Chapter 4

Maxwell's equations of electromagnetism

Maxwell's equations are the fundamental laws of electromagnetism formulated at the end of the 19th century by James Clerk Maxwell on the basis of the various theorems of Gauss, Ampère and Faraday which described electric and magnetic phenomena separately before Maxwell unified them. Maxwell's laws govern all classical phenomena related to electric and magnetic fields, and thereby represent one of the most beautiful applications of the concept of fields in physics. But Maxwell's equations of electromagnetism are a postulate deduced from experimental observations, and we admit them because they correspond to the experimental observations.

In this chapter, we theoretically demonstrate the existence of a set of equations to describe the rotations and shear strains of the cosmological lattice in the absence of variations in volume expansion, and we note that there is a complete and perfect analogy between this set of equations and Maxwell's set of equations. This analogy not only demonstrates that it is possible to theoretically deduce the set of these equations on the basis of some fundamental physical principles applied to the cosmological lattice, but it also makes it possible to consider the cosmological lattice as a physical support for the electromagnetic fields, and to give physical interpretations to the various physical quantities of electromagnetism.

We start by showing the separability of the volume expansion field from the other fields in Newton's equation of a cosmological lattice in the case where the concentrations of point defects are constants. Newton's equation can be separated into two parts, a so-called *rotational part* and a so-called *divergent part*.

In the case where the volume expansion field can be considered as quasi-constant, the rotational part then shows a set of equations for the field of macroscopic rotations and local rotations (associated with the shears of the lattice) perfectly identical to the set of *Maxwell's equations of electromagnetism*. This analogy with Maxwell's equations leaves no room for the existence of *magnetic monopoles*, but there is however the possibility of imagining the existence of *vector electric charges*.

Separability of Newton's equation partly «rotational» and partly «divergent»

Suppose that the volume expansion field within a cosmological lattice has a homogeneous background field τ_0 with an elastic expansion field $\tau^{él}$ superimposed on it, so that it can be written $\tau = \left(\tau_0 + \tau^{él}\right)$. Supposing further that the atomic concentrations of vacancies and auto-interstitials are *homogeneous constants* throughout the lattice, and therefore that they do not depend on time ($dC_I / dt = dC_L / dt = 0$), we can write Newton's equation of the lattice under the shape shown in figure 4.1.

Thanks to the hypothesis of homogeneity of the concentrations of vacancies and auto-interstitials, the linearity of the relationships in the various velocities shows that it is possible to

split them into two contributions by separating the speeds $\vec{\phi}$, $\vec{\phi}_L$ and $\vec{\phi}_I$ into a component, indexed *"rot"*, associated with the deformations by shears and rotations on the one hand, and a component, indexed *"div"*, associated with the deformations by volume expansion on the other hand. There thus come two contributions to Newton's equation as shown in figure 4.1:

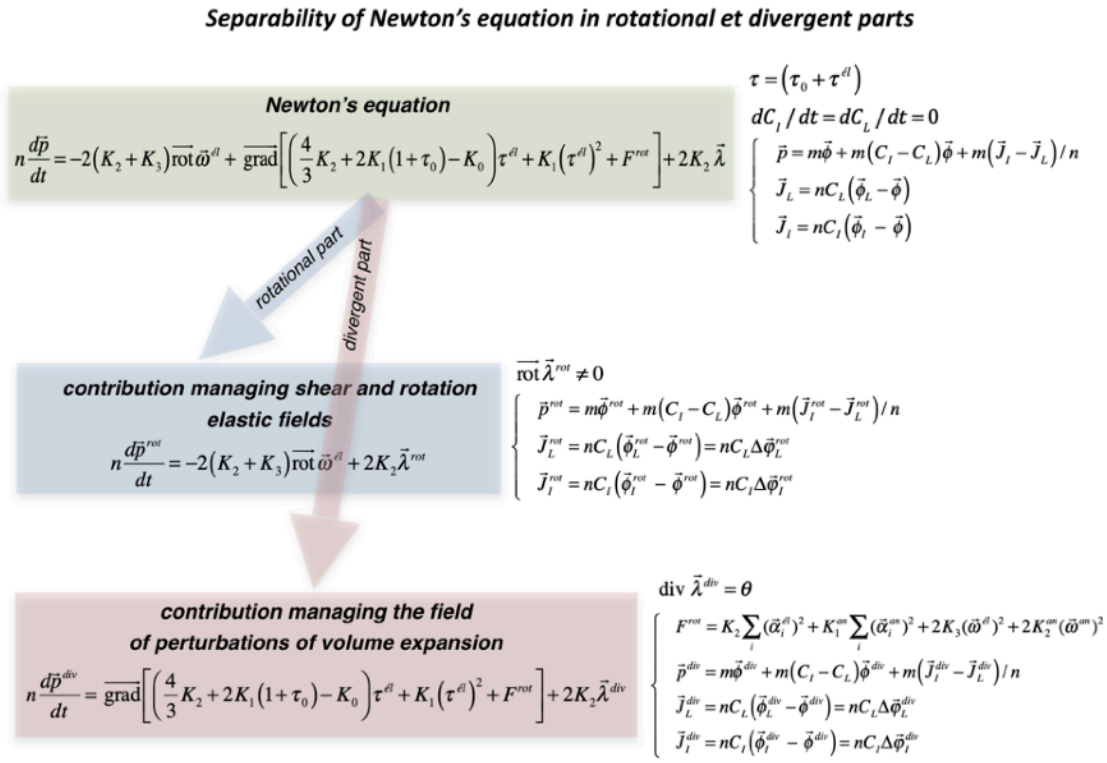


Figure 4.1 *- Separability of Newton's equation in rotational and divergent parts under conditions of homogenous concentrations of vacancies and self-interstitials*

- *a contribution managing the elastic fields of shears and rotation*, via the vector field of rotation $\vec{\omega}^{el}$. This contribution only depends on the volume expansion τ by the presence of the site density $n = n_0\,\mathrm{e}^{-(\tau_0+\tau^{el})}$,
- *a contribution managing the perturbation field of volume expansion*, which is dependent on the previous solution via the energy density F^{rot} of deformation by elastic and anelastic shears and rotations.

The density of flexion charges has also been split into two parts: *the "rotational" flexion charges* and *the "divergent" flexion charges*, which satisfy two relationships also shown in figure 4.1, and which allow the equation of Newton for expansion τ^{el} to be related to the flexion charge density θ within the lattice.

This splitting of Newton's equation in the case where the concentrations of vacancies and interstitials are homogeneous constants makes it possible to solve the problems of spatio-temporal evolution of the cosmological lattice, by separating the resolution of the elastic fields of shears and rotation of that of the volume expansion field. But as the density of sites

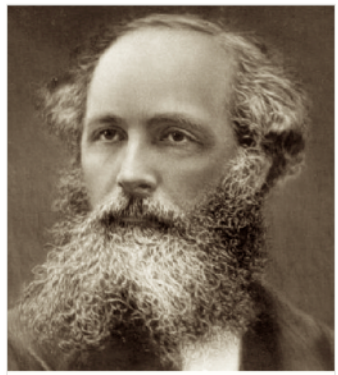
$n = n_0 \, e^{-(\tau_0 + \tau^{él})}$ intervenes at the same time in the rotational and divergent parts, there exists a certain coupling between the results of the two partial equations of Newton. However, with additional simplifying assumptions, it may be possible to solve these two sets of equations completely independently. This is what we will show in the following, considering the specific case where the volume expansion field can be considered to be quasi-constant.

«Maxwellian» behavior of the rotational part of Newton's equation

Let us now assume that the average value $\langle \tau \rangle = \tau_0 + \langle \tau^{él} \rangle$ of the volume expansion within the cosmological lattice can be considered as a first approximation as constant and homogeneous, so that the density n of sites can also be considered on average as a homogeneous constant. With this hypothesis, Newton's equation is reduced to its purely rotational part.

In this case, the torque vector $\vec{m}$ derives from a virtual equation of state, *the virtual volume density of free energy of elastic rotation*, linked to shear deformations and pure elastic rotations, without volume expansions, which is written $F^{él}_{rotation}\left(\vec{\omega}^{él}\right) = 2\left(K_2 + K_3\right)\left(\vec{\omega}^{él}\right)^2$. Still by assumption, we will also assume that *the lattice anelasticity* manifests itself only by shear and / or rotation, so that it can very well be represented here by an anelastic rotation vector $\vec{\omega}^{an}$.

The equations necessary for the complete description of the shears and elastic rotations of the cosmological lattice must still incorporate the topological equations for the elastic vector of rotation $\vec{\omega}^{él}$, namely the geometro-kinetic equation and the geometro-compatibility equation in the presence of dislocation charges. As the mass density ρ of inertia of the lattice is a constant $\rho = m\left(n + n_I - n_L\right) = mn\left(1 + C_I - C_L\right) = cste$, we deduce that $\mathrm{div}\left(n\vec{p}^{rot}\right) = -\partial\rho / \partial t = 0$. With all these considerations, we can finally deduce the complete set of equations reported in figure 4.2a, which describes the spatio-temporal evolution of the cosmological lattice in the presence of pure shears and local rotations.



James Clerk Maxwell (1831-1879)

The relationships thus obtained for the cosmological lattice in the local frame of reference $\boldsymbol{O}x_1x_2x_3$ mobile with the medium are then compared with *the Maxwell equations of electromagnetism* (figure 4.2b) in an electrically charged, conductive, magnetic and dielectric medium. We note that there is a very strong analogy between these two sets of equations, except for the fact that the evolution equations involve in principle the material derivative, while the Maxwell's equations involve the partial derivative with respect to time. However, it should be noted here that the material derivative in a local referential mobile with the medium can be replaced by the time partial derivative if the deformations remain sufficiently weak and / or slow in the vicinity of the origin of the local referential, this that we assumed in the table in figure 4.2a.

The analogy between the equations of a cosmological lattice taken with almost constant and homogeneous volume expansion and the Maxwell's equations of electromagnetism is quite remarkable, because it is absolutely complete, as the equations reported in the tables of figures 4.2a and b. The Maxwell's equations have a precise correspondence with the equations of the

$$\begin{cases} -\dfrac{\partial(2\vec{\omega}^{el})}{\partial t}+\overrightarrow{\mathrm{rot}}\,\vec{\phi}^{rot}\equiv(2\vec{J}) & = \textit{geometro - kinetic equation} \\ \mathrm{div}\,(2\vec{\omega}^{el})=(2\lambda) & = \textit{geometro - compatibility equation} \end{cases}$$

$$\begin{cases} \dfrac{\partial(n\vec{p}^{rot})}{\partial t}\equiv-\overrightarrow{\mathrm{rot}}\left(\dfrac{\vec{m}}{2}\right)+2K_2\vec{\lambda}^{rot} & = \textit{Newton's equation} \\ \mathrm{div}(n\vec{p}^{rot})=0 & = \textit{conservation equation of the mass density} \end{cases}$$

$$\begin{cases} (2\vec{\omega}^{el})=\dfrac{1}{(K_2+K_3)}\left(\dfrac{\vec{m}}{2}\right)+(2\vec{\omega}^{an})+\left(2\vec{\omega}_0(t)\right) & = \textit{phenomenology of elasticity and anelasticity} \\ (n\vec{p}^{rot})=(nm)\left[\vec{\phi}^{rot}+\left(C_I-C_L\right)\vec{\phi}^{rot}+\left(\dfrac{1}{n}\left(\vec{J}_I^{rot}-\vec{J}_L^{rot}\right)\right)\right] & = \textit{phenomenology of mass transport} \end{cases}$$

$$\begin{cases} \dfrac{\partial(2\lambda)}{\partial t}\equiv-\mathrm{div}(2\vec{J}) & = \textit{continuity of rotation charges} \end{cases}$$

$$\begin{cases} -\left(\dfrac{\vec{m}}{2}\right)(2\vec{J})\equiv \\ \vec{\phi}^{rot}\dfrac{\partial(n\vec{p}^{rot})}{\partial t}+\left(\dfrac{\vec{m}}{2}\right)\dfrac{\partial(2\vec{\omega}^{el})}{\partial t}-\mathrm{div}\left(\vec{\phi}^{rot}\wedge\left(\dfrac{\vec{m}}{2}\right)\right) & = \textit{equation of energetic balance} \end{cases}$$

$$\begin{cases} c_t=\sqrt{\dfrac{K_2+K_3}{mn}} & = \textit{celerity of transverse waves} \end{cases}$$

Figure 4.2a *- «Maxwellian» formulation* ***of evolution equations of the cosmological lattice*** *in a local frame* $Ox_1x_2x_3$ *mobile with the lattice*

rotations in the cosmological network: the Maxwell-Ampère equation corresponds to the geometro-kinetic equation, the Maxwell-Gauss equation to the geometro-compatibility equation, the equation of Maxwell-Faraday to the Newton's equation and finally the Maxwell-Thompson equation to the mass density conservation equation.

In fact, our equations contain an additional term for a *"rotational" flexion charge density* $\vec{\lambda}^{rot}$ in the second pair of equations, which has no counterpart in Maxwell's equations. Assuming then a cosmological lattice in which $\vec{\lambda}^{rot}$ can be neglected, namely that $\vec{\lambda}^{rot}\approx 0$, the analogy between the equations of the cosmological lattice and the Maxwell's equations becomes perfect, and deserves to be commented on in more detail.

Analogy between rotation charges and electric charges

The equations in tables 4.2a and b show a complete analogy between the density λ of rotation charges and the density ρ of electric charges, which are involved in the geometro-compatibility equation and in the Maxwell-Gauss equation, as well as between the vector flux $\vec{J}$ of rotation charges and the electric current density $\vec{j}$, which are involved in the geometro-kinetic equation and in the Maxwell-Ampère equation respectively.

$$\begin{cases} -\dfrac{\partial \vec{D}}{\partial t} + \overrightarrow{\mathrm{rot}}\,\vec{H} = \vec{j} \\ \mathrm{div}\,\vec{D} = \rho \end{cases}$$

= equation of Maxwell - Ampère

= equation of Maxwell - Gauss

$$\begin{cases} \dfrac{\partial \vec{B}}{\partial t} = -\overrightarrow{\mathrm{rot}}\,\vec{E} \\ \mathrm{div}\,\vec{B} = 0 \end{cases}$$

= equation of Maxwell - Faraday

= equation of Maxwell - Thompson

$$\begin{cases} \vec{D} = \varepsilon_0 \vec{E} + \vec{P} + \vec{P}_0(t) \\ \vec{B} = \mu_0 \left[\vec{H} + \left(\chi^{para} + \chi^{dia} \right) \vec{H} + \vec{M} \right] \end{cases}$$

= phenomenology of dielectricity

= phenomenology of magnetism

$$\begin{cases} \dfrac{\partial \rho}{\partial t} = -\mathrm{div}\,\vec{j} \end{cases}$$

= continuity of electric charges

$$\begin{cases} -\vec{E}\,\vec{j} = \\ \vec{H}\dfrac{\partial \vec{B}}{\partial t} + \vec{E}\dfrac{\partial \vec{D}}{\partial t} - \mathrm{div}\left(\vec{H} \wedge \vec{E} \right) \end{cases}$$

= equation of energetic balance

$$\begin{cases} c = \sqrt{\dfrac{1}{\varepsilon_0 \mu_0}} \end{cases}$$

= celerity of light

Figure 4.2b** - «Maxwellian» formulation of the **electromagnetism equations

The equation of continuity of the rotation charges is written in these tables considering that the source of rotation charges $S^{\lambda} = \left[d\left(\mathrm{div}\,\vec{\omega}^{\acute{e}l} \right) / dt - \mathrm{div}\left(d\vec{\omega}^{\acute{e}l} / dt \right) \right]$ described in figure 2.5 is zero ($S^{\lambda} = 0$), and it then corresponds to the equation of continuity of the electric charges when it is assumed the absence of creation and annihilation of electric charges. We immediately imagine that there is certainly a link between the source S^{λ} of rotation charges due to the non-commutation of the operators of time and space, and the phenomena of creation-annihilation of electric charges.

Analogy between anelasticity of the lattice and dielectricity of the matter

The phenomenon of anelasticity introduced here by the term $2\vec{\omega}^{an}$ becomes, in comparison with Maxwell's equations of electromagnetism, the analog of dielectric polarization $\vec{P}$ in the relation $\vec{D} = \varepsilon_0 \vec{E} + \vec{P} + \vec{P}_0(t)$, giving the electric displacement $\vec{D}$ according to the electric field $\vec{E}$ and the polarization $\vec{P}$ of matter. This analogy between the fields $2\vec{\omega}^{an}$ and $\vec{P}$ is very strong since the possible phenomenological behaviors of these two quantities are completely similar, with in both cases relaxation, resonant or hysteretic behaviors described in

detail in the book[1]. For example, in the case of pure relaxation, it is possible to link $\vec{\omega}$ to $\vec{m}$ via a complex modulus, just as it is possible to link $\vec{D}$ to $\vec{E}$ via a complex dielectric coefficient in electromagnetism. In fact, a closer comparison would even show that the behaviors associated with thermal activation, and therefore temperature, also present analogies.

As for the term of homogeneous dielectric polarization $\vec{P}_0(t)$ that we have introduced here, it is analogous to a term of global rotation $2\vec{\omega}_0(t)$ of the lattice, therefore of the local frame in the absolute referential of the ***GO***. This term of analogy therefore disappears if the local coordinate system $\boldsymbol{O}x_1x_2x_3$ is only in translation $\vec{\phi}_{\boldsymbol{O}}(t)$ with respect to the absolute referential.

Analogy between mass transport in the lattice and magnetism in the matter

As the quantity $n\vec{p}^{rot}$ represents both the average momentum per unit volume of the solid and the average mass flow within the solid, we deduce that the mass flow within the solid is due both to a mass transport $nm\vec{\phi}^{rot}$ at velocity $\vec{\phi}^{rot}$ by the movement of the lattice, to a mass transport $nm\left(C_I - C_L\right)\vec{\phi}^{rot}$ at velocity $\vec{\phi}^{rot}$ by the driving movement of point defects by the lattice and to a mass transport $m\left(\vec{J}_I^{rot} - \vec{J}_L^{rot}\right)$ due to the phenomenon of self-diffusion of vacancies and interstitials.

Each of these mass transports has an analog in Maxwell's equations of electromagnetism. Mass transport $nm\vec{\phi}^{rot}$ via the lattice is analogous to the basic term $\mu_0\vec{H}$ of *magnetic induction* in the vacuum. The mass transport $nm\left(C_I - C_L\right)\vec{\phi}^{rot}$ by entrainment of point defects by the lattice corresponds perfectly to the term $\mu_0(\chi^{para} + \chi^{dia})\vec{H}$ of magnetism, in which the magnetic susceptibility consists of two parts: the positive paramagnetic susceptibility χ^{para}, which therefore becomes the analog of the concentration of interstitials, and the negative diamagnetic susceptibility χ^{dia}, which is therefore analogous to the concentration of vacancies.

As for the phenomenon of self-diffusion by vacancies and interstitials, it appears in these equations by the term $n\vec{p}^{rot}_{auto-diffusion} = m\left(\vec{J}_I^{rot} - \vec{J}_L^{rot}\right) = mn\left(C_I\Delta\vec{\varphi}_I^{rot} - C_L\Delta\vec{\varphi}_L^{rot}\right)$ connecting the last part of $n\vec{p}^{rot}$ to the velocities $\Delta\vec{\varphi}_L^{rot}$ and $\Delta\vec{\varphi}_I^{rot}$ of self-diffusion of point defects.

The term $\left(\vec{J}_I^{rot} - \vec{J}_L^{rot}\right)/n = C_I\Delta\vec{\varphi}_I^{rot} - C_L\Delta\vec{\varphi}_L^{rot}$ associated with this mass transport by self-diffusion of point defects becomes, in comparison with Maxwell's equations of electromagnetism, the perfect analogue of the magnetization $\vec{M}$ of matter in the relation giving magnetic induction $\vec{B}$. The analogy between the fields $C_I\Delta\vec{\varphi}_I^{rot} - C_L\Delta\vec{\varphi}_L^{rot}$ and $\vec{M}$ is very strong since there are similar phenomenological behaviors of these two quantities, like relaxation behaviors described in the book[1], which derive from transport equations and which implicitly assume that the self-diffusion processes are of Markovian type, therefore that they do not depend on history, that is to say on the previous transport processes, which is the case of usual solids.

But nothing precludes a priori from imagining solid lattices for which the transport processes would not be of the Markovian type. As an example, we can imagine a hypothetical lattice in which the vacancies are very strongly anchored in the lattice, while the interstitials are almost

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[1] *G. Gremaud, "Théorie eulérienne des milieux déformables – charges de dislocation et désinclinaison dans les solides", Presses polytechniques et universitaires romandes (PPUR), Lausanne (Switzerland) 2013, 751 pages, ISBN 978-2-88074-964-4*
G. Gremaud, "Eulerian theory of newtonian deformable lattices – dislocation and disclination charges in solids", Amazon, Charleston (USA) 2016, 312 pages, ISBN 978-2-8399-1943-2

free to move there. The momentum $n\vec{p}^{rot}$ within the solid would then be written $n\vec{p}^{rot} = nm\left[\vec{\phi}^{rot} + \left(C_I - C_L\right)\vec{\phi}^{rot} + C_I\Delta\vec{\varphi}_I^{rot}\right]$, and the mass transport $n\vec{p}^{rot}$ would now contain a term $\left(2C_I - C_L\right)\vec{\phi}^{rot}$ associated with both the vacancies and the interstitials, whose coefficient $\left(2C_I - C_L\right)$ is analogous to magnetic susceptibility χ in electromagnetism, and which can take a positive or negative value depending on concentrations C_I and C_L of point defects. It would also contain the term $nmC_I\Delta\vec{\varphi}_I^{rot}$ associated with a mass transport by inertial conservative movement of interstitials, perfectly analogous to the permanent magnetization $\vec{M}$ of ferromagnetic and antiferromagnetic materials in electromagnetism.

The presence of a constant term $nmC_I\Delta\vec{\varphi}_I^{rot}$ in $n\vec{p}^{rot}$ would then correspond very clearly to a non-Markovian type process, since the value of $\Delta\vec{\varphi}_I^{rot}$ must essentially depend on the history of this hypothetical solid lattice. One could imagine for example that the movement of the interstitials is controlled by a dry type friction with the lattice, in which case there would exist a critical force of depinning of the interstitials, which would lead to the appearance of hysteresis cycles of $\Delta\vec{\varphi}_I^{rot}(t)$ depending on $\Delta\vec{\varphi}_I^{rot}(t)$, absolutely analogous to the hysteresis cycles of magnetization $\vec{M}(t)$ as a function of the magnetic field $\vec{H}(t)$ observed in ferromagnetic or antiferromagnetic materials.

The complete analogy with the physical quantities of the electromagnetism theory

The analogy reported in the tables of figures 4.2a and b between the equations of a cosmological lattice taken with almost constant and homogeneous volume expansion and the Maxwell's equations of electromagnetism is quite remarkable, because it is absolutely complete, and it also calls upon very similar relaxation and hysteretic processes in the two systems. The complete analogy which exists between the physical quantities of our approach and the electromagnetic quantities of Maxwell's approach of electromagnetism can be reported in tables of figures 4.3a and b.

The effects of volume expansion of the lattice in the absolute frame of GO

In this analogy, the existence of a uniform translation at non-zero velocity $\vec{\phi}_O(t)$ of the lattice, therefore of the local frame $Ox_1x_2x_3$ of reference with respect to the absolute frame $Q\xi_1\xi_2\xi_3$ of reference of ***GO***, would have for analogy, in Maxwell's equations, a homogeneous magnetic field $\vec{H}_0(t)$ in space. This last remark implies that, if a solid lattice was expanding in the absolute frame of ***GO*** there should appear a field $\vec{\phi}_O(t)$ in the local frames $Ox_1x_2x_3$. This field $\vec{\phi}_O(t)$ should have for analogous *a locally homogeneous magnetic field* $\vec{H}_0(t)$ *in space if the Universe was in expansion*, and which would point in the direction of the movement of the local frame of reference of the observer compared to the absolute space.

Are there "magnetic monopoles" in this analogy?

The equation $\mathrm{div}(n\vec{p}^{rot}) = 0$ reflects the fact that we consider a solid with a uniform and static volume expansion field. The existence of a non-zero and constant value of $\mathrm{div}(n\vec{p}^{rot})$, such that $\mathrm{div}(n\vec{p}^{rot}) = \mathrm{div}\left[mn\left(1 + C_I - C_L\right)\vec{\phi}^{rot}\right] + \mathrm{div}\left[m\left(\vec{J}_I^{rot} - \vec{J}_L^{rot}\right)\right] \neq 0$ would imply that there is a constant and divergent field of velocity $\vec{\phi}^{rot}$ of the lattice sites, and therefore, with the

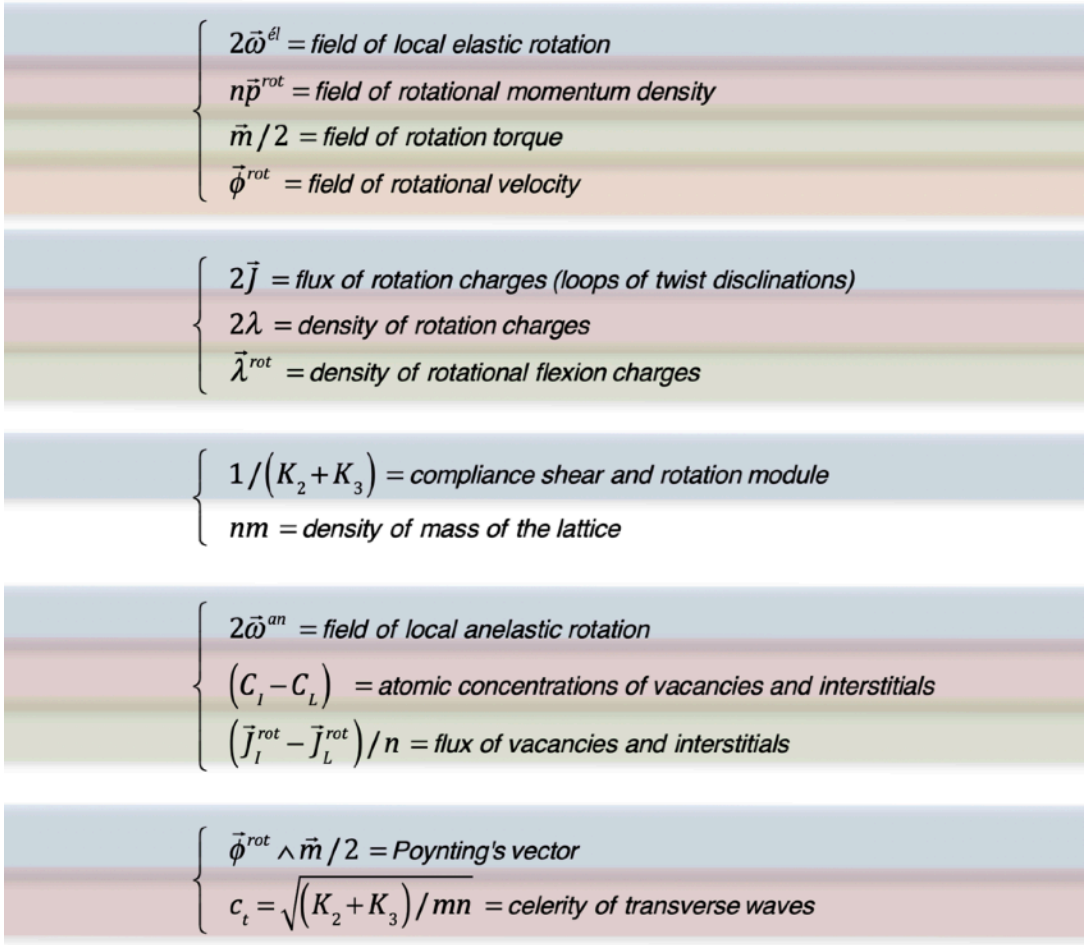

Figure 4.3a *- Complete analogy between* ***the physical quantities of the cosmological lattice*** *and the electromagnetic quantities of the Maxwell's equations*

assumption that $\tau = cste$, a non-zero source S_n of lattice sites, or that there would be a constant and divergent flow of self-diffusion $m\left(\vec{J}_I^{rot} - \vec{J}_L^{rot}\right)$, which would necessarily require localized and non-zero sources of point defects S_L^{pl} and / or S_I^{pl}, which is very difficult to imagine.

Within the framework of the analogy with electromagnetism, a relation $\mathrm{div}(n\vec{p}^{rot}) = cste \neq 0$ would have for analogy the relation $\mathrm{div}\,\vec{B} = cste \neq 0$. However, this last relation reveals the well-known notion of *magnetic monopoles*, of *particles of unipolar magnetic charge*, proposed by certain theories, but never observed experimentally. According to our analogy with the cosmological lattice, magnetic monopoles could not be stable particles, but should correspond to localized and continuous sources of lattice sites or point defects, which is particularly difficult to imagine. We deduce from this that in our analogy, the existence of magnetic monopoles as electromagnetically isolated particles is not possible.

Are there "vector electric charges" in this analogy?

One can legitimately wonder what the analogy of the density of "rotational" flexion charges $\vec{\lambda}^{rot}$ could be in Maxwell's equations. If there existed a quantity analogous to $\vec{\lambda}^{rot}$ in Maxwell's

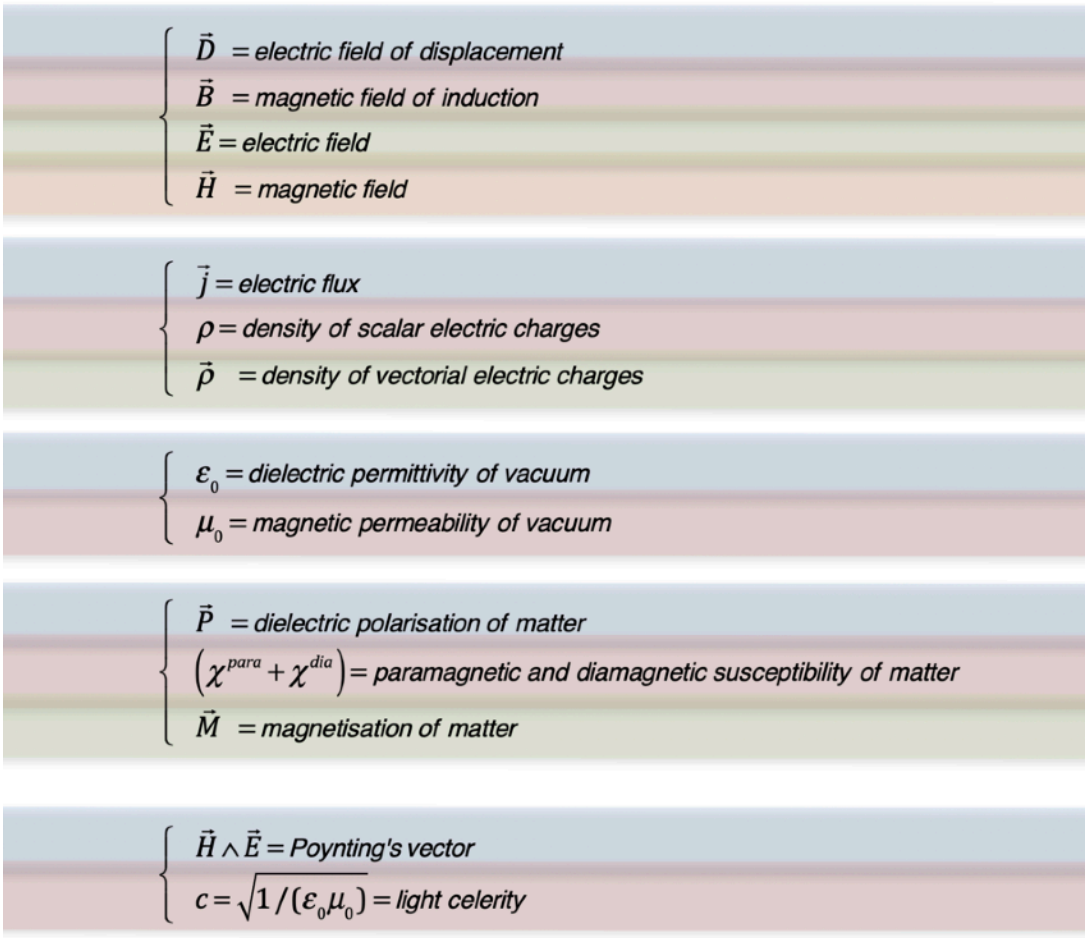

Figure 4.3b *- Complete analogy between the physical quantities of the cosmological lattice and* ***the electromagnetic quantities of the Maxwell's equations***

equations, we could hypothetically qualify it as *the density* $\vec{\rho}$ *of "vector electric charges"* by making the following analogy $\vec{\rho}\Leftrightarrow\vec{\lambda}^{rot}$. Maxwell's equations would then be written a little differently from known equations, with an additional charge term not in the equation $\mathrm{div}\,\vec{B}=0$ as suggested by magnetic monopole theories, but in the Maxwell-Faraday equation as follows $\partial\vec{B}/\partial t=-\overrightarrow{\mathrm{rot}}\,\vec{E}+\kappa\vec{\rho}$, in which κ is a new electrical coefficient, analogous to the module $2K_2$: $\kappa\Leftrightarrow 2K_2$.

In the static case, if such a vector charge really existed, the equation containing it would be written as follows $\overrightarrow{\mathrm{rot}}\,\vec{E}=\kappa\vec{\rho}$, and would have the analogous equation $\overrightarrow{\mathrm{rot}}\left(\vec{m}/2\right)=2K_2\vec{\lambda}^{rot}$ in the cosmological lattice. It would therefore imply for the displacement field that $\overrightarrow{\mathrm{rot}}\,\vec{D}=\varepsilon_0\kappa\vec{\rho}$, so that *the density* $\vec{\rho}$ *of "vector electric charges"* would be a source of a rotational electric field $\vec{E}$ and of a rotational electric displacement field $\vec{D}$, just as the scalar density ρ of electric charges is a source of a divergent electric displacement field $\vec{D}$ by the relation $\mathrm{div}\,\vec{D}=\rho$. If we now compare the coefficients of the two theories, we obtain, from the analogies $\varepsilon_0\Leftrightarrow 1/\left(K_2+K_3\right)$ and $\kappa\Leftrightarrow 2K_2$, that there is the following analogy $\varepsilon_0\kappa\Leftrightarrow 2K_2/(K_2+K_3)$ between the coefficients of the two theories.

However, experimental observations have never revealed the existence of such "vectorial

electric charges". In fact, this can be explained quite simply by the fact that the topological singularities considered in the cosmological lattice will always be exclusively twist disclination loops, edge dislocation prismatic loops and mixed dislocation glide loops, and in the case of such loops, it is easy to see that the overall vectorial charge $\vec{q}_{\vec{\lambda}}$ obtained by integrating the linear flexion charge $\vec{\Lambda}$ on the contour of the loop is zero, so that the vectorial electric charge density $\vec{\rho}$ obtained as the average value of the sum of all the vectorial charges $\vec{q}_{\vec{\lambda}}$ contained per unit volume is necessarily zero, so that $\vec{\rho}=0$. We can therefore introduce here a new conjecture for our approach, namely:

Conjecture 5 - *There are no localized electrical vector charges $\vec{q}_{\vec{\lambda}}$ in the cosmological lattice, so that the charge density $\vec{\rho}$ of vectorial electrical charges is necessarily zero in Maxwell's equations:*

$$\vec{\rho}=0$$

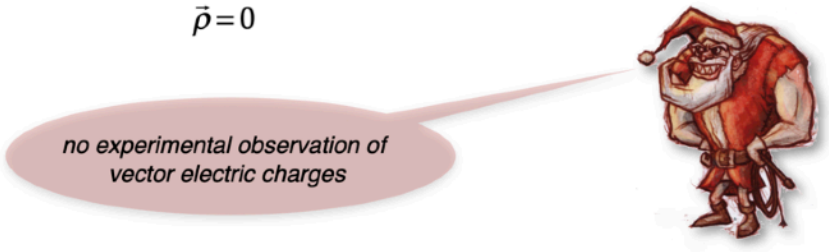

Figure 4.4 - *The fifth conjecture that concludes to the non-existence of "vector electrical charges"*

Note that there could perhaps be long "strings" of edge dislocation that would cross the entire cosmological lattice and that would indeed have a linear density $\vec{\Lambda}$ of vector electric charge, which would then effectively cause a non-zero density $\vec{\rho}$ of vector electric charge to appear in Maxwell's equations. But this is a somewhat extravagant hypothesis.

The importance of this analogy

In fact, the existence of an analogy between two theories is always very fruitful in physics, by the reciprocal contribution of each of the theories. In our case, it is clear that this analogy with the theory of electromagnetic fields will allow us in the following to use for the description of a lattice all the arsenal of theoretical tools developed since a very long time in field theory, such as for example the Lorentz transformation or the theory of delayed potentials.

In the other sense, the approach developed here is in fact a much more complex theory than classical electromagnetism, since it follows from a tensor theory which can be reduced to a vector theory by contraction on the tensor indices, and moreover, by choosing particular “restrained” cases of behavior of the solid lattice, such as the constancy and the homogeneity of the volume expansion. By taking into account the tensorial aspect of the theory of solid lattices and by renouncing to the "clamping" of the behaviors of these, the analogy will become particularly interesting and fruitful, as we will see later.