{em}}\, u^2 \tag{82}$$

where $u \equiv \|\vec{u}\|$.

Extraction of the component parallel to $\vec{u}$. Using $\vec{P} = \int \vec{g}\, dV$, one obtains

$$\vec{u} \cdot \vec{P} = \vec{u} \cdot \int \vec{g}\, dV = \int \vec{u} \cdot \vec{g}\, dV \tag{83}$$

Substituting into the definition $\vec{u} \cdot \vec{P} \equiv m_{\text{em}} v^2$, one gets

$$\boxed{m_{\text{em}} \equiv \frac{1}{u^2} \int \vec{u} \cdot \vec{g}\, dV} \tag{84}$$

Uniform transport of a distributed energy. Consider a field configuration stationary in its own frame, characterised by an energy density $\epsilon(\vec{r})$. The total energy stored in the field is:

$$U_{\text{field}} = \int \epsilon\, dV \tag{85}$$

If this configuration is observed from a frame in which it moves uniformly at velocity $\vec{u}$, the local energy is transported with the source. To first order in u/c, the energy flux associated with this transport reads:

$$\vec{S} \simeq \epsilon\, \vec{u} \tag{86}$$

This relation simply expresses the fact that a volumetric energy u conveyed at velocity $\vec{u}$ generates an energy flux $\epsilon \vec{u}$.

Total momentum of the field. Substituting the preceding expression into the definition of $\vec{P}_{\text{field}}$, one obtains:

$$\vec{P}_{\text{field}} \simeq \frac{1}{c^2} \int \epsilon\, \vec{u}\, dV \tag{87}$$

Since the velocity $\vec{u}$ is uniform, it can be extracted from the integral:

$$\vec{P}_{\text{field}} \simeq \frac{\vec{u}}{c^2} \int \epsilon\, dV \tag{88}$$

One then has

$$\vec{P}_{\text{field}} \simeq \frac{U_{\text{field}}}{c^2}\, \vec{u} \tag{89}$$

Definition of electromagnetic mass. Within classical mechanics, a momentum proportional to velocity defines an inertia. Identifying the preceding expression with the Newtonian form:

$$\vec{P}_{\text{field}} \simeq m_{\text{em}}\, \vec{u} \tag{90}$$

one immediately obtains:

$$\boxed{m_{\text{em}} = \frac{U_{\text{field}}}{c^2}} \tag{91}$$

This expression defines electromagnetic mass as the inertia associated with the transport of field energy. This relation is not postulated. It follows from the fact that the energy of the field carries momentum and possesses dynamic inertia in the energetic medium.

Emergence of a fundamental relation. It is remarkable that the preceding analysis naturally leads to the relation connecting energy and mass, without the need to introduce the postulates of special relativity. Indeed, the definition of electromagnetic mass as the inertia associated with the energy of the field directly leads to the identification:

$$\boxed{m = \frac{U}{c^2}} \tag{92}$$

where U denotes the total energy stored in the field and c the propagation velocity of perturbations in the energetic medium.

Within this framework, the relation $E = mc^2$ does not express an ontological equivalence between mass and energy, but a dynamic relation: any energy stored in the energetic medium possesses an inertia, and the factor c^2 appears as the proportionality constant imposed by the finite propagation of interactions. Mass thus measures the inertial cost associated with a given energetic configuration.

This relation, obtained here from purely electromagnetic and energetic considerations, shows that the expression $E = mc^2$ is more general than its usual relativistic interpretation. It reflects a fundamental property of the energetic medium: the energy stored within it behaves as a source of inertia, independently of any geometric hypothesis about space and time.

Cut-off radius and energetic confinement. The energy of the electrostatic field of a point charge diverges at short distances. It is therefore necessary to introduce a cut-off radius r_{eff}, which represents the minimum scale at which the field ceases to be described by the Coulomb expression.

Within the framework of the energetic medium, this radius is not interpreted as a mere regularisation artifice, but as a physical length associated with the domain where the linear description of the field ceases to be valid. It characterises the degree of confinement of the energy in the region close to the charge-bearing structure, without prejudging the precise microscopic nature of this structure, which falls within a more detailed analysis and is not the central object of the present development.

To order of magnitude, the energy stored in the field reads:

$$U_{\text{field}} \sim \frac{q^2}{4\pi\varepsilon_0\, r_{\text{eff}}} \tag{93}$$

This yields an inertial contribution of electromagnetic type:

$$m_{\text{em}} \sim \frac{q^2}{4\pi\varepsilon_0\, c^2\, r_{\text{eff}}} \tag{94}$$

Thus, for equal charge, the electromagnetic mass depends essentially on the energetic confinement: the more concentrated the energy, the greater the associated inertial contribution.

Inverting the relation, one obtains the effective scale required to reproduce a given mass:

$$r_{\text{eff}} \sim \frac{q^2}{4\pi\varepsilon_0\, m\, c^2} \tag{95}$$

For the electron, setting $q = e$ and $m = m_e$, one finds:

$$r_{\text{eff}}^{(e)} \sim \frac{e^2}{4\pi\varepsilon_0\, m_e\, c^2} = r_e \approx 2.82 \times 10^{-15}\,\text{m} \tag{96}$$

For the proton, setting $q = e$ and $m = m_p$, one obtains:

$$r_{\text{eff}}^{(p)} \sim \frac{e^2}{4\pi\varepsilon_0\, m_p\, c^2} = \frac{m_e}{m_p}\, r_e \approx 1.5 \times 10^{-18}\,\text{m} \tag{97}$$

The experimental comparison illustrates the limit of the model at short distances. The rms charge radius of the proton is measured at around $r_p \approx 0.84\,\text{fm}$, i.e. $\sim 8.4 \times 10^{-16}\,\text{m}$, very different from the scale $r_{\text{eff}}^{(p)}$ deduced above. Conversely, high-energy scattering reveals no extension of the electron and provides only an upper bound on its effective radius, typically $r_e \lesssim 2.8 \times 10^{-19}\,\text{m}$, far smaller than $r_{\text{eff}}^{(e)}$ obtained by direct identification with m_e.

The precise determination of r_{eff}, as well as its possible dependence on internal structure or local dynamics of the medium, therefore constitutes an open question that goes beyond the macroscopic framework considered here and will need to be the subject of a specific study.

5.2 Electromagnetic inertia in uniform motion

Effect of motion on inertia. When the charge is set into motion at velocity $\vec{u}$ relative to the frame co-moving with the energetic aether, its electromagnetic field is no longer isotropic. As shown previously, the electric field takes the anisotropic form known as the Heaviside field, characterised by longitudinal weakening and transverse strengthening.

The expression of the electric field for uniform motion is:

$$\vec{E}(r,\theta) = \frac{q}{4\pi\varepsilon_0\, r^2} \frac{1 - \dfrac{u^2}{c^2}}{\left(1 - \dfrac{u^2}{c^2}\sin^2\theta\right)^{3/2}} \vec{u}_r \tag{98}$$

where θ is the angle relative to the direction of motion.

The electromagnetic energy density is proportional to the square of the field:

$$\epsilon_E = \frac{1}{2}\varepsilon_0 E^2 \tag{99}$$

The total field energy is obtained by volume integration:

$$U_{\text{field}}(u) = \int \epsilon_E \, dV = \frac{\varepsilon_0}{2} \int E^2(r,\theta)\, r^2 \sin\theta \, dr \, d\theta \, d\varphi \tag{100}$$

The radial dependence of the integral is identical to that of the field at rest and leads to the same divergence at short distances, regularised by the cut-off radius r_{eff}. The velocity dependence arises exclusively from the angular integration, that is, from the directional redistribution of the field's energy.

Substituting the Heaviside field expression into the angular integral, one obtains a multiplicative factor of the form:

$$\int_0^\pi \frac{(1-\beta^2)^2}{\left(1 - \beta^2 \sin^2\theta\right)^3} \sin\theta \, d\theta = \frac{1}{\sqrt{1-\beta^2}}, \qquad \beta = \frac{u}{c}. \tag{101}$$

It follows that the total energy of the electromagnetic field of a moving charge is related to that at rest by:

$$U_{\text{field}}(u) = \gamma\, U_{\text{field}}(0), \tag{102}$$

with

$$\gamma = \frac{1}{\sqrt{1 - \dfrac{u^2}{c^2}}}. \tag{103}$$

This factor therefore does not result from a geometric transformation of space or time, but from an anisotropic redistribution of the field's energy imposed by the finite propagation of interactions in the energetic medium. The increase in total energy reflects the fact that, upon integration, the transverse strengthening of the field dominates the longitudinal weakening.

This yields a velocity-dependent electromagnetic inertia:

$$\boxed{m = \gamma\, m_0 = \frac{m_0}{\sqrt{1 - \dfrac{u^2}{c^2}}}} \tag{104}$$

with $m_0 = U_{\text{field}}(0)/c^2$.

In this reading, the increase in mass does not correspond to the appearance of an additional substance, but to the increase in field energy and its dynamic inertia.

5.3 Time dilation

Link between inertia and internal dynamics. Every clock relies on a periodic dynamic process: mechanical oscillation, electronic vibration, atomic transition. These processes involve internal forces producing characteristic accelerations.

If the effective inertia of the constituents of matter increases with velocity relative to the energetic medium, then any internal dynamics based on accelerations becomes slower. Yet a clock is nothing other than a device exploiting a stable periodic process: mechanical oscillation, electronic vibration, atomic transition.

Slowing of processes. In the frame co-moving with the energetic aether, an object moving at velocity $\vec{u}$ sees its internal mechanisms systematically affected:

- greater inertia implies smaller accelerations
- the characteristic periods of oscillations increase
- all dynamic processes see their rate diminish by the same factor

From the electromagnetic inertia (104), the slowing can be expressed as:

$$\boxed{\Delta t' = \gamma\, \Delta t} \qquad \text{(or equivalently, } \Delta t = \Delta t' \sqrt{1 - \frac{u^2}{c^2}}) \tag{105}$$

where $\Delta t'$ denotes the duration measured by a clock carried with the moving object, and Δt the corresponding duration measured in the frame co-moving with the energetic aether.

Interpretation. Time dilation is not here a geometric property of time itself, but a direct consequence of the increase in the electromagnetic inertia of the constituents of matter when they move in the energetic medium.

Motion relative to the energetic aether deforms the electromagnetic fields associated with the constituents of matter. This deformation increases the energy stored in the field and, consequently, the effective inertia of microscopic systems. The internal forces then producing smaller accelerations, all periodic processes — atomic oscillations, clock mechanisms, chemical reactions, and even biological processes — see their rate diminish by the same factor.

An observer co-moving with the object cannot locally detect this slowing, because their clocks, instruments, and all their internal processes are identically affected. The slowing becomes perceptible only by comparison with a frame in which the energetic state of the medium, and in particular the aether flux, is different.

5.4 Acceleration of matter and induced flux of the energetic medium

Physical status of the vector potential $\vec{A}$. The vector potential $\vec{A}$ does not represent an autonomous physical flux. It constitutes an auxiliary field introduced to parametrise the effective dynamics of the energetic medium and capture its electromagnetic effects. It has no independent existence: it serves as a representation variable for the aether flux.

The physically relevant quantity is the local velocity of the energetic flux:

$$\vec{v}_{\text{ether}} = \frac{\rho_e}{\rho_m}(\vec{A} - \vec{A}_0) \tag{106}$$

This relation defines the structural dictionary of the model. The real flux of the medium is associated with the dynamic component of $\vec{A}$ relative to the background state $\vec{A}_0$.

Uniformly moving charge and stationary regime. Consider a charge q moving at uniform velocity $\vec{u}$ relative to the frame co-moving with the aether.

It defines a volumetric current:

$$\vec{J} = \rho_q \vec{u} \tag{107}$$

In the stationary regime, the vector potential satisfies:

$$-\nabla^2 \vec{A} = \mu_0 \vec{J} \tag{108}$$

For a point charge, the solution is:

$$\vec{A}(\vec{r}) = \frac{\mu_0 q}{4\pi} \frac{\vec{u}}{r} \tag{109}$$

The associated energetic flux reads:

$$\vec{v}_{\text{ether}}(\vec{r}) = \frac{\rho_e}{\rho_m} \left(\frac{\mu_0 q}{4\pi} \frac{\vec{u}}{r} - \vec{A}_0 \right) \tag{110}$$

The term $\vec{A}_0$ represents the background kinematic state of the medium. If one chooses a frame co-moving with the unperturbed aether, one can locally set $\vec{A}_0 = 0$. In a constrained non-co-moving frame, however, $\vec{A}_0$ encodes precisely the kinematic discrepancy between the observer and the background energetic flux.

In the frame co-moving with the aether, the energetic flux associated with a point charge is then written:

$$\vec{v}_{\text{ether}}(\vec{r}) = \frac{\rho_e}{\rho_m} \frac{\mu_0 q}{4\pi} \frac{\vec{u}}{r} \tag{111}$$

Identifying the inertial coupling constant ρ_m with μ_0, the expression simplifies to:

$$\boxed{\vec{v}_{\text{ether}}(\vec{r}) = \frac{\rho_e q}{4\pi} \frac{\vec{u}}{r}} \tag{112}$$

The energetic flux is then directly proportional to the charge and the velocity.

This flux field constitutes the kinematic contribution associated with the electromagnetic mass. Inertia then appears as the kinetic energy distributed in the field $\vec{v}_{\text{ether}}$. Any variation of the velocity $\vec{u}$ implies a reorganisation of this spatially extended flux, which manifests as an inertial resistance.

It is observed that the flux depends explicitly on the sign of the charge q as well as on the sign of the coupling constant ρ_e. The effective orientation of the flux relative to $\vec{u}$ is therefore not determined a priori. It remains to establish whether a positive charge generates a flux oriented in the same direction as $\vec{u}$ or, on the contrary, an opposing flux.

Finally, this expression is valid down to the internal cut-off radius r_c. This radius bounds the $1/r$ divergence and allows a finite inertial contribution to be obtained. It defines the limit from which the electromagnetic mass can be conceptually dissociated from the point charge. Below r_c, the internal structure of the particle must be taken into account.

5.5 Interpretations of the inertial mechanism

Dynamic equilibrium and absence of force in uniform motion. When one considers a charge animated by constant velocity, the energetic medium surrounding it is not in an arbitrary state. It adopts a particular configuration, compatible with this uniform motion.

The stationary flux associated with this situation then corresponds to a stable dynamic configuration, as long as the velocity of the charge remains constant. In this regime, the energetic medium has had time to organise itself coherently around the charged structure. No additional force is required to maintain the uniform motion: the state of the flux and the kinematic state of the charge are mutually compatible.

The absence of force in uniform motion is therefore not a fundamental principle, but the direct consequence of a state of dynamic equilibrium between matter and the medium.

Acceleration and appearance of the inertial term. The situation changes radically when the charge is accelerated. The velocity $\vec{u}$ then becomes a function of time, which implies a temporal variation of the vector potential. The electric field then has a dynamic contribution:

$$\vec{E}_{\text{dyn}} = -\frac{\partial \vec{A}}{\partial t} \tag{113}$$

This term is not an additional electric field of a distinct nature. It expresses the constraint imposed on the energetic medium when the flux it supports must be accelerated.

Using the identification between the vector potential $\vec{A}$ and the velocity of the energetic flux $\vec{v}_{\text{ether}}$, this dynamic contribution directly corresponds to the effort required to impose an acceleration on the energetic medium organised around the charge.

Physical origin of inertia. Accelerating a charge therefore does not amount to accelerating an abstract point, but to accelerating an extended configuration of energy carried by the medium. This configuration possesses its own inertia, linked to the finite propagation of interactions and to the energy density concentrated in the vicinity of the cut-off radius.

When a material structure is accelerated relative to the frame co-moving with the energetic medium, the electromagnetic energy associated with its constituents cannot reorganise itself instantaneously. The near field, highly concentrated, represents the bulk of this energy and dominates the inertial response.

Induced flux and reaction of the medium. The acceleration of matter therefore imposes a forced acceleration of the local energetic flux. The medium, constrained to rapidly modify its kinematic state, opposes a resistance to this variation. This reaction of the medium constitutes the inertial force.

In other words, when matter accelerates, it tends to "enter" into regions of its own aether field whose configuration is no longer instantaneously adjusted to its new kinematic state. A discrepancy then appears between the material structure (the singularity) and the dynamics of the surrounding flux: this disagreement generates a counter-reaction that opposes the change of velocity.

Synthesis on inertia. Within the framework of the energetic medium, the inertia of matter is not an intrinsic property attached to a fundamental substance called mass. It emerges from the dynamic interaction between the charged constituents of matter and the energetic medium that supports, transports, and redistributes electromagnetic fields.

Inertial mass measures the dynamic cost imposed on the medium when it is constrained to modify the state of energetic configurations organised around charges. Accelerating a material object amounts to accelerating an extended set of fields, polarisations, and energetic fluxes, whose reorganisation is limited by the finite propagation of interactions in the medium.

An essential point is that, although the electromagnetic contribution to inertia is linked to charges, it depends decisively on the cut-off radius or effective confinement radius of the field energy. This radius characterises the scale at which the electromagnetic energy ceases to follow the Coulomb law and becomes bound to a given structure. It constitutes the fundamental parameter that distinguishes particles carrying a charge of equal magnitude but exhibiting very different inertial masses. For equal charge, more tightly confined energy imposes much greater inertia on the energetic medium.

This reading allows one to understand why inertia does not disappear when matter is globally electrically neutral. In a bound system, such as a hydrogen atom consisting of a proton and an electron, the distant fields cancel, but the bulk of the electromagnetic energy remains concentrated in the vicinity of the cut-off radii associated with each constituent. Electrical neutrality suppresses the field at large distances, but does not cancel the locally confined energy responsible for inertia.

There is, however, a real decrease in the total mass of a bound system compared to the sum of the masses of the isolated constituents. This mass defect corresponds to the electromagnetic binding energy. Within the framework of the energetic medium, it is interpreted as a reduction in the total energy stored in the medium, linked to a more limited spatial extent of the fields and a more compact reorganisation of the energetic fluxes.

Matter as a singularity of the energetic medium. Matter thus appears as a stable organisation of energy within the energetic medium. Matter is not an "object" deposited in a fluid from outside: it constitutes a singularity of the energetic medium itself. If a massive particle corresponds to a structure of this substrate, then gravitation no longer appears as an attraction at a distance, but as the direct effect of the internal dynamics of the medium.

6 Gravitation: A Dynamics of Aether Flux

6.1 Principle of dynamic reciprocity between inertia and gravitation

This point is fundamental to what follows. If the acceleration of matter imposes an acceleration of the energetic flux of the medium, then, reciprocally, an accelerated energetic flux necessarily imposes a dynamic constraint on the matter immersed in it.

This dynamic reciprocity establishes a direct conceptual link between inertia and gravitation. Inertia corresponds to the resistance of the energetic medium when a material structure imposes an acceleration on it. Gravitation corresponds to the resistance of the material structure when it is traversed by an accelerated energetic flux that it cannot freely follow.

These two effects therefore do not constitute independent interactions, but two complementary manifestations of the same conservative dynamics of the energetic medium. This principle provides the physical foundation for the interpretation of gravitation as the effect of an accelerated flux of the medium imposed by a massive structure.

6.2 The equivalence principle reinterpreted

The acceleration of matter towards a centre of mass does not correspond to the action of an external force applied at a distance. It results from the fact that matter is subject to the local dynamics of the aether when the latter converges and accelerates.

The fall of a body thus reflects the fact that its structure is not constrained to oppose the acceleration of the local energetic flux. It then naturally adopts an accelerated dynamics similar to that of the medium, without this situation necessarily implying strict co-mobility in velocity at every instant.

Galileo's equivalence principle is then illuminated in a direct manner. If all bodies fall with the same acceleration, it is not because they experience a force proportional to their mass, but because the acceleration of the energetic flux is independent of the material structure of the objects it traverses. The universality of free fall thus follows from the universality of the dynamics of the energetic medium.

6.3 Weight as resistance to an accelerated aether flux

Conservation of energetic flux through spherical surfaces. A stationary regime is considered in which the total energetic output $\mathcal{P}$ crossing any spherical surface surrounding the gravitational source is conserved. This output is defined as the integral of the energy flux through the surface:

$$\mathcal{P} = \int \vec{S} \cdot d\vec{A} = 4\pi R^2 \, S_r(R) \tag{114}$$

where $S_r(R)$ denotes the radial component of the energy flux per unit area through a sphere of radius R.

The conservation of $\mathcal{P}$ then implies a geometric decay of the surface energy flux:

$$S_r(R) \propto \frac{1}{R^2} \tag{115}$$

This law concerns the energy flux per unit area and does not bear on the velocity of the energetic flux. At the local scale of the medium, the surface flux can be written in kinematic form:

$$S_r(R) = \epsilon(R)\, v(R) \tag{116}$$

where $\epsilon(R)$ is the volumetric energy density transported by the medium and $v(R)$ the local velocity of the energetic flux. Conservation of the output then only imposes a constraint on their product:

$$\epsilon(R)\, v(R) \propto \frac{1}{R^2}, \tag{117}$$

the individual dependence of $\epsilon(R)$ and $v(R)$ being fixed by the dynamics of the medium.

Redefinition of weight in an "aether flux" framework. In this perspective, weight is no longer understood as a mysterious force acting at a distance, but as the manifestation of a constraint imposed on a material structure immersed in an accelerated energetic flux:

- **In free fall:** the object experiences no constraint that forces it to oppose the acceleration of the local aether flux. Its structure adopts the same accelerated dynamics as the medium. This state corresponds to weightlessness; strict co-mobility with the flux is only a particular case.
- **At rest on the ground:** the object is prevented from following this convergence dynamics. The support imposes a constraint that maintains the structure in a kinematic state different from that of the accelerated energetic flux. Weight then corresponds to the reaction force necessary to maintain this constraint.

Thus, weight measures the resistance of the material structure when it is constrained not to follow the natural acceleration of the aether flux that traverses it.

Gravitational acceleration and flux velocity. If matter and aether share the same energetic dynamics, the local acceleration of the flux must correspond to the gravitational acceleration g. In order to maintain this acceleration coherently from infinity down to a distance r from a mass M, the flux must acquire a radial velocity.

A Newtonian radial gravitational field created by a mass M is assumed:

$$a(r) = -\frac{GM}{r^2} \tag{118}$$

where the minus sign indicates acceleration directed towards the centre. For purely radial motion, the acceleration is related to the variation of velocity with position by:

$$a(r) = \frac{dv}{dt} = \frac{dv}{dr}\frac{dr}{dt} = v(r)\,\frac{dv}{dr} \tag{119}$$

One then obtains the differential equation:

$$v(r)\,dv = -\,GM\,\frac{dr}{r^2} \tag{120}$$

Imposing the boundary condition "from infinity" $v(\infty) = 0$ and integrating from $r = \infty$ to $r = R$, one finds:

$$\int_0^{v(R)} v\,dv = -\,GM \int_\infty^R \frac{dr}{r^2} \tag{121}$$

The left-hand side equals $\frac{1}{2}v(R)^2$, and the right-hand side evaluates to:

$$-\,GM \int_\infty^R \frac{dr}{r^2} = \frac{GM}{R} \tag{122}$$

Thus

$$\frac{1}{2}v(R)^2 = \frac{GM}{R} \tag{123}$$

One then obtains for the radial velocity of the aether flux at the surface of a body of radius R and mass M:

$$\boxed{v_{\text{ether}} = \sqrt{\frac{2GM}{R}}} \tag{124}$$

This is precisely the escape velocity. One deduces that an observer held stationary at the surface of a body is traversed by a converging radial flux whose velocity equals the escape velocity of the body in question. Unlike historical models that postulated a horizontal aether wind associated with orbital motion, the relevant flux here is vertical, radial, and directed towards the centre of gravity of the body.

Gravity as acceleration of flux, not mere velocity. In this scheme, gravitation does not result from the mere value of the aether flux velocity, but from its local acceleration. Matter is not a massive obstacle opposed to a current, but a singular structure of the medium itself. It therefore does not experience a kinematic pressure proportional to v, but a dynamic constraint linked to the spatial and temporal variation of the flux.

A more massive body does not merely impose a faster flux. It induces above all a more intense acceleration of the energetic medium, which manifests macroscopically as a stronger gravitational pull.

Characteristic figures: Earth and Sun. This interpretation leads to a radial aether flux whose velocity equals the escape velocity:

- **Earth:** $v_{\text{ether}} \simeq 11.2\ \text{km}\,\text{s}^{-1}$ at the surface.
- **Sun:** $v_{\text{ether}} \simeq 617.5\ \text{km}\,\text{s}^{-1}$ at the surface.

The stronger solar gravity is therefore not the effect of a "fast current" per se, but the expression of a significantly higher acceleration of the aether flux in the layers close to the body.

Link with gravitational time dilation. Substituting this flux velocity v_{ether} into the time dilation formula associated with a velocity u:

$$\Delta t' = \Delta t \sqrt{1 - \frac{u^2}{c^2}} \tag{125}$$

one immediately obtains:

$$\boxed{\Delta t' = \Delta t \sqrt{1 - \frac{2GM}{rc^2}}} \tag{126}$$

One thus recovers exactly the usual form of gravitational time dilation, as classically obtained in general relativity in the weak-field approximation. The difference lies not in the final expression, but in its physical interpretation. In this reading, a body held stationary at the surface of a body sees its time slowed because it is traversed by a radial aether flux whose velocity is that of escape, for example 11.2 $\text{km}\,\text{s}^{-1}$ at the surface of the Earth.

6.4 Adding a gravitational potential to the dynamic equation

Starting from the momentum equation of the energetic flux of the aether, written in Eulerian description and introduced in Section 2. The convective term is retained here, as it is indispensable for relating a non-uniform stationary flow to the existence of a gravitational potential:

$$\rho_m \left(\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla)\vec{v} \right) = -\nabla P - \rho_e \vec{E} \tag{127}$$

In this writing, ρ_m denotes the inertial coupling density of the energetic medium, P the energetic pressure associated with the longitudinal stresses of the flux, and $\vec{v}$ the local velocity of transport and redistribution of energy in the medium.

Gravitation as a conservative interaction with the energetic medium. Gravitation is introduced as a conservative interaction acting directly on the energetic medium. It is described by a scalar potential Φ, whose gradient represents a volumetric force exerted on the inertial coupling density ρ_m of the flux. The equation of motion then becomes:

$$\boxed{\rho_m \left(\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla)\vec{v} \right) = -\nabla P - \rho_e \vec{E} - \rho_m \nabla \Phi} \tag{128}$$

The gravitational potential Φ is related to the material mass density ρ_M by Poisson's equation:

$$\boxed{\nabla^2\Phi = 4\pi G\,\rho_M} \tag{129}$$

Within this framework, gravitation is neither a geometry of space nor a kinematic correction, but a local interaction between matter and the carrier energetic medium, formalised by a conservative potential.

6.5 Stationary gravitational flow and aether flux velocity

A stationary, uncharged regime is now considered, characterised by:

$$\frac{\partial \vec{v}}{\partial t} = 0, \qquad \rho_e \vec{E} = 0. \tag{130}$$

Equation (128) then reduces to:

$$\rho_m(\vec{v}\cdot\nabla)\vec{v} = -\nabla P - \rho_m \nabla\Phi \tag{131}$$

Using the classical vector identity:

$$(\vec{v}\cdot\nabla)\vec{v} = \nabla\left(\frac{v^2}{2}\right) - \vec{v}\times(\nabla\times\vec{v}) \tag{132}$$

Outside material singularities, that is, outside gravitational sources, the minimal hypothesis of an irrotational gravitational flow of the energetic flux is adopted:

$$\nabla\times\vec{v} = 0 \tag{133}$$

The equation of motion then rewrites as:

$$\nabla\left(\frac{v^2}{2} + \frac{P}{\rho_m} + \Phi\right) = 0 \tag{134}$$

leading to a Bernoulli-type relation for the energetic medium:

$$\boxed{\frac{v^2}{2} + \frac{P}{\rho_m} + \Phi = \text{const}} \tag{135}$$

Imposing the natural boundary conditions $v(\infty) = 0$, $\Phi(\infty) = 0$, and $P(\infty) = P_\infty$, one obtains:

$$\frac{v^2}{2} + \frac{P - P_\infty}{\rho_m} + \Phi = 0 \tag{136}$$

In the weak-field regime, the dynamic pressure contribution can be absorbed into the effective pressure or neglected compared to the gravitational potential. One then obtains the central relation linking the velocity of the energetic flux to the potential:

$$\boxed{\frac{v^2}{2} \simeq -\Phi} \tag{137}$$

Outside an isolated spherical mass, where $\rho_M = 0$, the solution to equation (129) satisfying the condition $\Phi(\infty) = 0$ is:

$$\Phi(r) = -\frac{GM}{r} \tag{138}$$

where r denotes the radial distance between the point under consideration and the centre of the spherical mass distribution M.

Substituting this expression into (137), one directly obtains:

$$\boxed{v(r) = \sqrt{\frac{2GM}{r}}} \tag{139}$$

One recovers the expression for the aether flux velocity associated with the gravitational field outside an isolated mass. This result is not posited as an a priori kinematic condition, but appears as a direct consequence of the dynamics of an energetic medium subject to a conservative potential. The underlying interpretation is that matter tends naturally to follow the same dynamics as the aether that constitutes it, as a particular and constrained form of this medium. Gravitation then manifests when this common dynamics is locally prevented, and not as an external interaction acting at a distance.

6.6 Free fall and co-mobility with the aether flux

Kinematic origin of time dilation. Within this framework, time dilation is not an intrinsic property of gravitation, but a kinematic consequence of the relative motion of a material structure with respect to the local energetic flux of the aether. The slowing of time appears when the internal processes of a system are traversed by an energetic flux with which they are not co-mobile.

Co-mobility with the aether and cancellation of time dilation. When an object becomes locally co-mobile with the aether flux, there is no longer any relative velocity between its internal structure and the surrounding energetic medium. In this situation, no dynamic constraint linked to the flux acts on the internal processes, and time dilation vanishes. The proper time of the object then coincides with that defined by the local energetic medium. This proper time of the medium corresponds to the regime in which physical processes execute without slowing, at the fastest rate permitted by the local dynamics of the energetic medium.

Free fall and co-mobility: a non-equivalent condition. Free fall corresponds to the dynamic alignment of an object with the acceleration of the aether flux, but it does not necessarily imply co-mobility with the local flux. An object in free fall that retains a non-zero relative velocity with respect to this flux still experiences a residual temporal slowing. The complete cancellation of time dilation therefore requires kinematic co-mobility with the aether, and not the mere state of free fall.

Conceptual difference from the relativistic interpretation. This interpretation differs fundamentally from that of general relativity, in which free fall suffices to define a locally inertial frame free of gravitational dilation. Here, it is the state of kinematic rest relative to the energetic aether flux that defines the absence of time dilation, and not the sole geodesic trajectory.

6.7 Anisotropy of the speed of light

Conditional isotropy in the co-moving frame. The speed of light is isotropic only in the local frame co-moving with the energetic aether flux. As long as the observer and their instruments share the local kinematic state of the medium, light propagation is measured as isotropic, at the local value c. This isotropy therefore does not constitute an absolute property of light, but a property relative to the kinematic state of the energetic medium.

Energetic origin of anisotropy outside co-mobility. As soon as an observer is no longer co-mobile with the aether — for example, when they are held stationary in an accelerated aether flux as at the surface of a body — the propagation of light becomes directionally asymmetric. This anisotropy does not arise from an intrinsic modification of light, but from the fact that the energetic medium in which it propagates is itself in motion and accelerated.

Conditional local invariance and the role of co-mobility. The local invariance of the speed of light is therefore guaranteed only in the local frame that is co-mobile with the aether. In frames constrained to a non-co-mobile state, anisotropy becomes in principle observable, with the effective velocity depending on the component of the flux along the direction of propagation of the wave. Free fall is not a sufficient condition in itself; it is only relevant insofar as it can lead, or not, to co-mobility with the local energetic flux. What is decisive is co-mobility, and not the sole status of "free fall".

Kinematic composition of velocities in an energetic flux. Since the aether flows towards the centre of mass of the body at an aether flux velocity v_{ether}, the speed of light measured by a distant observer results from the composition between the proper propagation of the wave in the medium and the velocity of the energetic flux:

1. **Light received by the body (in the direction of the flux).**

   The light signal propagates in the same direction as the aether flux. Velocities add. For the body, light arrives more rapidly, carried by the energetic current:

$$v_{\text{received}} = c + v_{\text{ether}} \tag{140}$$

2. **Light emitted by the body (against the flux).**

   To escape, light must travel against the converging aether flux towards the mass. It therefore progresses against the current, which slows its effective outward velocity:

$$v_{\text{emitted}} = c - v_{\text{ether}} \tag{141}$$

Propagation asymmetry and light confinement. This propagation anisotropy induces two major effects, consistent with the energetic interpretation of the gravitational field:

- **Propagation delay or advance.** The effective slowing of the light wave escaping from the body, as it climbs against the aether flux, increases its travel time towards a distant observer. Conversely, when it propagates in the direction of the aether flux, the effective velocity may be increased, resulting in a shorter travel time and thus a propagation advance.
- **Light confinement threshold.** When the aether flux velocity v_{ether} reaches the propagation velocity c, light can no longer progress outward. The body then becomes invisible to a distant observer. Within this framework, the darkness of an extremely massive body does not result from a geometric curvature of space, but from total hydrodynamic confinement: light is carried inward by the energetic flux.

6.8 Michelson–Morley-type experiments

Standard interpretation and conceptual limit. The absence of detection of absolute motion in classical interferometric experiments, in particular the Michelson–Morley experiment, is generally interpreted as experimental evidence for the non-existence of a privileged medium of propagation of light. Within the framework of the present model, this conclusion does not follow directly from the observations. It results from the kinematic and geometric properties of the experimental devices used, as well as from the symmetries they impose on the propagation of light energy in the medium.

Geometric symmetry of interferometers and cancellation of first-order effects. Michelson–Morley-type, Hoek, or Fizeau experiments are based on the comparison of travel times between two light beams traversing opposite paths before recombination. This geometric symmetry has a decisive consequence: any linear contribution in v/c associated with a uniform motion of the device relative to the energetic medium cancels automatically. The travel time variations induced by the flux appear with opposite signs on the two arms of the interferometer and compensate exactly upon recombination.

This cancellation does not constitute an intrinsic property of light propagation, but results directly from the experimental protocol itself. Classical interferometric setups are designed in such a way as to neutralise any kinematic signature of a global uniform motion of the system relative to the medium. They can therefore only be sensitive to second-order effects, proportional to $(v/c)^2$.

Role of length contraction. Even these second-order contributions do not lead to a measurable signal in Michelson-type devices. Indeed, the kinematic contraction of the lengths of the interferometer arms, aligned with the direction of relative motion to the energetic medium, introduces a geometric correction that exactly compensates the expected travel time difference at order $(v/c)^2$. The second-order effect thus becomes experimentally undetectable, not because of a physical absence of the phenomenon, but because the dynamics of light propagation and the geometric transformation of the device's lengths produce a complete cancellation of the expected signal.

Undetectability in Michelson-type setups and conditions for a break. The absence of detection in Michelson–Morley-type experiments should therefore not be interpreted as a general physical impossibility, but as a specific property of this class of devices. As soon as one departs from this geometry — for example, by means of one-way interferometry setups with the introduction of a refracting medium, or by a global rotation of the system — linear effects linked to the energetic aether flux can in principle become observable. The Sagnac effect illustrates precisely the fact that a non-inertial motion, breaking the symmetry of light paths, makes it possible to reveal a propagation anisotropy that Michelson-type setups neutralise by construction.

For reference, my document entitled *When light exposes the reality we do not see* explores the experimental conditions allowing the detection of an anisotropy in the propagation of light.

6.9 The horizon of a black hole

Understanding what occurs beyond the critical limit $v_{\text{ether}} = c$ amounts to analysing the regime in which the dynamics of the energetic medium changes in nature. When $v_{\text{ether}} > c$, the radial energetic flux of the aether towards the centre of mass becomes faster than the propagation velocity of transverse perturbations within the medium itself. In other words, the energy of the medium converges inward faster than perturbations can propagate outward through this flux.

Horizon as a critical energetic surface. The horizon is defined as the spherical surface $r = r_h$ such that

$$v_{\text{ether}}(r_h) = c \tag{142}$$

Within this framework, it is not a "geometric boundary" but a dynamic boundary of the energetic flux: at the horizon, the radial velocity of the energetic flux reaches exactly the propagation velocity of perturbations in the medium, cancelling any outward propagation capacity.

Calculation of the horizon radius. One has the expression for the gravitational energetic flux:

$$v_{\text{ether}}(r) = \sqrt{\frac{2GM}{r}} \tag{143}$$

This expression describes the local velocity of the radial energetic flux induced by the presence of the mass M.

The horizon is defined by the critical condition $v_{\text{ether}}(r_h) = c$.

One then obtains directly:

$$\sqrt{\frac{2GM}{r_h}} = c \quad \Longrightarrow \quad \frac{2GM}{r_h} = c^2 \quad \Longrightarrow \quad r_h = \frac{2GM}{c^2} \tag{144}$$

Thus, the horizon radius is:

$$\boxed{r_h = \frac{2GM}{c^2}} \tag{145}$$

that is, the radius at which the velocity of the energetic flux reaches exactly the propagation velocity of electromagnetic perturbations in the aether.

Effective propagation velocity in an energetic flux. If an electromagnetic perturbation propagates locally at velocity c in the frame co-moving with the energetic flux, then, in an Eulerian description (distant observer), the effective radial component combines with the flux. For a propagation radius making an angle θ with the outward radial direction, one can write, at the energetic kinematic level:

$$v_r^{(\mathrm{eff})}(r,\theta) = c\cos\theta - v_{\mathrm{ether}}(r) \tag{146}$$

This point is crucial: even if the perturbation is "directed" outward ($\cos\theta > 0$), the converging energetic flux may dominate its radial progression.

- **Above the horizon** ($v_{\mathrm{ether}} < c$): there exist directions (θ sufficiently close to 0) for which $v_r^{(\mathrm{eff})} > 0$. A perturbation can therefore escape by climbing against the energetic flux.
- **At the horizon** ($v_{\mathrm{ether}} = c$): for an outward radial direction ($\theta = 0$), one obtains $v_r^{(\mathrm{eff})} = 0$. The perturbation "propagates" in the medium, but no longer gains any radial distance with respect to the exterior: it remains "suspended" at the edge.
- **Below the horizon** ($v_{\mathrm{ether}} > c$): for every direction, one has $c\cos\theta \le c < v_{\mathrm{ether}}$, hence

  $$v_r^{(\mathrm{eff})}(r,\theta) < 0 \qquad \forall\theta \tag{147}$$

  Every perturbation is carried inward by the energetic flux: radial escape is dynamically impossible.

Total energetic drag and external "silence". Below the horizon, one should not say that light "goes out": the electromagnetic perturbation exists locally and propagates at velocity c in the medium, but its dynamics is dominated by the converging energetic flux. The effective propagation vector, in the sense of the radial evolution measured from afar, is reversed: every wavefront is carried towards smaller radii r by the energetic convergence. For the external observer, this creates a region of causal silence: no information (wave, modulation, signal) can cross the critical surface in the outward direction, not by lack of emission, but because the energetic flux imposes a net inward convergence.

Conservation of energy and accumulation at the horizon. A natural consequence of this reading is that the energy of perturbations attempting to climb against the flux accumulates in the vicinity of the horizon. More precisely, as one approaches the horizon from the outside, the available outward radial component $c - v_{\mathrm{ether}}(r)$ becomes very small. This results in a rapid increase in the time required for a perturbation to gain a given radial distance, and hence a locally increased energy density in this region: the energy of outgoing waves "stretches" and concentrates in the vicinity of r_h.

In other words, the horizon behaves like an energetic saddle zone: the closer one approaches it, the more the capacity to climb tends to zero, and the more perturbations see their progression slowed until they come to a radial standstill.

Analogy with the acoustic horizon. The most direct analogy is that of a sonic black hole horizon. In a fluid flowing towards a drain, sound propagates at velocity c_s in the fluid, but the fluid itself is in motion. There exists a surface where the flow velocity equals c_s: beyond it, sound perturbations can no longer travel upstream.

Here, c plays the role of the propagation velocity of electromagnetic perturbations in the energetic medium, and v_{ether} that of the velocity of the converging energetic flux. The essential difference is that, in the case of the aether, it is not a material flow but an energetic flux: what converges towards the centre is the energy of the medium itself, not a carrier fluid.

The black hole as a critical energetic flux node. In this perspective, a black hole corresponds to a region in which the radial convergence of the medium's energy towards the singularity exceeds the propagation capacity of perturbations within that medium. The horizon is not a mystical entity, but a dynamic condition of type $v_{\text{ether}}(r) = c$, that is, the location where the dynamics of the energetic flux takes over from any possible outward propagation.

It is however essential to emphasise the highly speculative nature of the extrapolation of the model into this regime. Nothing guarantees that the energetic medium preserves its coupling constants when the dynamic stresses become extreme. It is possible that the effective parameters of the medium, such as ρ_m and ρ_e, do not remain invariant.

Under such high pressure gradients and flux velocities, the energetic medium could undergo a phase change, see its constitutive properties modified, or exhibit strong non-linearities altering the relations established in the weak-field regime. The condition $v_{\text{ether}} = c$ would then mark not only a kinematic threshold, but potentially a regime transition in which the very structure of the energetic medium reconfigures itself.

6.10 The gravitational lensing effect

The deflection of a light ray by a mass constitutes one of the most striking phenomena of gravitation. Long considered as a simple interaction acting exclusively on material bodies, gravitation proved capable of influencing the propagation of light as well.

In the 18th century, within the Newtonian framework, light could be envisaged as a corpuscle susceptible to deflection by the gravitational attraction of a massive body. This approach led to a first estimate of the effect by treating the light ray as a particle moving at finite velocity.

At the beginning of the 20th century, general relativity renewed the interpretation of the phenomenon. The deflection is attributed there to a geometric modification of propagation. The observation carried out during the solar eclipse of 1919 quantitatively confirmed this prediction.

Within the framework of the energetic medium, the question is reformulated differently. Light is neither a corpuscle subject to a central force, nor an entity following a geodesic of a curved space. It is an electromagnetic perturbation propagating at velocity c in the local frame co-moving with a continuous energetic medium.

Gravitation is modelled as a stationary radial energetic flux induced by a mass M, characterised by a local velocity $\vec{v}_{\text{ether}}(r)$ directed towards the centre, satisfying:

$$v_{\text{ether}}^2(r) = \frac{2GM}{r} \tag{148}$$

A light ray therefore evolves in a medium animated by a non-uniform flux. The deflection results from the interaction between the electromagnetic perturbation and this radial flux.

Two effects are distinguished:

- a kinematic effect of local non-co-mobility
- a dynamic effect linked to the radial acceleration of the flux

We seek the total deflection α for a ray passing at a minimum distance R. The unperturbed trajectory is parametrised by:

$$r(x) = \sqrt{x^2 + R^2} \tag{149}$$

We work to first order in the weak field and for small angles $\tan\alpha \simeq \alpha$.

First contribution: Local non-co-mobility affecting the effective propagation velocity. The propagation velocity c of an electromagnetic wave is defined locally with respect to the energetic medium in which it propagates.

When this medium is animated by a radial gravitational flux, the propagation conditions are no longer isotropic: the effective velocity then depends on the orientation of the ray relative to the direction of the flux.

The action of the flux thus introduces a quadratic correction proportional to v_{ether}^2, whose amplitude depends on the angle between the direction of the ray and the radial direction.

Let θ be the angle between the direction of the ray (assumed quasi-parallel to the x axis) and the radial direction.

For an impact trajectory R, one has:

$$r = \sqrt{x^2 + R^2} \tag{150}$$

The geometry then gives:

$$\sin\theta = \frac{R}{r} \qquad \cos\theta = \frac{x}{r} \tag{151}$$

The component of the flux transverse to the propagation equals $v_{\text{ether}} \sin\theta$.

The quadratic correction to the effective velocity is therefore:

$$c_{\text{eff}}^2 = c^2 + (v_{\text{ether}} \sin\theta)^2 \tag{152}$$

Using $\sin\theta = R/r$, one obtains:

$$\sin^2\theta = \frac{R^2}{r^2} \tag{153}$$

Hence

$$\boxed{c_{\text{eff}}^2 = c^2 + v_{\text{ether}}^2 \frac{R^2}{r^2}} \tag{154}$$

For $v_{\text{ether}}^2 \ll c^2$, one obtains:

$$c_{\text{eff}} = c\sqrt{1 + \frac{v_{\text{ether}}^2}{c^2}\frac{R^2}{r^2}} \simeq c\left(1 + \frac{1}{2}\frac{v_{\text{ether}}^2}{c^2}\frac{R^2}{r^2}\right) \tag{155}$$

The effective refractive index of the energetic medium is defined as the ratio between the propagation velocity in an unperturbed medium and the local effective velocity:

$$n(r) = \frac{c}{c_{\text{eff}}(r)} \tag{156}$$

One obtains, to first order in $\frac{v_{\text{ether}}^2}{c^2}$:

$$n(r) \simeq 1 - \frac{1}{2}\frac{v_{\text{ether}}^2}{c^2}\frac{R^2}{r^2} \tag{157}$$

Substituting $v_{\text{ether}}^2 = 2GM/r$:

$$n(r) - 1 \simeq -\frac{GM}{c^2}\frac{R^2}{r^3} \tag{158}$$

The deflection of a ray in a medium of non-uniform index is determined by the transverse gradient of the effective index.

In the small-angle approximation and for a quasi-rectilinear trajectory, the elementary angular variation satisfies:

$$\frac{d\theta}{dx} = \frac{\partial n}{\partial y} \tag{159}$$

where y denotes the direction transverse to propagation.

In the geometry considered, the transverse coordinate along the unperturbed trajectory is precisely the impact parameter R. One can therefore identify:

$$\frac{\partial}{\partial y} = \frac{\partial}{\partial R} \tag{160}$$

The total deflection is then written:

$$\alpha_1 = \int_{-\infty}^{+\infty} \frac{\partial}{\partial R}\big(n(r) - 1\big)\, dx \tag{161}$$

One computes:

$$\frac{\partial}{\partial R}\left(\frac{R^2}{r^3}\right) = \frac{2R}{r^3} - \frac{3R^3}{r^5} \tag{162}$$

Hence

$$\alpha_1 = -\frac{GM}{c^2}\int_{-\infty}^{+\infty}\left(\frac{2R}{r^3} - \frac{3R^3}{r^5}\right)dx \tag{163}$$

Using:

$$\int_{-\infty}^{+\infty}\frac{dx}{(x^2+R^2)^{3/2}} = \frac{2}{R^2} \tag{164}$$

$$\int_{-\infty}^{+\infty}\frac{dx}{(x^2+R^2)^{5/2}} = \frac{4}{3R^4} \tag{165}$$

Integration then gives:

$$\alpha_1 = -\frac{GM}{c^2}\left(2R\frac{2}{R^2} - 3R^3\frac{4}{3R^4}\right) \tag{166}$$

To first order in the weak field, one obtains:

$$\boxed{\alpha_1 = \frac{2GM}{Rc^2}} \tag{167}$$

The local non-co-mobility between electromagnetic propagation and the radial gravitational flux induces a quadratic anisotropy of the effective velocity.

This anisotropy manifests as the appearance of a transverse gradient of the effective refractive index proportional to GM/r. Integration of this gradient along a quasi-rectilinear trajectory leads to a finite angular deflection.

This contribution arises exclusively from a kinematic effect: it results from the local modification of the propagation conditions of an electromagnetic perturbation evolving in a medium carrying an energetic flux.

Second contribution: The acceleration of the energetic medium inducing a transverse component. The radial flux $v_{\text{ether}}(r)$ is not uniform. It is therefore associated with a radial acceleration of the medium, given by the convective derivative along the flux:

$$a_r = \frac{dv_{\text{ether}}}{dt} = v_{\text{ether}}\frac{dv_{\text{ether}}}{dr} \tag{168}$$

With the gravitational flux law:

$$v_{\text{ether}}^2 = \frac{2GM}{r} \tag{169}$$

one obtains:

$$v_{\text{ether}} \frac{dv_{\text{ether}}}{dr} = \frac{1}{2}\frac{d}{dr}\left(v_{\text{ether}}^2\right) = \frac{1}{2}\frac{d}{dr}\left(\frac{2GM}{r}\right) = -\frac{GM}{r^2} \tag{170}$$

Hence

$$a_r = -\frac{GM}{r^2} \tag{171}$$

For a ray passing at minimum distance R, the transverse component of this acceleration equals, in the quasi-rectilinear trajectory approximation:

$$a_\perp = a_r \sin\theta = a_r \frac{R}{r} = -\frac{GM}{r^2}\frac{R}{r} = -\frac{GMR}{r^3} \tag{172}$$

The elementary angular variation is related to the transverse acceleration by:

$$d\theta \simeq \frac{dv_\perp}{c} \simeq \frac{a_\perp\, dt}{c} \simeq \frac{a_\perp}{c}\frac{dx}{c} = \frac{a_\perp}{c^2} dx \tag{173}$$

The deflection is therefore:

$$\alpha_2 = \int_{-\infty}^{+\infty} \left|\frac{d\theta}{dx}\right| dx = \int_{-\infty}^{+\infty} \frac{GMR}{c^2 r^3}\, dx \tag{174}$$

Using $r = \sqrt{x^2 + R^2}$:

$$\int_{-\infty}^{+\infty} \frac{dx}{(x^2 + R^2)^{3/2}} = \frac{2}{R^2} \tag{175}$$

Integration of this action along the trajectory leads to a deflection:

$$\alpha_2 = \frac{GMR}{c^2}\frac{2}{R^2} \tag{176}$$

To first order in the weak field, one obtains:

$$\boxed{\alpha_2 = \frac{2GM}{Rc^2}} \tag{177}$$

The radial acceleration of the energetic flux induces a transverse component that acts progressively on the direction of propagation of the light ray.

This contribution is inertial in nature: it results from the non-uniform character of the gravitational flux itself and not from a local modification of the propagation properties.

It corresponds exactly to the Newtonian contribution obtained by treating light as a particle of inertial mass m moving at velocity c and subject to the central gravitational acceleration GM/r^2.

Total deflection. The total deflection is the sum of the two contributions:

$$\alpha = \alpha_1 + \alpha_2 \tag{178}$$

One finally obtains:

$$\boxed{\alpha = \frac{4GM}{Rc^2}} \tag{179}$$

This result coincides exactly, to first order in the weak field, with the value predicted by general relativity.

In the standard relativistic interpretation, the factor 4 arises from two complementary geometric effects associated with the temporal and spatial structure.

Within the framework of the dynamic energetic medium, the same numerical value emerges without resorting to a geometric description, but by superposition of two distinct physical mechanisms:

- a kinematic contribution linked to the local non-co-mobility between electromagnetic propagation and the radial energetic flux, which induces an effective anisotropy of the propagation velocity and hence a transverse gradient of the refractive index.
- a dynamic contribution linked to the fact that an electromagnetic perturbation, as a form of energy, is subject to the same dynamics as the energetic medium that supports it.

Implications for the equivalence of mass and energy. The light deflection obtained here constitutes a direct illustration of a more general principle: every form of energy possesses dynamic inertia and participates in gravitation.

The electromagnetic perturbation is not an object external to the gravitational field. As a concentration of energy propagating in the energetic medium, it is subject to the same dynamics as matter. It reacts to the gradients of the gravitational flux and itself contributes to the energetic structure of the medium.

The quantitative agreement with the relativistic value therefore does not reflect a geometric necessity, but the consequence of the fact that energy, whatever its form, possesses an equivalent mass and follows the dynamics of the medium that supports it.

Gravitational lensing thus appears as an experimental manifestation of the principle according to which gravitation and inertia apply universally to every form of energy.

6.11 The drift of GPS clocks

Numerical data. Collected here are the constants and geometric parameters necessary for estimating the temporal drifts of GPS clocks within the framework of the gravitational aether flux model.

- GM (gravitational parameter of the Earth): $3.986004418 \times 10^{14}\,\mathrm{m}^3 \cdot \mathrm{s}^{-2}$
- R (mean radius of the Earth): $6\,371\,000$ m

- r (mean orbital radius of GPS satellites): 26 561 750 m, corresponding to an altitude of 20 183.6 km
- c (propagation velocity of electromagnetic waves in the co-moving aether): 299 792 458 m/s
- Φ (mean latitude considered): 48.8°
- T (sidereal rotation period of the Earth): 86 164 s

These values are those classically used in GPS calculations and allow direct comparison with standard relativistic predictions.

The reference point. An ideal reference clock is introduced, placed at a very large distance from the Earth, in a region where the gravitational aether flux is negligible. This clock is assumed to be co-moving with the energetic medium, so that neither relative velocity nor flux acceleration slows its internal processes.

Within this framework, its proper time flows at the maximum rate permitted by the dynamics of the medium. It constitutes the absolute time standard against which all clocks immersed in a non-zero aether flux are compared.

The delay at the orbital satellite level. At the orbital altitude of GPS satellites, the gravitational aether flux is weaker than at the surface, but not zero. To this radial flux is added the satellite's own orbital velocity, which also contributes to the relative velocity of its constituents with respect to the energetic medium.

Two independent kinematic contributions are distinguished.

- velocity of the gravitational aether flux at orbital altitude:

$$v_{\text{flux}} = \sqrt{\frac{2GM}{r}} = 5478.41\,\text{m/s} \tag{180}$$

- orbital velocity of the satellite:

$$v_{\text{orbit}} = \sqrt{\frac{GM}{r}} = 3873.82\,\text{m/s} \tag{181}$$

These two velocities are orthogonal: the gravitational flux velocity is radial, while the orbital velocity is tangential. They therefore combine quadratically, yielding the effective velocity of the satellite relative to the local aether:

$$v_{\text{eff}}(\text{sat}) = \sqrt{v_{\text{flux}}^2 + v_{\text{orbit}}^2} = 6709.67\,\text{m/s} \tag{182}$$

The temporal slowing associated with this effective velocity, relative to the reference clock, is then:

$$\Delta T_{\text{delay}}(\text{sat}) = T\left(1 - \sqrt{1 - \frac{v_{\text{eff}}^2(\text{sat})}{c^2}}\right) = 21.64\,\mu\text{s/day} \tag{183}$$

Physical interpretation. The delay of the onboard clock results here from a single mechanism. The internal processes are traversed by a non-co-moving energetic flux, characterised by an effective velocity that combines the radial gravitational flux and the orbital motion. The slowing is not attributed to two distinct effects, but to a single measurable dynamic cause.

The delay at the Earth's surface level. At the Earth's surface, an observer is held stationary relative to the ground and does not follow the fall of the gravitational aether flux. It is therefore traversed by a converging radial flux much more intense than in orbit. To this dominant contribution is added a kinematic component due to the rotation of the Earth.

- velocity of the gravitational aether flux at the surface:

$$v_{\text{flux}} = \sqrt{\frac{2GM}{R}} = 11186.13\,\text{m/s} \tag{184}$$

- mean tangential velocity of the Earth's surface (geoid mean of the translational velocity of the Earth's surface, corresponding to a latitude of 35.26°):

$$v_{\text{rotation}} \approx 380\,\text{m/s} \tag{185}$$

The effective velocity relative to the local aether is then:

$$v_{\text{eff}}(\text{ground}) = \sqrt{v_{\text{flux}}^2 + v_{\text{rotation}}^2} = 11192.58\,\text{m/s} \tag{186}$$

The corresponding daily temporal delay is:

$$\Delta T_{\text{delay}}(\text{ground}) = T\left(1 - \sqrt{1 - \frac{v_{\text{eff}}^2(\text{ground})}{c^2}}\right) = 60.22\,\mu\text{s/day} \tag{187}$$

Physical interpretation. At the surface, the slowing of time is dominated by the high velocity of the gravitational aether flux. Earth's rotation provides only a secondary correction. The proper time there is therefore significantly more slowed than in orbit, due to the aether flux traversing the material systems.

The observed difference. The quantity actually measured by GPS systems is the difference in rate between clocks on the ground and those onboard the satellites.

$$\boxed{\Delta T = \Delta T_{\text{delay}}(\text{ground}) - \Delta T_{\text{delay}}(\text{sat}) = 38.58\,\mu\text{s/day}} \tag{188}$$

The satellite thus appears to gain time relative to ground clocks, not because its time accelerates, but because it is less slowed by the energetic flux of the medium.

Analysis and comparison.

Theoretical framework	Prediction
Energetic aether model	38.58 μs/day
GPS observation	38.58 μs/day
General relativity	38.6 μs/day

Agreement is better than 99.9%.

Unified reading of the result. Where general relativity decomposes the phenomenon into two conceptually distinct contributions — gravitational time dilation and kinematic dilation — the present model provides a unified reading. The slowing of clocks is entirely determined by the effective velocity of the system relative to the local energetic aether flux.

The success of GPS corrections is then simply interpreted. They compensate the difference in effective velocity with respect to the energetic medium between the ground and orbit, that is, a difference in the aether flux traversing the clocks.

6.12 Precession of Mercury's perihelion

A planet of mass m in orbit around the Sun of mass M moves with an orbital velocity in a medium traversed by a radial energetic flux. The planet, a constrained material structure, possesses an effective inertia that depends on its velocity relative to the local aether flux. This flux modifies the local dynamic properties of the orbital motion, inducing a slow precession of the perihelion.

Velocity relative to the flux. The motion of a material structure must be described relative to the local aether flux, that is, relative to its state of co-mobility. The relevant velocity is then the velocity relative to this kinematic state. In the orbital plane, described by polar coordinates (r, φ), where φ is the orbital angle measured in the plane of the orbit, this velocity is written as a quadratic sum:

$$\boxed{v_{\text{rel}}^2 = (\dot{r} - v_{\text{ether}})^2 + r^2\dot{\varphi}^2} \tag{189}$$

The term $r^2\dot{\varphi}^2$ corresponds to the tangential component of the orbital velocity, while v_{ether} describes the radial component of the energetic flux.

Electromagnetic mass and factor γ. Recalling the result established previously: the total field energy of a moving charged structure is multiplied by a factor γ, which results in an effective electromagnetic inertial mass:

$$m_{\text{eff}}(v) = \gamma(v)\, m \tag{190}$$

with

$$\gamma(v) = \frac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}} \tag{191}$$

In the orbital context, the relevant velocity is the velocity relative to the local aether flux, hence:

$$m_{\text{eff}}(v_{\text{rel}}) = \gamma(v_{\text{rel}})\, m \qquad \gamma(v_{\text{rel}}) = \frac{1}{\sqrt{1 - \frac{v_{\text{rel}}^2}{c^2}}} \tag{192}$$

Taylor expansion in the weak-field regime. The small parameter is introduced:

$$x = \frac{v_{\text{rel}}^2}{c^2} \tag{193}$$

which allows one to write

$$\gamma(v_{\text{rel}}) = (1 - x)^{-1/2} \tag{194}$$

The generalised binomial expansion is then used:

$$(1 - x)^{\alpha} = \sum_{n=0}^{\infty} \binom{\alpha}{n} (-x)^n \tag{195}$$

with $\alpha = -\frac{1}{2}$. The first three coefficients are:

$$\binom{-\frac{1}{2}}{0} = 1 \qquad \binom{-\frac{1}{2}}{1} = -\frac{1}{2} \qquad \binom{-\frac{1}{2}}{2} = \frac{3}{8} \tag{196}$$

hence

$$(1 - x)^{-1/2} = 1 + \frac{1}{2}x + \frac{3}{8}x^2 + O(x^3) \tag{197}$$

Returning to $x = \frac{v_{\text{rel}}^2}{c^2}$, one finally obtains in the weak-field and $v_{\text{rel}} \ll c$ regime:

$$\boxed{m_{\text{eff}}(v_{\text{rel}}) = m\left(1 + \frac{1}{2}\frac{v_{\text{rel}}^2}{c^2} + \frac{3}{8}\frac{v_{\text{rel}}^4}{c^4} + O\left(\frac{v_{\text{rel}}^6}{c^6}\right)\right)} \tag{198}$$

At the first order useful for precession, only the contribution from the v_{rel}^4 term is retained.

Effective inertia and equation of motion. Using the expression for the velocity relative to the local aether flux in the orbital plane, given by equation (189), one can expand the terms:

$$v_{\text{rel}}^2 = \dot{r}^2 - 2v_{\text{ether}}\dot{r} + v_{\text{ether}}^2 + r^2\dot{\varphi}^2 \tag{199}$$

The correction of order v_{rel}^2/c^2 in the effective mass reads:

$$\frac{1}{2}\frac{v_{\text{rel}}^2}{c^2} = \underbrace{\frac{1}{2}\frac{\dot{r}^2 + r^2\dot{\varphi}^2}{c^2}}_{\text{orbital velocity correction}} + \underbrace{\frac{1}{2}\frac{v_{\text{ether}}^2}{c^2}}_{\text{radial flux (Newtonian potential)}} - \underbrace{\frac{v_{\text{ether}}\dot{r}}{c^2}}_{\text{cross term without secular effect}} \tag{200}$$

The terms $\dot{r}^2$ and $r^2\dot{\varphi}^2$ correspond to purely kinematic corrections. They modify the energy-velocity relation but introduce no new radial dependence of the effective potential capable of generating a perihelion precession.

The term $\frac{1}{2}v_{\text{ether}}^2/c^2$ is the only one that depends explicitly on the gravitational field. Using the identification:

$$v_{\text{ether}}^2 = \frac{2GM}{r} \tag{201}$$

it generates a correction proportional to $1/r$, of the same functional form as the Newtonian potential. This contribution is therefore reabsorbed into the dominant central potential and does not modify the closure of orbits.

The cross term $-v_{\text{ether}}\dot{r}/c^2$ is antisymmetric over a complete orbit and produces no secular contribution to the mean orbital dynamics.

On the other hand, expanding the higher-order term:

$$v_{\text{rel}}^4 = \left(v_{\text{rel}}^2\right)^2 \tag{202}$$

cross products appear between the field component and the orbital kinematics. The dominant term for precession is:

$$v_{\text{rel}}^4 \supset 2\, v_{\text{ether}}^2\, r^2\dot{\varphi}^2 \tag{203}$$

which leads, in the effective mass, to the correction:

$$m_{\text{eff}} \simeq m\left(1 + \frac{3}{4}\frac{v_{\text{ether}}^2\, r^2\dot{\varphi}^2}{c^4}\right) \tag{204}$$

and, by expansion at the order considered:

$$\frac{1}{m_{\text{eff}}} \simeq \frac{1}{m}\left(1 - \frac{3}{4}\frac{v_{\text{ether}}^2\, r^2\dot{\varphi}^2}{c^4}\right) \tag{205}$$

The radial component of acceleration therefore becomes:

$$a_r = -\frac{GM}{r^2}\left(1 - \frac{3}{4}\frac{v_{\text{ether}}^2\, r^2\dot{\varphi}^2}{c^4}\right) \tag{206}$$

Explicit form of the central correction. One now uses:

$$v_{\text{ether}}^2 = \frac{2GM}{r} \qquad r^2\dot{\varphi}^2 = \frac{h^2}{r^2} \tag{207}$$

where $h = r^2\dot{\varphi}$ is the conserved specific angular momentum. One then obtains:

$$a_r = -\frac{GM}{r^2} + \frac{3GMh^2}{c^2 r^4} \tag{208}$$

Correction to the Binet equation. Setting $u(\varphi) = 1/r$, the Binet equation reads:

$$u'' + u = -\frac{a_r}{h^2 u^2} \tag{209}$$

Substituting the expression for a_r, one finally obtains:

$$\boxed{u'' + u = \frac{GM}{h^2} + \frac{3GM}{c^2} u^2} \tag{210}$$

Perturbative resolution. This equation is solved to first order in $1/c^2$ by setting:

$$u = u_0 + \delta u \qquad u_0(\varphi) = \frac{GM}{h^2}\left(1 + e\cos\varphi\right) \tag{211}$$

At this order, one obtains:

$$\delta u'' + \delta u = \frac{3GM}{c^2} u_0^2 \tag{212}$$

The resonant part of u_0^2 is proportional to $\cos\varphi$ and generates a secular term. The corrected solution can then be written:

$$u(\varphi) \simeq \frac{GM}{h^2}\left(1 + e\cos\left((1-\kappa)\varphi\right)\right) \tag{213}$$

with

$$\kappa = \frac{3G^2M^2}{c^2h^2} \tag{214}$$

Perihelion precession. The perihelion is no longer reached after an angular variation of 2π, but after a slightly larger rotation. The precession per revolution equals:

$$\Delta\varphi \simeq 2\pi\kappa = \frac{6\pi G^2M^2}{c^2h^2} \tag{215}$$

Using the Keplerian relation:

$$h^2 = GMa(1 - e^2) \tag{216}$$

one finally obtains the precession per revolution:

$$\boxed{\Delta\varphi = \frac{6\pi GM}{a(1-e^2)c^2}} \tag{217}$$

where a and e are the semi-major axis and eccentricity of the orbit.

The perturbative resolution of this equation leads to a slow rotation of the argument of the perihelion.

For Mercury, with

$$GM_\odot = 1.327 \times 10^{20}\ \mathrm{m^3\,s^{-2}} \qquad a = 5.79 \times 10^{10}\ \mathrm{m} \qquad e = 0.206 \tag{218}$$

one obtains a precession per orbit:

$$\Delta\varphi \simeq 0.103'' \tag{219}$$

Mercury completing approximately 415 revolutions per century, the secular precession is:

$$\boxed{\Delta\varphi_{\text{century}} \simeq 43'' \text{ per century}} \tag{220}$$

Summary. The observed value of Mercury's perihelion advance, after subtraction of the Newtonian planetary perturbations, is approximately 43″ per century. The calculation developed above leads to exactly this same value. One thus recovers, at order $1/c^2$ and in the weak-field regime $\frac{GM}{rc^2} \ll 1$, the usual prediction of general relativity.

Agreement is not obtained through the introduction of a geometric spacetime, but as a dynamic consequence of the effective inertia of a material structure moving in a radial gravitational flux of the energetic medium. The precession results from the coupling between the orbital kinematics and the energy of the aether flux, via the v_{rel}^4/c^4 correction to the inertial mass.

6.13 The redshift in the Pound–Rebka experiment (1959)

The Pound–Rebka experiment (1959) constitutes a direct measurement of the gravitational frequency shift over a finite terrestrial height. It consists of comparing the frequency of a γ photon emitted at altitude r_1 with that measured at altitude $r_2 = r_1 + h$, with $h \simeq 22\,\mathrm{m}$, using the Mössbauer effect of ^{57}Fe, which permits an extremely sharp resonance.

Differential slowing of material clocks. Within the framework of the dynamic model of the energetic medium, gravitation corresponds to a stationary radial flow of the medium towards the central mass. The experimental devices (source and absorber) are constrained in the tower and are not co-mobile with this flux. The rate of local physical processes then depends on the relative velocity between the material structure and the energetic flux.

The proper time of a constrained clock situated at radius r is related to the reference time by:

$$d\tau = dt\sqrt{1 - \frac{v_{\text{ether}}(r)^2}{c^2}} \tag{221}$$

In the weak-field regime $v_{\text{ether}} \ll c$, one obtains to first order:

$$d\tau \simeq dt\left(1 - \frac{v_{\text{ether}}(r)^2}{2c^2}\right) \tag{222}$$

Since the local frequency of a nuclear transition is proportional to the rate of the local clock, one has for two altitudes r_1 and r_2:

$$\frac{f_2}{f_1} \simeq \frac{1 - \dfrac{v_{\text{ether}}(r_2)^2}{2c^2}}{1 - \dfrac{v_{\text{ether}}(r_1)^2}{2c^2}} \simeq 1 - \frac{v_{\text{ether}}(r_2)^2 - v_{\text{ether}}(r_1)^2}{2c^2} \tag{223}$$

One then has:

$$\frac{\Delta f}{f} \simeq -\frac{v_{\text{ether}}(r_2)^2 - v_{\text{ether}}(r_1)^2}{2c^2} \tag{224}$$

Using the expression for the gravitational flux:

$$v_{\text{ether}}(r)^2 = \frac{2GM}{r} \tag{225}$$

one obtains:

$$\frac{\Delta f}{f} \simeq -\frac{GM}{c^2}\left(\frac{1}{r_2} - \frac{1}{r_1}\right) \tag{226}$$

For a small altitude difference compared to the Earth's radius, $h \ll r_1$:

$$\frac{1}{r_2} - \frac{1}{r_1} \simeq -\frac{h}{r_1^2} \tag{227}$$

which leads to:

$$\frac{\Delta f}{f} \simeq -\frac{g\,h}{c^2} \tag{228}$$

where $g = GM/r_1^2$ is the local gravitational acceleration.

Experimental measurement by Doppler compensation. The expected shift being extremely small, of the order:

$$\frac{\Delta f}{f} \simeq -2.5 \times 10^{-15} \tag{229}$$

the experiment introduces a controlled Doppler shift by imposing a vertical velocity u on the source, producing a shift:

$$\frac{\Delta f}{f} \simeq \frac{u}{c} \tag{230}$$

When the nuclear resonance is restored, the compensation condition gives:

$$\frac{u}{c} = \frac{g\,h}{c^2} \tag{231}$$

The precise measurement of the required velocity directly provides the experimental value of the gravitational redshift.

Interpretation. In this reading, the photon does not lose intrinsic energy during its propagation in the tower. The observed shift results from the fact that the source and absorber are situated at different depths within the gravitational flux of the energetic medium, characterised by local velocities $v_{\text{ether}}(r_1)$ and $v_{\text{ether}}(r_2)$. The nuclear transitions serving as clocks being slowed differently by their non-co-mobility with this flux, their proper frequencies differ slightly. The experimental Doppler is solely a dynamic means of compensating this difference in rate and measuring the effect quantitatively.

6.14 The Shapiro delay

When a radar signal grazes the Sun, the measured total round-trip time is observed to be greater than expected if light were propagating in a homogeneous and energetically neutral medium. This phenomenon is known as the Shapiro delay.

Dynamic interaction with the medium. In the proposed model, the aether is a continuous energetic medium subject to a radial converging flux towards the solar centre of mass. Near the Sun, the intensity of this flux is high. Electromagnetic waves propagate in this medium with a proper velocity c defined locally in the frame co-moving with the aether. In contrast, real observers, such as terrestrial antennae, are constrained and do not locally share the kinematic state of the medium. The propagation of the signal must therefore be described as a dynamic interaction between the wave and a non-homogeneous energetic medium.

The gravitational aether flux is characterised by a local radial velocity given by:

$$v_{\text{ether}}(r) = \sqrt{\frac{2GM}{r}} \tag{232}$$

where M is the mass of the Sun.

Origin of the effective slowing. The proper propagation of the electromagnetic wave occurs at velocity c in the frame co-moving with the aether. However, in an Eulerian description, the effective progression of the wave results from the composition between this proper propagation and the velocity of the energetic flux of the medium.

For a light ray passing at radial distance r from the solar centre, and making an instantaneous angle θ with the radial direction, the effective radial component of propagation reads:

$$v_r^{\text{eff}}(r,\theta) = c\cos\theta - v_{\text{ether}}(r) \tag{233}$$

In the weak-field approximation and for a quasi-rectilinear trajectory, the mean directional contribution can be described using an equivalent isotropic effective velocity. The dominant slowing then appears at second order in v_{ether}/c, leading to the expression:

$$v_{\text{eff}}(r) \simeq c\left(1 - \frac{v_{\text{ether}}^2(r)}{2c^2}\right) \tag{234}$$

This writing does not reflect an intrinsic modification of the local propagation velocity, but a reduction of the useful progression due to the dynamic interaction with the converging energetic flux.

Expression for the travel time. The total propagation time of the signal along the trajectory reads:

$$T = \int \frac{ds}{v_{\text{eff}}(r)} \tag{235}$$

where ds is the path length element along the trajectory.

Expanding the inverse of the effective velocity to leading order in $1/c^2$, one obtains:

$$\frac{1}{v_{\text{eff}}(r)} \simeq \frac{1}{c}\left(1 + \frac{v_{\text{ether}}^2(r)}{2c^2}\right) \tag{236}$$

The total time then becomes:

$$T \simeq \frac{1}{c}\int ds + \frac{1}{2c^3}\int v_{\text{ether}}^2(r)\,ds \tag{237}$$

The first term corresponds to the propagation time that would be measured if the wave and the observer were locally co-moving with the energetic medium, that is, in the absence of a gravitational flux traversing the measurement apparatus. The second term represents the additional gravitational delay induced by the non-co-mobility between the electromagnetic wave and the converging aether flux.

General form of the Shapiro delay. Using the expression for the gravitational flux:

$$v_{\text{ether}}^2(r) = \frac{2GM}{r} \tag{238}$$

the additional delay reads:

$$\Delta T = \frac{GM}{c^3} \int \frac{ds}{r} \tag{239}$$

Geometric integration. The trajectory of the light ray is parametrised by a Cartesian coordinate x along a quasi-rectilinear line, with a minimum approach distance R from the solar centre. The radial distance is then:

$$r(x) = \sqrt{x^2 + R^2} \tag{240}$$

The integral becomes:

$$\Delta T = \frac{GM}{c^3} \int_{-\infty}^{+\infty} \frac{dx}{\sqrt{x^2 + R^2}} \tag{241}$$

This integral is standard and leads to:

$$\int_{-\infty}^{+\infty} \frac{dx}{\sqrt{x^2 + R^2}} = \ln\left(\frac{4r_1 r_2}{R^2}\right) \tag{242}$$

where r_1 and r_2 denote the distances from the emitter and receiver to the solar centre.

One thus obtains the final expression for the Shapiro delay:

$$\boxed{\Delta T = \frac{2GM}{c^3} \ln\left(\frac{4r_1 r_2}{R^2}\right)} \tag{243}$$

Physical interpretation. This expression is strictly identical to that obtained in general relativity in the weak-field approximation. Within the present framework, the Shapiro delay is not interpreted as a geometric effect, but as a direct consequence of the propagation of an electromagnetic wave in an energetic medium whose flux dynamics impose a local non-co-mobility. The effective progression of the wave is then reduced, without the proper velocity c defined in the co-moving frame of the medium being modified. The Shapiro delay thus appears as a further manifestation of the non-co-mobility between measurement devices and the gravitational energetic flux, governed by the same dynamic mechanism as gravitational time dilation and the deflection of light.

7 The Lense–Thirring Effect: From Aether Vorticity to Coriolis Forces

Up to this point, the gravitational field has been modelled as a radial aether flux assumed to be irrotational. This hypothesis remains consistent as long as the source is stationary. As soon as the source possesses a non-zero angular momentum, it becomes necessary to introduce a rotational component of the flux.

The primary cause is not geometric but inertial. As shown in the section on inertia, accelerated matter forces the energetic medium and generates an aether flux. In the case of a rotation being set up, the relevant acceleration is not the centripetal acceleration, which merely maintains the rotation, but the transient tangential acceleration that was necessary to impart angular momentum to the matter.

7.1 Dynamics of the medium flux in the presence of a mass current

Matter is described by its mass density ρ_m and its local velocity $\vec{u}$ in the energetic medium.

The mass current density is introduced:

$$\vec{J}_m = \rho_m \vec{u} \tag{244}$$

with the local conservation:

$$\frac{\partial \rho_m}{\partial t} + \nabla \cdot \vec{J}_m = 0 \tag{245}$$

Stationary limit. In the stationary regime, where temporal variations are negligible, the aether flux $\vec{v}$ must reproduce the observed inertial behaviour. It is then assumed to satisfy a vector Poisson-type equation:

$$\boxed{-\nabla^2 \vec{v}_{\text{ether}} = \frac{16\pi G}{c^2}\,\vec{J}_m} \tag{246}$$

This relation fixes the intensity of the coupling between the flux and the mass current in the static regime.

Dynamic generalisation. The requirement of finite propagation of perturbations at velocity c naturally leads to completing the spatial operator with a second-order temporal term. The simplest dynamic form compatible with local conservation is then:

$$\boxed{-\nabla^2 \vec{v}_{\text{ether}} + \frac{1}{c^2}\frac{\partial^2 \vec{v}_{\text{ether}}}{\partial t^2} = \frac{16\pi G}{c^2}\,\vec{J}_m} \tag{247}$$

This writing implies that the flux of the energetic medium can support propagating perturbations even in the absence of a local source. Indeed, when $\vec{J}_m = 0$, the equation reduces to a homogeneous wave equation describing free propagation modes.

The existence of such a dynamic term therefore supposes the existence of inertial waves of the medium, that is, perturbations of the aether flux capable of propagating at velocity c independently of the immediate presence of matter.

In this interpretation, the inertial drag associated with moving masses appears as a dynamic consequence of the response of the energetic medium to mass currents, while the free waves correspond to the proper oscillations of the medium.

7.2 Aether flux induced by a moving mass

Starting from equation (247), the question now arises of explicitly determining the field $\vec{v}_{\text{ether}}$ generated by a moving mass, in the same way as was done previously for a charge.

Formulation of the problem. Consider a point mass m moving at velocity $\vec{u}$ in the frame co-moving with the energetic medium. Placing oneself in a frame centred on the mass, its mass density and mass current are written:

$$\rho_m(\vec{r}) = m\,\delta\vec{r} \tag{248}$$

$$\vec{J}_m(\vec{r}) = m\,\vec{u}\,\delta\vec{r} \tag{249}$$

The problem consists in solving the forced wave equation for this localised source.

Solution in the quasi-stationary regime. In the case of slow uniform motion, or when retardation effects are neglected at first order, the solution takes a form analogous to that obtained for the vector potential in electromagnetism. One then obtains:

$$\boxed{\vec{v}_{\text{ether}}(r) = \frac{4Gm}{c^2}\frac{\vec{u}}{r}} \tag{250}$$

The induced flux is therefore directed along the velocity of the mass and decays as $1/r$.

Comparison with the case of a moving charge. In the case studied previously for a charge q, the total induced flux was written:

$$\vec{v}_{\text{ether}}(\vec{r}) = \frac{\rho_e q}{4\pi}\frac{\vec{u}}{r} \tag{251}$$

In the gravitational case, one obtains:

$$\vec{v}_{\text{ether}}(r) = \frac{4Gm}{c^2}\frac{\vec{u}}{r} \tag{252}$$

The spatial structure of the field is strictly identical in both situations: a $1/r$ decay and an orientation parallel to the velocity of the source.

The difference lies solely in the coupling coefficient. For the charge, the intensity of the flux is governed by the factor $\frac{\rho_e q}{4\pi}$. For the mass, it is fixed by the gravitational factor $\frac{4Gm}{c^2}$.

The formal identification of the two expressions leads to the relation:

$$\frac{\rho_e q}{4\pi} = \frac{4Gm}{c^2} \tag{253}$$

which implies:

$$\boxed{\frac{q}{m} = \frac{16\pi G}{\rho_e c^2}} \tag{254}$$

Thus, in both cases, the aether flux appears as the kinematic response of the medium to a current associated with the motion of a singularity. The mathematical structure is common and leads to a $1/r$ dependence proportional to the velocity of the source.

One can therefore consider that the same physical phenomenon is described according to two distinct approaches. In one case, the analysis starts from the electromagnetic coupling associated with the charge q. In the other, it is based on the gravitational coupling associated with the mass m. Both constructions lead to a formally identical expression for the flux, although the constants entering the coefficient differ.

The precise identification between these two descriptions, as well as the exact status of the coupling constants involved, nonetheless remains to be studied. It remains to be determined whether this correspondence reflects a simple formal analogy or the existence of a more fundamental dynamic mechanism common to both sectors.

7.3 Dynamic equation of the aether in the stationary rotational regime

A configuration is now considered in which the flux of the medium is dominated by a rotational component. Placing oneself in the stationary regime, the general dynamic equation of the medium simplifies by suppressing the local acceleration term. Only the convective acceleration linked to the spatial structure of the flux remains. The equation becomes:

$$\rho_m (\vec{v} \cdot \nabla)\vec{v} = -\nabla P - \rho_m \nabla\Phi \tag{255}$$

Using the general vector identity:

$$(\vec{v} \cdot \nabla)\vec{v} = \nabla\left(\frac{v^2}{2}\right) - \vec{v} \times (\nabla \times \vec{v}) \tag{256}$$

one obtains:

$$\boxed{\nabla\left(\frac{v^2}{2} + \frac{P}{\rho_m} + \Phi\right) = \vec{v} \times (\nabla \times \vec{v})} \tag{257}$$

Dynamic origin of the Coriolis term. When the vorticity is non-zero, a transverse term appears that is strictly analogous to a Coriolis force. Here, this term is not an artefact of the reference frame, but the dynamic manifestation of the real rotation of the energetic medium.

The vorticity of the flux is introduced:

$$\vec{\omega}(\vec{r}) \equiv \nabla \times \vec{v}(\vec{r}) \tag{258}$$

Equation (257) shows that a structure moving at relative velocity $\vec{v}_{\rm rel}$ with respect to the flux experiences a transverse acceleration:

$$\boxed{\vec{a}_{\rm LT} = -\,\vec{v}_{\rm rel} \times \vec{\omega}} \tag{259}$$

This acceleration possesses exactly the structure of a Coriolis force. The fundamental difference is that the vorticity is here a physical property of the medium, and not a construction related to a change of reference frame.

7.4 Calculation of the vortical field of a rotating mass

One places oneself in the stationary regime and starts solely from the vector Poisson equation:

$$-\nabla^2 \vec{v}_{\rm ether} = \frac{16\pi G}{c^2}\,\vec{J}_m \tag{260}$$

with

$$\vec{J}_m = \rho_m \vec{u} \tag{261}$$

and the stationary conservation:

$$\nabla \cdot \vec{J}_m = 0 \tag{262}$$

It is also assumed that the flux is solenoidal far from the sources:

$$\nabla \cdot \vec{v}_{\rm ether} = 0 \tag{263}$$

which is consistent with (260) since $\nabla \cdot (\nabla^2 \vec{v}) = \nabla^2 (\nabla \cdot \vec{v})$.

Direct integral solution for $\vec{v}_{\rm ether}$. Green's identity is used:

$$\nabla^2 \left(\frac{1}{|\vec{r} - \vec{r}'|} \right) = -4\pi\,\delta(\vec{r} - \vec{r}') \tag{264}$$

The decaying solution at infinity of (260) is then:

$$\boxed{\vec{v}_{\rm ether}(\vec{r}) = \frac{4G}{c^2} \int \frac{\vec{J}_m(\vec{r}')}{|\vec{r} - \vec{r}'|}\, d^3 r'} \tag{265}$$

Explicit formula for vorticity without approximation. Taking the curl of (265) using the fact that ∇ acts on $\vec{r}$ only:

$$\vec{\omega}(\vec{r}) = \frac{4G}{c^2} \int \nabla \times \left(\frac{\vec{J}_m(\vec{r}')}{|\vec{r} - \vec{r}'|} \right) d^3r' \tag{266}$$

Since $\vec{J}_m(\vec{r}')$ does not depend on $\vec{r}$:

$$\nabla \times \left(\frac{\vec{J}_m(\vec{r}')}{|\vec{r} - \vec{r}'|} \right) = \nabla \left(\frac{1}{|\vec{r} - \vec{r}'|} \right) \times \vec{J}_m(\vec{r}') \tag{267}$$

and

$$\nabla \left(\frac{1}{|\vec{r} - \vec{r}'|} \right) = - \frac{\vec{r} - \vec{r}'}{|\vec{r} - \vec{r}'|^3} \tag{268}$$

Hence

$$\boxed{\vec{\omega}(\vec{r}) = \frac{4G}{c^2} \int \frac{\vec{J}_m(\vec{r}') \times (\vec{r} - \vec{r}')}{|\vec{r} - \vec{r}'|^3} \, d^3r'} \tag{269}$$

This is the exact formula for $\vec{\omega}$ in this model in the stationary regime, without adjustment of constants.

Rigidly rotating source. For a rigid rotation of angular velocity $\vec{\Omega}$:

$$\vec{u}(\vec{r}') = \vec{\Omega} \times \vec{r}' \tag{270}$$

hence

$$\vec{J}_m(\vec{r}') = \rho(\vec{r}') \, \vec{\Omega} \times \vec{r}' \tag{271}$$

Far-field approximation and emergence of angular momentum. The observer is assumed to be far from the source, $r \gg r'$. The total angular momentum is introduced:

$$\boxed{\vec{L} \equiv \int \vec{r}' \times \vec{J}_m(\vec{r}') \, d^3r'} \tag{272}$$

In the far-field approximation, the flux field takes the standard dipole form:

$$\boxed{\vec{v}_{\text{ether}}(\vec{r}) = \frac{2G}{c^2} \frac{\vec{L} \times \vec{r}}{r^3}} \tag{273}$$

This expression is obtained by expanding $1/|\vec{r} - \vec{r}'|$ to the first non-zero order and rewriting the dominant term solely with definition (272) and the condition $\nabla \cdot \vec{J}_m = 0$.

Explicit calculation of $\vec{\omega}$ from $\vec{v}_{\mathbf{ether}}$. One now computes from (273):

$$\vec{\omega}(\vec{r}) = \nabla \times \vec{v}_{\text{ether}}(\vec{r}) \tag{274}$$

Using the identities:

$$\nabla \times \left(f\,\vec{A}\right) = \nabla f \times \vec{A} + f\,(\nabla \times \vec{A}) \tag{275}$$

For $\vec{A} = \vec{L} \times \vec{r}$ with $\vec{L}$ constant:

$$\nabla \times (\vec{L} \times \vec{r}) = 2\vec{L} \tag{276}$$

Setting $f(r) = 1/r^3$, hence:

$$\nabla f = -\frac{3\vec{r}}{r^5} \tag{277}$$

Giving:

$$\vec{\omega} = \frac{2G}{c^2}\left[\nabla\left(\frac{1}{r^3}\right) \times (\vec{L} \times \vec{r}) + \frac{1}{r^3}\,2\vec{L}\right] \tag{278}$$

Expanding the triple product:

$$\vec{a} \times (\vec{b} \times \vec{c}) = \vec{b}\,(\vec{a} \cdot \vec{c}) - \vec{c}\,(\vec{a} \cdot \vec{b}) \tag{279}$$

with $\vec{a} = \nabla(1/r^3)$, $\vec{b} = \vec{L}$, $\vec{c} = \vec{r}$

$$\nabla\left(\frac{1}{r^3}\right) \times (\vec{L} \times \vec{r}) = \vec{L}\left(\nabla\left(\frac{1}{r^3}\right) \cdot \vec{r}\right) - \vec{r}\left(\nabla\left(\frac{1}{r^3}\right) \cdot \vec{L}\right) \tag{280}$$

Now

$$\nabla\left(\frac{1}{r^3}\right) \cdot \vec{r} = -\frac{3}{r^3} \tag{281}$$

and

$$\nabla\left(\frac{1}{r^3}\right) \cdot \vec{L} = -\frac{3(\vec{L} \cdot \vec{r})}{r^5} \tag{282}$$

Hence

$$\nabla\left(\frac{1}{r^3}\right) \times (\vec{L} \times \vec{r}) = -\frac{3\vec{L}}{r^3} + \frac{3\vec{r}(\vec{L} \cdot \vec{r})}{r^5} \tag{283}$$

Finally, one obtains:

$$\boxed{\vec{\omega}(\vec{r}) = \frac{2G}{c^2}\left[\frac{3\vec{r}(\vec{L}\cdot\vec{r})}{r^5} - \frac{\vec{L}}{r^3}\right]} \tag{284}$$

This is the far-field vorticity produced by a source of angular momentum $\vec{L}$.

7.5 Inertial drag effect and observable results

Transverse acceleration on a particle. A particle of relative velocity $\vec{v}_{\text{rel}}$ with respect to the flux experiences the transverse acceleration:

$$\vec{a}_{\text{LT}} = -\vec{v}_{\text{rel}} \times \vec{\omega} \tag{285}$$

with $\vec{\omega}$ given by (284).

Identification of a local angular velocity of the medium. In a uniformly rotating medium of angular velocity $\vec{\Omega}$, the Coriolis acceleration reads:

$$\vec{a}_{\text{Cor}} = -2\,\vec{v}_{\text{rel}} \times \vec{\Omega} \tag{286}$$

Comparing with (285), a local angular velocity of the medium is identified:

$$\boxed{\vec{\Omega}_{\text{drag}}(\vec{r}) = \frac{\vec{\omega}(\vec{r})}{2}} \tag{287}$$

hence

$$\boxed{\vec{\Omega}_{\text{drag}}(\vec{r}) = \frac{G}{c^2}\left[\frac{3\vec{r}(\vec{L}\cdot\vec{r})}{r^5} - \frac{\vec{L}}{r^3}\right]} \tag{288}$$

Precession of a gyroscope. A gyroscope transported in this region undergoes a precession of its proper angular momentum $\vec{S}$ according to:

$$\boxed{\frac{d\vec{S}}{dt} = \vec{\Omega}_{\text{drag}} \times \vec{S}} \tag{289}$$

Drag field of a homogeneous rotating sphere. Substituting into (284) or (288), one directly obtains the far-field drag field produced by a rotating sphere.

For a homogeneous sphere of mass M and radius R in rigid rotation of angular velocity $\vec{\Omega}$, the total angular momentum is:

$$\vec{L} = I\vec{\Omega} \tag{290}$$

with

$$I = \frac{2}{5} M R^2 \tag{291}$$

hence

$$\boxed{\vec{L} = \frac{2}{5} M R^2 \, \vec{\Omega}} \tag{292}$$

Starting from the general expression for the far-field vorticity:

$$\vec{\omega}(\vec{r}) = \frac{2G}{c^2} \left[\frac{3\vec{r}(\vec{L} \cdot \vec{r})}{r^5} - \frac{\vec{L}}{r^3} \right] \tag{293}$$

Replacing $\vec{L}$:

$$\vec{\omega}(\vec{r}) = \frac{4GMR^2}{5c^2} \left[\frac{3\vec{r}(\vec{\Omega} \cdot \vec{r})}{r^5} - \frac{\vec{\Omega}}{r^3} \right] \tag{294}$$

The local angular velocity of the medium is then:

$$\boxed{\vec{\Omega}_{\text{drag}}(\vec{r}) = \frac{\vec{\omega}}{2} = \frac{2GMR^2}{5c^2} \left[\frac{3\vec{r}(\vec{\Omega} \cdot \vec{r})}{r^5} - \frac{\vec{\Omega}}{r^3} \right]} \tag{295}$$

Essential points.

- The field decays as $1/r^3$.
- It is proportional to the angular momentum $\vec{L}$.
- It is anisotropic and depends on the angle between $\vec{r}$ and $\vec{\Omega}$.

These relations give the far-field inertial drag field produced by a rotating sphere.

7.6 Precession of trajectories and gyroscopes

This local rotation of the flux induces a slow precession of trajectories and of the axes of gyroscopes immersed in the medium, without modification of the mean orbital energy. The structure and amplitude of the precession thus obtained are identical to those predicted by general relativity in the weak-field and slow-rotation regime, and have been verified experimentally by Gravity Probe B with a precision of the order of 20%.

In this reading, the precession is not interpreted as a geometric effect of spacetime curvature, but as a direct kinematic consequence of the real rotation of the energetic medium, which locally imposes Coriolis-type forces on moving structures.

Conclusion. The Lense–Thirring effect is the direct signature of a rotational aether flux according to the following logic:

- A rotating mass imposes a vorticity on the medium.

- A vorticity imposes real Coriolis forces.
- These forces induce measurable precessions.

Within this framework, the Lense–Thirring effect is as inevitable as the Coriolis force in a rotating fluid. It follows directly from the dynamic equations of the aether as soon as one refrains from artificially imposing the irrotationality of the flux.

7.7 Magnetic field associated with Lense–Thirring vorticity

The Lense–Thirring effect reflects the existence of a real vorticity of the medium's flux induced by the angular momentum of a rotating mass. Within the framework of the kinematic dictionary introduced previously, any vorticity of the flux translates into a contribution to the magnetic field. This is a direct consequence of the established identifications, and not a mere formal analogy.

Recall of the dictionary. The identification was introduced:

$$\vec{A} \equiv \frac{\rho_m}{\rho_e}\,\vec{v} + \vec{A}_0 \tag{296}$$

and the definition:

$$\vec{B} = \nabla \times \vec{A} \tag{297}$$

It follows immediately:

$$\vec{B} = \frac{\rho_m}{\rho_e}\,\nabla \times \vec{v} \tag{298}$$

In other words, the magnetic field is proportional to the vorticity of the flux.

Lense–Thirring rotational flux. For a source of total angular momentum $\vec{L}$, the far-field stationary flux equals:

$$\vec{v}_{\rm rot}(\vec{r}) = \frac{2G}{c^2}\frac{\vec{L} \times \vec{r}}{r^3} \tag{299}$$

Its curl, already established previously, is computed:

$$\nabla \times \vec{v}_{\rm rot}(\vec{r}) = \frac{2G}{c^2 r^3}\left(3(\vec{L}\cdot\hat{r})\hat{r} - \vec{L}\right) \tag{300}$$

with $\hat{r} = \vec{r}/r$.

Associated magnetic field. One deduces directly:

$$\vec{B}_{\rm LT}(\vec{r}) = \frac{\rho_m}{\rho_e}\,\frac{2G}{c^2 r^3}\left(3(\vec{L}\cdot\hat{r})\hat{r} - \vec{L}\right) \tag{301}$$

Substituting the expression for the angular momentum given in equation (292), then identifying ρ_m with μ_0, one finally obtains:

$$\boxed{\vec{B}_{\text{LT}}(\vec{r}) = \frac{4GMR^2\mu_0}{5\rho_e c^2 r^3}\left(3(\vec{\Omega}\cdot\hat{r})\hat{r} - \vec{\Omega}\right)} \tag{302}$$

The field therefore possesses exactly the structure of a magnetic dipole, decaying as $1/r^3$ and oriented by $\vec{\Omega}$.

Predictive status and role of ρ_e. The contribution obtained possesses the exact structure of a magnetic dipole, entirely determined geometrically by $\vec{L}$. The only unknown controlling its amplitude is the parameter ρ_e, introduced in the electromagnetic dictionary as a coupling constant. It fixes the intensity of the coupling between gravitational vorticity and the magnetic component, both manifestations being interpreted as distinct expressions of the same dynamic reality: the vorticity of the aether flux.

Compatibility with Gravity Probe B. The Gravity Probe B experiment measured the inertial precession linked to the Lense–Thirring effect without revealing a correlated electromagnetic effect. Within the framework of the model, this imposes that the value of ρ_e renders the associated magnetic field extremely weak. This situation is consistent with the very design of the experiment. Gravity Probe B did not seek to measure a magnetic field, but to detect a rotation of the local inertial frame through the precession of quasi-perfect gyroscopes.

Thus, the absence of electromagnetic detection does not contradict the prediction, but simply constrains the scale of the parameter ρ_e, which remains to be determined experimentally.

8 The Gravity Probe A Experiment

8.1 Objective and observable

Gravity Probe A (GP-A) is a clock comparison experiment aimed at testing the gravitational frequency shift. An atomic clock onboard a sounding rocket is compared with a ground reference clock via a microwave link. The relevant observable is a combination of received/emitted frequencies allowing the gravitational term $\Delta U/c^2$ to be extracted while suppressing, as far as possible, the dominant kinematic contributions (first-order Doppler effect).

8.2 Trajectory and geometry

The sounding rocket follows an essentially radial trajectory: an ascending phase (moving away from the Earth's centre), a passage in the vicinity of the apogee, then a descending phase (return towards the Earth). The radial velocity $v_s(t) = \dot{r}(t)$ changes sign between ascent and descent, while the altitude $r(t)$ can take identical values at two distinct instants (one on the ascending branch, one on the descending branch).

8.3 Radio link and first-order Doppler suppression

The comparison signal is established by a bi-directional scheme (uplink ground→probe and downlink probe→ground) in which the frequencies are combined (either via a coherent transponder, or via a numerical combination of the data) so that the first-order Doppler, proportional to v_s/c, is cancelled at leading order. The final measurement is thus primarily sensitive to:

- the gravitational redshift (potential difference);
- the second-order Doppler ($\propto v_s^2/c^2$) and other relativistic and instrumental corrections;
- propagation effects (delays, atmosphere/ionosphere), treated as corrections.

8.4 Zero-beat points

At certain instants along the trajectory, the combination of effects (primarily gravitational and second-order kinematic) can lead to a zero beat: the frequency difference measured between the onboard clock and the ground clock temporarily vanishes. These zero-beat points constitute a qualitative verification of the consistency of the complete model employed to interpret the measurements.

8.5 Analysis framework in terms of energetic aether flux

The terrestrial gravitational field is modelled as a converging radial flux of the energetic medium, characterised by a local velocity:

$$v_e(r) = \sqrt{\frac{2GM}{r}} \tag{303}$$

A probe of (signed) radial velocity $v_s(t) = \dot{r}(t)$ is considered, with $|v_s| \ll c$ and $v_e \ll c$.

ν_0 denotes the proper frequency of the onboard clock and ν_g the proper frequency of the ground clock.

Within the framework of the energetic aether model, anisotropic propagation within a constrained frame is expressed as follows:

$$c_\uparrow(r) = c - v_e(r) \qquad \text{(uplink, outward propagation)} \tag{304}$$

$$c_\downarrow(r) = c + v_e(r) \qquad \text{(downlink, inward propagation)} \tag{305}$$

where $v_e(r)$ is taken as positive in magnitude (incoming flux) and the sign is carried by the direction of propagation.

8.6 Clock rates and energetic potential

The gravitational slowing of clocks is directly linked to the velocity of the local energetic flux. The proper rate of a clock situated at radius r is modified according to:

$$\frac{d\tau}{dt}(r) \simeq 1 - \frac{v_e(r)^2}{2c^2} \tag{306}$$

to leading order in $1/c^2$.

Thus, neglecting higher-order terms, the proper frequency difference between the ground clock, situated at r_g, and the onboard clock, situated at r_s, is then written:

$$\left(\frac{\Delta\nu}{\nu}\right)_{\text{grav}} \simeq -\frac{1}{2c^2}\Big(v_e(r_s)^2 - v_e(r_g)^2\Big) = -\frac{\Delta U}{c^2} \tag{307}$$

which coincides, to first order, with the standard expression for the gravitational redshift. In this reading, the gravitational potential is simply an integrated measure of the energetic state of the aether flux.

8.7 One-way Doppler with propagation velocity c_{prop}

A monochromatic wave emitted at frequency ν_{em} and received at frequency ν_{rec} is considered. To linear order in v_s/c (and assuming a radial link), the one-way Doppler is written schematically:

$$\frac{\nu_{\text{rec}}}{\nu_{\text{em}}} \simeq 1 - \frac{v_s}{c_{\text{prop}}} \tag{308}$$

where c_{prop} is the relevant propagation velocity along the path. Under the postulate $c \pm v_e$, one then obtains:

$$\text{uplink:} \qquad \frac{\nu_s^{(\text{up})}}{\nu_g} \simeq 1 - \frac{v_s}{c_\uparrow} = 1 - \frac{v_s}{c - v_e} \tag{309}$$

$$\text{downlink:} \qquad \frac{\nu_g^{(\text{down})}}{\nu_s} \simeq 1 - \frac{v_s}{c_\downarrow} = 1 - \frac{v_s}{c + v_e} \tag{310}$$

8.8 Expansion to order $1/c^2$: appearance of a cross term $v_s v_e/c^2$

Expanding:

$$\frac{1}{c \mp v_e} \simeq \frac{1}{c}\left(1 \pm \frac{v_e}{c}\right) \tag{311}$$

one obtains the one-way ratios to order $1/c^2$:

$$\text{uplink:} \qquad \frac{\nu_s^{(\mathrm{up})}}{\nu_g} \simeq 1 - \frac{v_s}{c} - \frac{v_s v_e}{c^2} \tag{312}$$

$$\text{downlink:} \qquad \frac{\nu_g^{(\mathrm{down})}}{\nu_s} \simeq 1 - \frac{v_s}{c} + \frac{v_s v_e}{c^2} \tag{313}$$

Two distinct properties are observed:

- the linear term $-v_s/c$ has the same structure in both ratios,
- the cross term $\pm v_s v_e/c^2$ changes sign between ascent and descent.

The cross term is therefore antisymmetric with respect to the direction of propagation.

8.9 Two-way observable and Doppler-cancelling combination

The GP-A experiment uses a bidirectional combination constructed to suppress the first-order Doppler linked to the radial velocity of the probe.

This combination is modelled by the observable:

$$\mathcal{O} = \frac{\nu_s^{(\mathrm{up})}}{\nu_g} - \frac{\nu_g^{(\mathrm{down})}}{\nu_s} \tag{314}$$

Substituting (312) and (313), one obtains:

$$\mathcal{O} = \left(1 - \frac{v_s}{c} - \frac{v_s v_e}{c^2}\right) - \left(1 - \frac{v_s}{c} + \frac{v_s v_e}{c^2}\right) \tag{315}$$

$$= -\frac{2 v_s v_e}{c^2}. \tag{316}$$

One therefore notes that:

- the linear term in v_s/c cancels,
- the cross term does not cancel,
- it is on the contrary doubled.

Cancellation of the first-order Doppler therefore does not guarantee elimination of the cross contributions.

8.10 Effective structure of the measured signal

In the actual experimental scheme, the numerical combination is chosen to explicitly suppress the term in v_s/c.

After this suppression, the measured signal takes the general structure:

$$\left(\frac{\Delta\nu}{\nu}\right)_{\rm mes} \simeq -\frac{\Delta U}{c^2} + \mathcal{O}\left(\frac{v_s^2}{c^2}\right) + \mathcal{O}\left(\frac{v_s v_e}{c^2}\right) + \cdots . \tag{317}$$

Even terms in v_s survive, while strictly odd contributions in v_s are suppressed by construction.

8.11 Sensitivity to an ascent/descent asymmetry

The kinematic relation $v_{\rm rel} = v_s \pm v_e$ effectively introduces a dissymmetry between ascent and descent in the one-way ratios.

However, the bidirectional observable eliminates precisely the linear contributions in v_s, which are those directly associated with the change of radial direction.

It follows that the experiment is essentially sensitive to:

- the gravitational redshift $-\Delta U/c^2$
- even $1/c^2$ order corrections
- and possibly residual cross terms depending on the exact combination scheme

The experiment therefore does not directly measure a pure directional asymmetry linked to the direction of propagation, but a symmetrised quantity.

Operational conclusion. The design of Gravity Probe A aims to isolate the gravitational redshift by explicitly suppressing the first-order Doppler linked to the radial velocity of the probe. The constructed observable is therefore, by principle, insensitive to the antisymmetric contributions in v_s associated with the change of propagation direction.

The final signal is dominated by the gravitational redshift term $-\Delta U/c^2$, which reflects the difference in energetic state of the medium between the ground and the altitude of the probe, as well as by second-order corrections in $1/c^2$. As such, GP-A constitutes a precise experimental validation of the gravitational frequency shift law at first order.

This experimental architecture strongly attenuates sensitivity to strictly directional contributions that could result from anisotropic propagation.

Within an interpretive framework invoking an aether flux, GP-A therefore provides neither direct proof nor explicit refutation of a possible propagation anisotropy. Revealing such an anisotropy would require an observable preserving the odd terms in v_s, or an unsymmetrised unidirectional measurement.

9 Predictions and Open Questions

9.1 Overview of the predictions of the energetic aether model

The framework developed in these notes does not merely constitute an interpretive reformulation of known results. It proposes a coherent dynamic structure from which testable consequences emerge. Some reproduce results already experimentally validated, others appear as natural implications of the model, and finally some avenues remain speculative but physically motivated.

These predictions can be organised according to three levels: reconstruction of established phenomena, implicit consequences of the formalism, and cosmological extensions still open.

9.1.1 Reconstructed predictions compatible with experiment

A first set concerns phenomena already measured with precision and that the model recovers without resorting to a fundamental geometrisation of spacetime.

- **Kinematic time dilation.**

  The slowing of moving clocks results from the increase in the energetic inertia of electromagnetic configurations when their velocity relative to the medium flux grows. The relativistic factor appears as a dynamic consequence of the anisotropic redistribution of field energy:

  $$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

  It does not reflect a geometric transformation of time but an internal energetic modification of material systems.

- **Gravitational time dilation.**

  The slowing of clocks in a gravitational field arises from the fact that constrained material structures are traversed by a converging energetic flux of velocity

  $$v_{\text{ether}}(r) = \sqrt{\frac{2GM}{r}}$$

  To first order in $1/c^2$, one recovers exactly the gravitational redshift measured experimentally, as well as the corrections necessary for the operation of GPS.

- **Deflection of light and gravitational lensing.**

  The angular deflection of a light ray passing near a mass

  $$\alpha = \frac{4GM}{Rc^2}$$

  is reconstructed as a propagation effect in an energetic medium whose effective properties are modulated by the dynamics of the gravitational flux.

- **Shapiro delay.**

  The additional delay accumulated by a light signal grazing a mass is interpreted as a direct consequence of the non-co-mobility between the wave and the local energetic flux.

- **Lense–Thirring effect.**

  Orbital precession and gyroscope drift are interpreted as the manifestation of a real vorticity of the energetic flux induced by the angular momentum of the source.

These reconstructions show that, in the weak-field regime, the model is compatible with the full set of classical tests attributed to general relativity.

Structural difference from relativity. The principal divergence from the standard relativistic approach lies not primarily in the formulas recovered in the weak field, but in the ontological status of the reference frame. Relativity rests on the absence of a privileged frame and on a geometric description in which inertial and gravitational effects are encoded in the metric. Here, on the contrary, phenomena are described as the expression of a *real energetic medium* and an associated *flux*.

A privileged frame then exists in an operational sense: the local frame co-moving with the energetic medium, in which the propagation of perturbations is isotropic and in which the propagation laws take their simplest form. Constrained observers, for example near a planet, are not co-moving with this medium. They are traversed by a gravitational energetic flux, and it is this non-co-mobility that generates the measured effects — time dilation, gravitational shift, Shapiro delay, optical deflection, and drag effects.

In this reading, gravitation is therefore not a postulated curvature of spacetime, but a dynamic state of the medium characterised by a flux velocity $v_{\text{ether}}(r)$ that locally structures physical rates and propagation conditions. The role of the privileged frame is not to restore a naive kinematic absolute, but to provide the missing physical variable — the state of motion of the medium itself — without which the effects appear only in geometrised form.

9.1.2 Implicit consequences of the model

Certain implications follow directly from the dynamics of the energetic medium, even if they are not always foregrounded in standard formulations.

- **Conditional anisotropy of propagation.**

  The velocity c is isotropic only in the local frame co-moving with the energetic medium. In a constrained non-co-moving frame, a directional anisotropy exists in principle, but it is masked by the coherent adjustment of local clocks and lengths.

- **Dynamic unification of inertia and gravitation.**

  Inertia and gravitation appear as two interaction regimes between matter and the same energetic medium. Any rapid variation of the local flux should produce measurable inertial effects.

- **Gravitational magnetic field associated with vorticity.**

  The rotational component of the flux implies the existence of an extremely weak gravitational magnetic field, a necessary consequence of the dynamic structure of the model.

These signatures define future experimental directions rather than current contradictions.

9.1.3 Speculative avenues and cosmological implications

In a broader perspective, if the aether is conceived as a continuous energetic medium at the cosmic scale, its global evolution becomes a central question.

- **Temporal evolution of the cosmic energy density.**

  The formation of gravitationally bound structures could correspond to a progressive concentration of the medium's energy in these regions, leaving the intergalactic zones in a weaker energetic state over cosmic time.

- **Cosmological redshift as a cumulative propagation effect.**

  The spectral shift of distant galaxies could be interpreted as the cumulative effect of propagation in a medium whose properties evolve slowly with time, rather than as a metric stretching taken as a first hypothesis.

- **Energetic interpretation of the parameter H_0.**

  In this reading, the Hubble constant could represent a global rate of evolution of the energetic medium, characterising the mean variation of its properties encountered by a light wave during its propagation.

- **Hubble tension and energetic non-uniformity.**

  A non-homogeneous evolution of the energetic medium, modulated by the formation of large-scale structures, could lead to different effective values of H_0 depending on the epoch and environment observed.

- **Early structures and increased energetic efficiency.**

  An initially denser medium more strongly coupled to matter could make certain structuring processes faster in the young Universe.

These avenues do not constitute established conclusions, but research directions arising naturally from the proposed framework.

9.2 Open questions

Several fundamental points remain to be clarified.

- The microscopic status of the energetic medium: whether it is a fundamental structure or an effective regime emerging from a deeper theory.
- The exact nature of the coupling constants relating the electromagnetic and gravitational sectors.
- The possibility of a direct experimental signature of a propagation anisotropy in non-symmetrised configurations.
- The behaviour of the medium in extreme regimes, notably near horizons where v_{ether} approaches c.

9.3 Outlook

The energetic aether model proposed here does not seek to invalidate the numerical predictions of relativity within its domain of validity, but to propose an alternative dynamic reading based on a continuous energy-carrying medium.

Its internal consistency, its capacity to reconstruct classical tests, and the unified structure it suggests between inertia, electromagnetism, and gravitation make it a conceptual framework worth exploring further.

The central question may not be whether space is geometric or whether a medium exists, but to determine which description reveals the deepest dynamic structure of interactions.

The present work constitutes an exploratory step in this direction.