Chapter 5

Topological singularities within the cosmological lattice

Newton's equation can also be separated differently into *two partial Newton's equations* which allow on the one hand to calculate the elastic distortion fields associated with the topological singularities contained in the lattice, and on the other hand to calculate the perturbations of the volume expansion associated with the elastic distortion energies of these topological singularities. Using Newton's first partial equation, we can then describe the elastic distortion fields and energies of topological singularities within a cosmological lattcie. It is thus possible to find conditions on the elastic modules of this lattice such that it is possible to attribute in a completely classic way a mass of inertia to the topological singularities, which always satisfies the famous *«Einstein's formula"* $E_0 = M_0 c^2$.

Separability of Newton's equation in three partial equations in the presence of a topological singularity

Suppose the existence of a localized singularity of dislocation charges of spherical, tubular or membrane shape, containing charge densities $\vec{\lambda}_i$, $\vec{\lambda}$ and / or λ , and suppose that one can neglect the anelasticity and the self-diffusion in the lattice , by assuming that $\vec{\alpha}_i^{an} = \vec{\omega}^{an} = 0$ and that $dC_I / dt = dC_L / dt = 0$. The presence of a localized singularity of dislocation charges can be introduced into this equation by considering that the fields prevailing in the lattice are of three different natures: the elastic fields due to the charges of the singularity, which will be indexed *(ch)*, the fields independent of the singularity within the lattice, which are due for example to the other singularities, and which will be indexed *(ext),* the background field τ_0 of the volume expansion of the lattice and finally a perturbation field $\tau^{(p)}$ of the volume expansion due to the energy of distortion F_{dist} stored in the lattice by the elastic fields of the considered singularity. These fields represented in figure 5.1 can be introduced into Newton's equation, which can be developed by judiciously grouping the different terms, and we note that the Newton equation is in fact composed of three coupled equations which manage the different fields prevailing in the lattice, and which we have reported in figure 5.1.

Newton's third partial equation deals with *fields external to the singularity* associated with thw velocity $\vec{\phi}^{ext}$. But this Newton's equation is not in fact perfectly independent of the other fields, due to the presence of $n = n_0 \exp\left[-\left(\tau_0 + \tau^{ch} + \tau^{ext} + \tau^{(p)}\right)\right]$ in the expression of the momentum associated with $\vec{\phi}^{ext}$. One can suppose, to simplify the problem of the treatment of the fields specific to the singularity, that the external field τ^{ext} can be regarded as constant, that is to say $\vec{\phi}^{ext} = 0$ and $\tau^{ext} = \tau^{ext}(\vec{r})$, in which case the equation put in its static form becomes perfectly independent of fields τ^{ch} and $\tau^{(p)}$.

As for the fields $\vec{\omega}^{ch}$, τ^{ch} and $\tau^{(p)}$, which are associated with the singularity, they then satisfy two other strongly coupled partial Newton's equations, which we will discuss now.

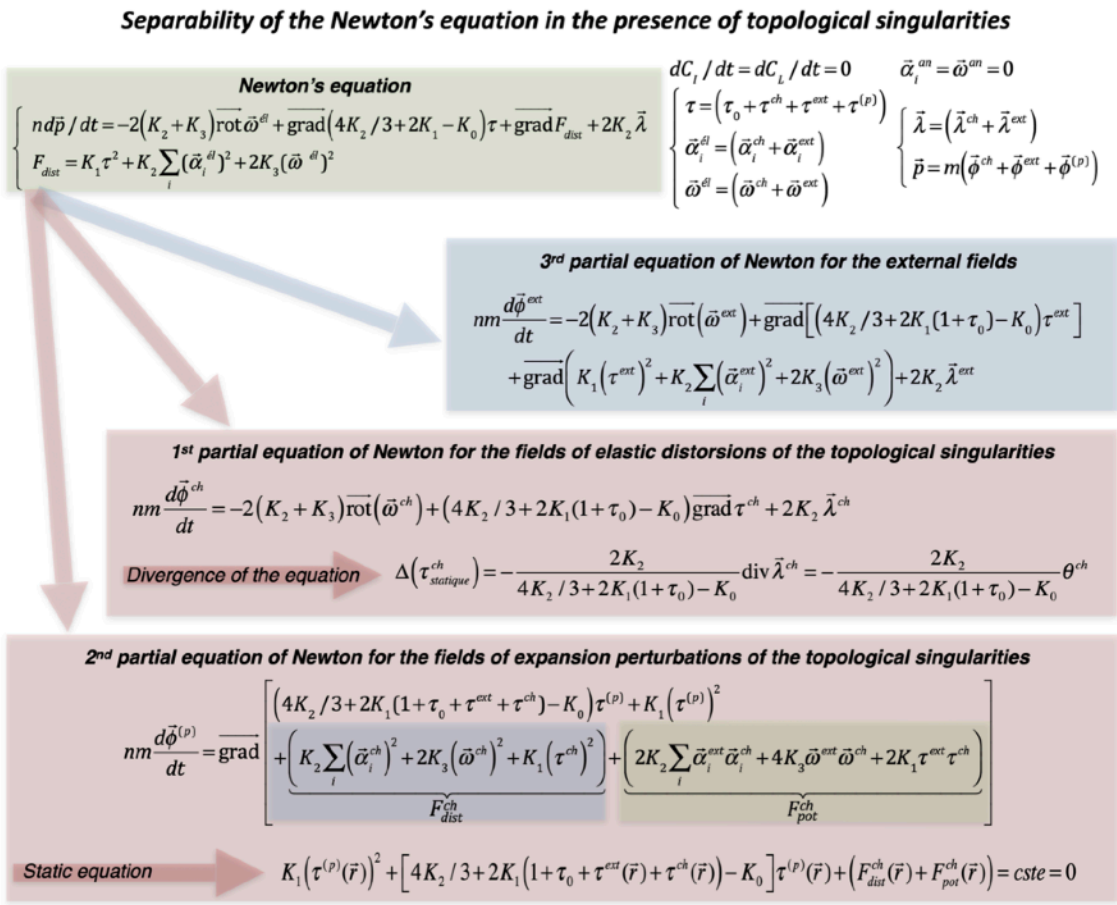


Figure 5.1 *- Separability of the Newton's equation in three partial equations in the presence of topological singularities*

Newton's first partial equation is concerned with *the fields of elastic distortions* $\vec{\omega}^{ch}$ *and* τ^{ch} *associated with the charges contained in the singularity*. This equation is coupled to the fields τ^{ext} andt $\tau^{(p)}$ by the value $n = n_0 \exp\left[-\left(\tau_0 + \tau^{ch} + \tau^{ext} + \tau^{(p)}\right)\right]$ appearing in the expression of the momentum associated with $\vec{\phi}^{ch}$. In the static case, this coupling disappears, so that it makes it possible to deduce the static fields of elastic distortions $\vec{\omega}^{ch}$ and τ^{ch} generated by the topological singularity in a completely independent way from the fields τ^{ext} and $\tau^{(p)}$.

One notes also that this first partial equation of Newton depends on the density $\vec{\lambda}^{ch}$ of flexion charges of the singularity. The divergence of this equation in its static form then provides a static equation depending on the density θ^{ch} of curvature charges of the singularity, since the divergence of the density $\vec{\lambda}^{ch}$ of flexion charges is equal to the density θ^{ch} of curvature charges of the singularity, which is also shown in figure 5.1.

The second partial Newton's equation which can be extracted deals with the problem of the perturbations $\tau^{(p)}$ of the expansion field by the elastic energy stored in the lattice by the singularity. It is clear that this last equation is very strongly coupled to the fields $\vec{\omega}^{ext}$, τ^{ext}, $\vec{\omega}^{ch}$ and τ^{ch} deduced from the two other Newton's equations. First, there is a dynamic coupling via the term $n = n_0 \exp\left[-\left(\tau_0 + \tau^{ch} + \tau^{ext} + \tau^{(p)}\right)\right]$ appearing in the expression of the momentum associated with $\vec{\phi}^{(p)}$. There also appears a coupling term associated with the module K_1 in the form $2K_1(1+\tau_0+\tau^{ext}+\tau^{ch})$. But the main coupling terms are those due to the elastic energy

of the singularity and to the coupling energy of the singularity with the external fields, which appear in two particular contributions which have very precise meanings:
- *the density of elastic energy* F_{dist}^{ch} stored in the lattice by the elastic fields due to the singularity, in other words *the energy density of distortion of the singularity,*
- *the energy density* F_{pot}^{ch} *of coupling* of the singularity with the external fields, in other words *the potential energy density of the singularity.*

These two terms $F_{dist}^{ch}(\vec{r},t)$ and $F_{pot}^{ch}(\vec{r},t)$ are obtained by solving the first partial equation and the third partial equation. *In the static case,* if we have solved these two equations taken in the static state, and we therefore know the equilibrium values of the fields $\vec{\omega}^{ext}(\vec{r})$, $\tau^{ext}(\vec{r})$, $\vec{\omega}^{ch}(\vec{r})$ and $\tau^{ch}(\vec{r})$, the second partial equation becomes an equilibrium equation for the static field of perturbation whose solution is an equation of the second degree in $\tau^{(p)}(\vec{r})$, which is also reported in figure 5.1. The constant $cste$ was introduced when passing from the gradient to the gradient argument. However, as $\tau^{(p)}(\vec{r})$ must necessarily be identically zero if the energy $F_{dist}^{ch}(\vec{r})+F_{pot}^{ch}(\vec{r})$ is zero, this constant can only be zero.

Applications and potentialities of the separability of Newton's equation

The decomposition of Newton's equation into three partial equations that we have just presented reveals a partial equation (the 3rd) for the external fields, a partial equation (the 1st) for the elastic distortion fields associated with the presence of a topological singularity and a partial equation (the 2nd) for the expansion perturbation fields due to the elastic distortion energies associated with the topological singularity. The methodology to be used to solve the problem of fields associated with a topological singularity is then the following:
- in a first step, we must independently solve the first partial Newton's equation, in order to find the elastic distortion fields $\vec{\omega}^{ch}$ and τ^{ch} generated by the singularity, without taking into account the expansion perturbations due to energies $F_{dist}^{ch}(\vec{r},t)$ and $F_{pot}^{ch}(\vec{r},t)$ of the singularity,
- then, starting from the elastic fields $\vec{\omega}^{ch}$ and τ^{ch} obtained previously by the first partial Newton's equation, the additional perturbations $\tau^{(p)}(\vec{r},t)$ of the expansion field due to the elastic energies $F_{dist}^{ch}(\vec{r},t)$ and $F_{pot}^{ch}(\vec{r},t)$ of the singularity are calculated using the second partial equation, or using the second degree equation in the static case.

At first glance this process seems quite complex, but it contains enormous potential with regard to the description and interpretation of the behaviors of topological singularities within the cosmological lattice. Indeed, we will show in the following that it becomes possible to deal with the following themes:
- the existing link between the "first partial Newton equation" for elastic distortion fields and Einstein's Special Relativity: the first partial Newton equation allowing to find the elastic distortion fields associated with topological singularities will allow us to calculate the fields and energies associated with screw dislocations, edge dislocations, screw dislocation loops, edge dislocation loops and mixed dislocation loops, and to show that these fields are subject to a relativistic dynamic, which will lead us to discuss the *"ether role"* that the cosmological lattice plays with respect to topological singularities, as well as analogies and differences with Einstein's Special Relativity.
- the link between Newton's second partial equation for expansion perturbation fields and Einstein's General Relativity and Quantum Physics: Newton's second partial equation for finding

the associated volume expansion perturbations is also very important. Indeed, we will see that this one, if applied to macroscopic clusters of singularities with a rather low mass density, leads to the existence of a static volume expansion field, which is deduced from Newton's second partial equation in its static form, and which allows to find the gravitational effects, and to discuss the analogies and differences of our approach with Newton's Gravitation, Einstein's General Relativity and the Modern Cosmology of the Universe. Then we will also see that this partial equation, if applied to microscopic singularities of high mass density, cannot present static solutions and must therefore be solved in its dynamic form, which allows us to find Quantum Physics, and to discuss the analogies and differences with Schrödinger's equations, the concepts of fermions and bosons, Heisenberg's uncertainty and Pauli's exclusion principles, and the notions of spin and magnetic moment of elementary particles.

The fact that the mass density of clusters of singularities plays a considerable role in the resolution of the second partial Newton equation in static or dynamic form is quite remarkable, as this will provide *an objective criterion for quantifying the quantum decoherence phenomenon which is the basis for a realistic explanation of the quantum phenomenon.*

Elastic energy, kinetic energy and inertial mass of a dislocation

It is possible to calculate the distortion energy and the kinetic energy of a dislocation string in the cosmological lattice. The distortion energy is obtained by calculating the lattice distortions associated with the presence of the dislocation and by summing the elastic energy due to these distortions in the whole lattice. Similarly, the kinetic energy associated with the movement of a dislocation moving at low velocity $\vec{\boldsymbol{v}}$ compared to the celerity c_t of the transverse waves is obtained by calculating the velocities of all the points of the lattice associated with the movement of the dislocation and by summing the kinetic energy which is associated with these movements in the whole lattice. If these calculations are easy enough to do in the case of a screw dislocation, they become very difficult in the case of an edge dislocation. We will not dwell on it here and will give the results obtained in the cosmological lattice in figure 5.2. These complete calculations can be found in the theoretical book *«Universe and Matter conjectured as a 3-dimensional Lattice with Topological Singularities»* published in 2016.

In these relations, we note that the elastic and kinetic energies depend on the proper dimensions of the cosmological lattice, via the expression $\ln(R_\infty / a)$, in which R_∞ is *the external dimension of the cosmological lattice* and a is *the step of the cosmological lattice*, with obviously $R_\infty >> a$. These energies also depend on the squares Λ^2 and $\vec{\Lambda}^2$ of the linear densities of charges of the screw and edge dislocations respectively.

By comparing the kinetic energy E_{cin}^{screw} stored in the lattice by the movement of the line of screw dislocation with the elastic potential energy E_{dist}^{screw} stored in the lattice by the presence of this same line, one finds the famous *expression of Einstein* $E_{dist}^{screw} = M_0^{screw} c_t^2$ *connecting the mass of inertia to the rest energy of the dislocation via the celerity of the transverse waves*. But this relation is found here *without in any way calling upon a relativistic dynamic of the line*, because it is due to the fact that the rest energy and the kinetic energy are nothing other than elastic potential energy (of shear and local rotation) and kinetic energy stored within the lattice by the dynamic deformation imposed on this lattice by the elastic distortion fields (shear and local rotation) of the mobile screw dislocation.

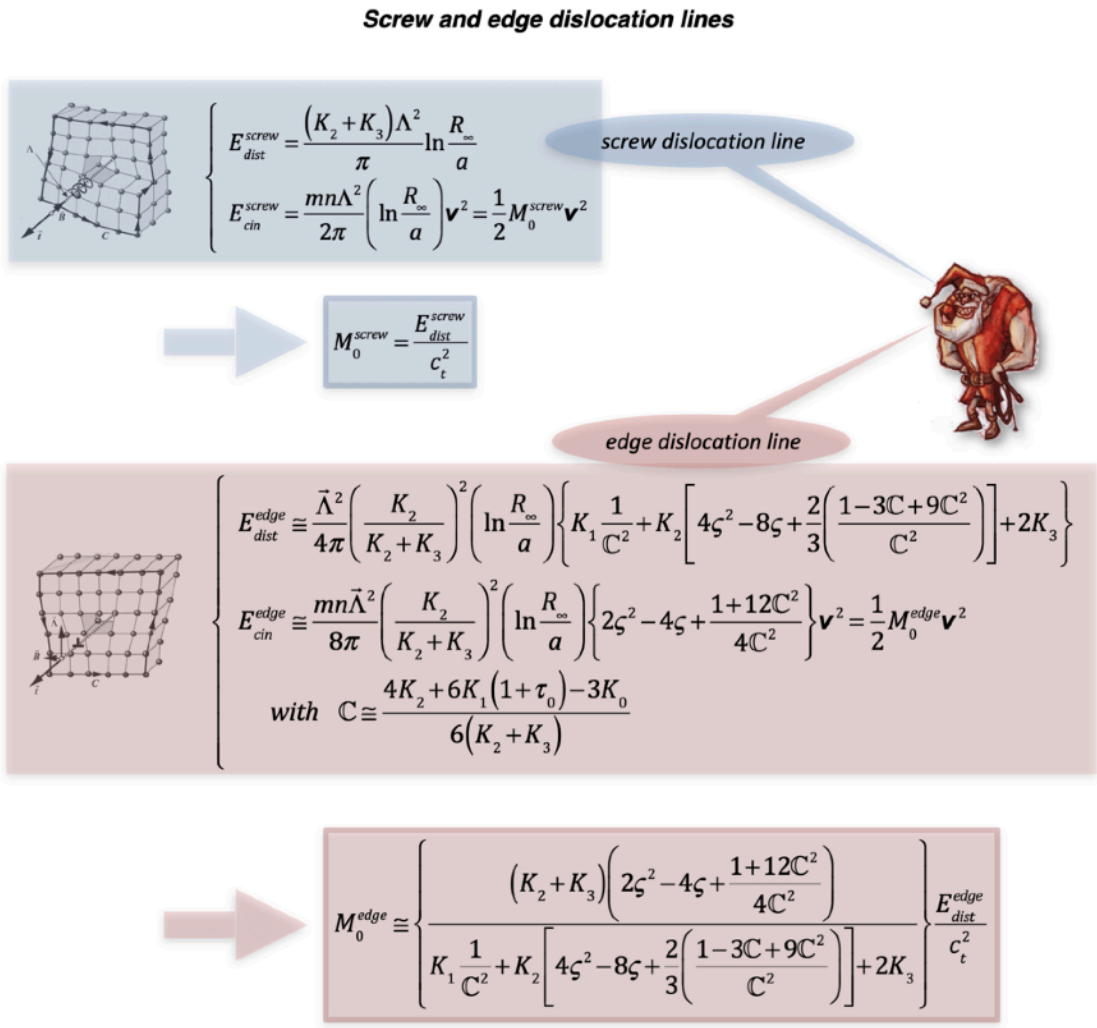


Figure 5.2 - *Elastic energy, kinetic energy and mass of inertia of a screw dislocation and an edge dislocation in the cosmological lattice*

In the case of the edge dislocation, it is very different. It is observed in fact that the resting energy depends in a rather complicated way on the four elastic modules K_0, K_1, K_2, K_3, in particular via a parameter $\mathbb{C}$, and that it also appears a parameter ς which depends in fact on the boundary conditions of the lattice which are used to carry out the computations of energies. Likewise, the relation between the energy of distortion and the mass of inertia of an edge dislocation differs quite strongly from Einstein's relation via the term reported between braces, which depends on the parameter ς and the modules K_0, K_1, K_2, K_3, in particular via the module $\mathbb{C}$.

To ensure a complete analogy between the topological singularities of our approach and the particles of the real universe, it would be desirable that the edge dislocations also exactly satisfy Einstein's relation. However, for an edge dislocation satisfies this relation, the term between braces in the relation between the energy of distortion and the mass of inertia of the edge dislocation must be equal to 1.

Since the lattice under consideration is finite, the conditions at the lattice boundaries are free. We can then show that the value of the parameter ς is the one that will minimize the distortion energy of the edge dislocation, and this condition implies that $\varsigma = 1$. We can then show that, for the edge dislocations to also satisfy Einstein's relation, the modules K_0, K_1, K_2, K_3 must satisfy fairly strict conditions that we will issue in the form of a conjecture, conjecture 6 in figure 5.3, which states that the modules K_0 and K_3 are equal and positive, and modules K_1 and K_2 are also positive (or zero), but much smaller than the modules K_0 and K_3.

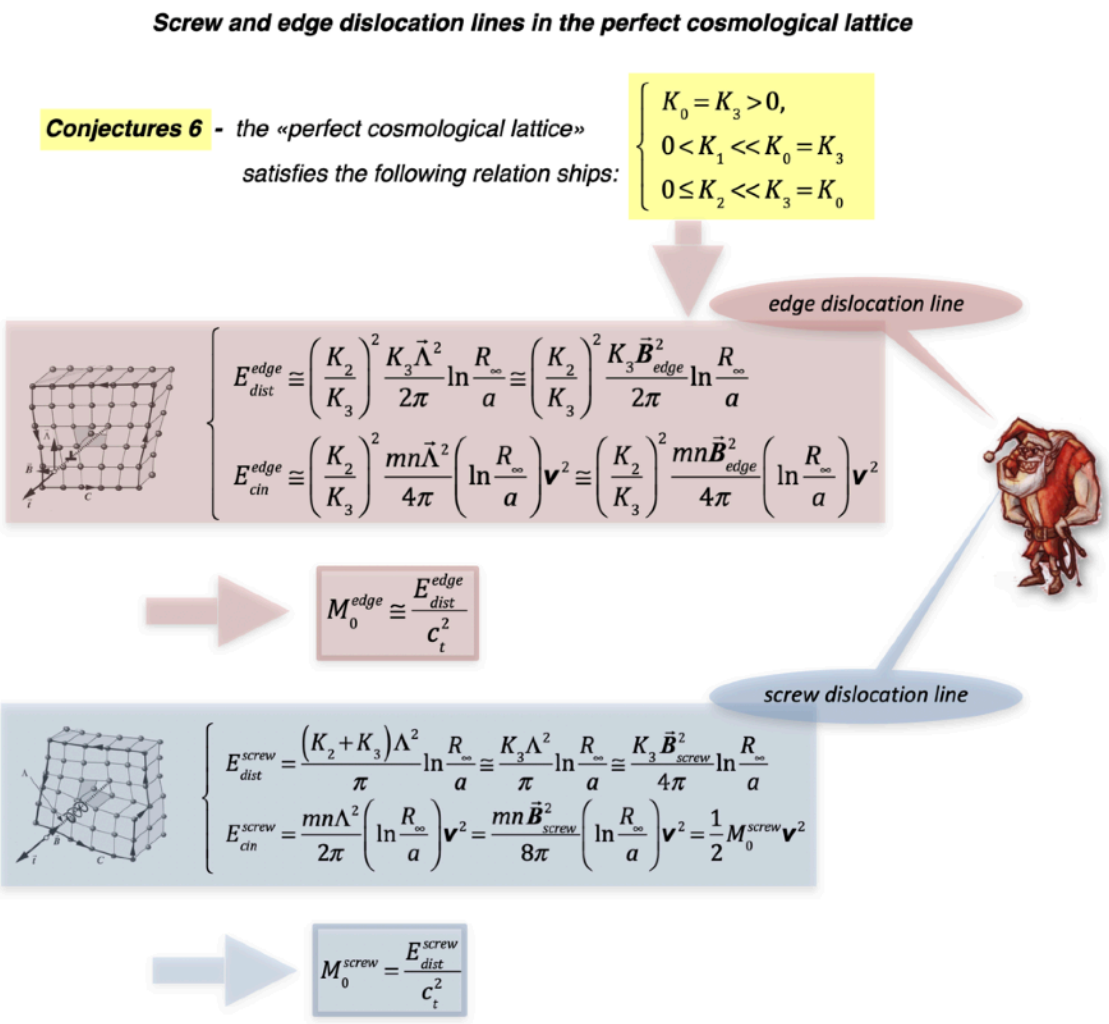


Figure 5.3 *- Elastic energy, kinetic energy and mass of inertia of a screw dislocation and an edge dislocation in the perfect cosmological lattice satisfying the sixth conjecture*

This set of conditions expressed by the sixth conjecture will ensure that the screw and edge dislocations both satisfy real Einstein's relations, which are deduced in a purely classical manner, without making appeal to a principle of special relativity, which are written $M_0^{screw} \cong E_{dist}^{screw} / c_t^2$ and $M_0^{edge} \cong E_{dist}^{edge} / c_t^2$ respectively. The cosmological lattice thus obtained will be qualified as a *perfect cosmological lattice*.

We note that the potential energy and the non-relativistic kinetic energy of an edge dislocation in *the perfect cosmological lattice* are both *extremely weaker* than the potential energy and the non-relativistic kinetic energy of a screw dislocation since, for a screw dislocation and an edge dislocation of Burgers vectors of the same norm $\left|\vec{\boldsymbol{B}}_{edge}\right| = \left|\vec{\boldsymbol{B}}_{screw}\right|$, we have $E_{dist}^{edge} \cong 2\left(K_2 / K_3\right)^2 E_{dist}^{screw} <<< E_{dist}^{screw}$ and $E_{cin}^{edge} \cong 2\left(K_2 / K_3\right)^2 E_{cin}^{screw} <<< E_{cin}^{screw}$. We will see later what important role can be attributed, in our analogy with the physical theories of the Universe, to the facts that edge dislocations exactly follow Einstein's relation and that they also present much weaker energies than screw dislocations in a perfect cosmological lattice satisfying the relationships of conjecture 6.

Spherical singularities of rotation and curvature charges

Imagine the existence within a perfect cosmological lattice of a localized macroscopic cluster of topological singularities, in the form of a sphere of radius $R_{cluster}$ containing a uniform density λ of rotation charges, as shown in figure 5.4. It is possible and quite simple to calculate the elastic rotation field $\vec{\omega}^{él}$ associated with this charge, both inside and outside the singularity. Let's introduce the global charge $\boldsymbol{Q}_\lambda$ given by the integration of the density λ in the volume of the cluster, or given by the sum of the elementary charges $\boldsymbol{q}_{\lambda(i)}$ within the cluster, and the vector $\vec{\boldsymbol{n}}$ which represents the vector normal to the spherical surface. The result of these calculations is shown in figure 5.4. Outside the cluster, that is to say for $r > R_{cluster}$, the external field of rotation $\vec{\omega}_{ext}^{él}$ due to the cluster of charges is independent of the radius $R_{cluster}$ of the cluster. But the field $\vec{\omega}_{int}^{él}$ inside the cluster, that is to say for $r < R_{cluster}$, depends on $R_{cluster}$.

To calculate the elastic energy stored in the lattice by the presence of the field of rotation $\vec{\omega}^{él}$ of the singularity, in other words t*he energy of elastic distortion* $E_{dist}^{(Q_\lambda)}$ *of the lattice due to the charge of the cluster*, one should in principle calculate the energy associated with the field of rotation, increased by the energy of the shear strain fields associated with the field of rotation. But in the case of *a perfect cosmological lattice*, we have the relationship $K_2 << K_3$ between the rotation and shear moduli, so that in principle we can neglect the energy associated with shear strain. The calculation provides the distortion energy $E_{dist\,ext}^{(Q_\lambda)}$ stored outside the singularity in a quasi-infinite medium, that is to say a medium for which $R_\infty >> R_{cluster}$ and the elastic distortion energy $E_{dist\,int}^{(Q_\lambda)}$ stored inside the singularity. *The rest elastic energy* $E_{dist}^{(Q_\lambda)}$ of the spherical cluster of rotational charge $\boldsymbol{Q}_\lambda$ and radius $R_{cluster}$ can therefore be written as the sum of the energies stored outside and inside the singularity. We see that it is finished and depends essentially on the radius $R_{cluster}$ and the charge $\boldsymbol{Q}_\lambda$ of the cluster.

A localized macroscopic topological singularity of radius $R_{cluster}$, apart from having a global charge $\boldsymbol{Q}_\lambda$ of rotation, can also have a global charge $\boldsymbol{Q}_\theta$ of curvature. Indeed, such a singularity can be formed of a cluster of elementary topological singularities of the lattice, such as prismatic dislocation loops which each have an elementary charge $\boldsymbol{q}_{\theta(i)}$ of curvature. If $\boldsymbol{Q}_\theta > 0$, we are talking about *a cluster of vacancy nature* because lattice sites are missing within the cluster, and if $\boldsymbol{Q}_\theta < 0$, we are talking about *a cluster of interstitial nature*, because there is then an excess of lattice sites within the cluster.

A localized curvature singularity is responsible for a non-zero and divergent flexion field in its vicinity. Indeed, if we know the density $\theta^{ch}(\vec{r})$ of curvature charges within the singularity, we

can easily calculate the divergent flexion field outside the singularity, linked to a spatial curvature of the lattice. The result of the calculation is shown in figure 5.4.

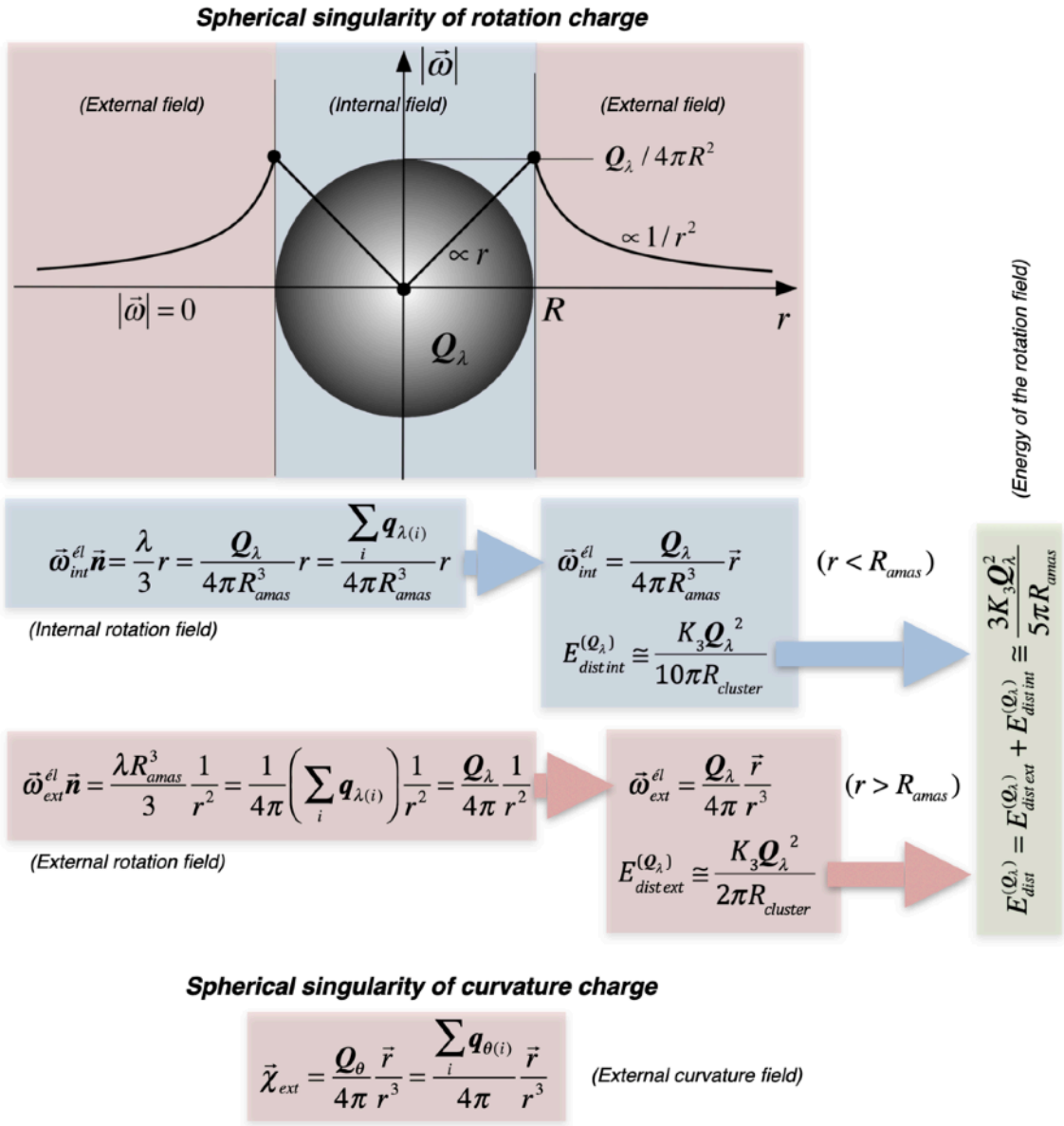


Figure 5.4 *- Fields and energies of a spherical singularity of rotation charge or curvature charge*

The vectors of this flexion field converge towards the singularity if this is of interstitial nature (excess of lattice sites within the singularity), and diverge from the singularity if it is of interstitial nature (depletion of lattice sites within the singularity). On the other hand, we also note that the flexion field due to the cluster of curvature charges does not depend on the radius $R_{cluster}$ of the cluster apart from the cluster.

Charge, fields, energies and mass of a twist disclination loop (BV)

The simplest topological singularity of a lattice which can have a localized charge q_λ of rotation, among all the topological singularities described above on the scale of a solid lattice, is

obviously the twist diclination loop *(**BV** = Boucle Vis in French)* described in figure 2.30. Recall that such a loop is generated by a rotation $\vec{\Omega}_{BV}$ of the upper plane of a circular cut in the middle of an angle α_{BV} relative to the lower plane (figure 5.5). The fact that two planes which have been displaced with respect to each other by rotation are glued together, is the cause of the appearance of a surface charge Π_{BV} of rotation on the plane of the loop. We then have $\vec{\Omega}_{BV} = \alpha_{BV}\vec{n} = -\vec{n}\Pi_{BV}$, which implies that $\boldsymbol{q}_{\lambda BV} = \pi R_{BV}^2 \Pi_{BV} = -\pi R_{BV}^2 \Omega_{BV}$. This charge $\boldsymbol{q}_{\lambda BV}$ is in fact the global rotation charge of the twist disclination loop as seen from a long distance from the loop. This means that such a loop can effectively behave as the source of a divergent field of rotation $\vec{\omega}$ within the solid medium. Such a loop can also be seen a little differently. Indeed, the fact of carrying out the rotation of the two planes one relative to the other induces a curvilinear displacement $R_{BV}\alpha_{BV}$ along the loop similar to that of a screw dislocation. The curvilinear Burgers vector $\vec{\boldsymbol{B}}_{BV}$ and the linear charge Λ_{BV} of this screw pseudo-dislocation loop then has a value $\vec{\boldsymbol{B}}_{BV} = R_{BV}\alpha_{BV}\vec{t}$, which leads to a linear pseudo-charge of the loop with a value $\Lambda_{BV} = -\vec{\boldsymbol{B}}_{BV}\vec{t}/2$ and to a global charge $\boldsymbol{q}_{\lambda BV} = 2\pi R_{BV}\Lambda_{BV} = -\pi R_{BV}\vec{\boldsymbol{B}}_{BV}\vec{t}$ of the loop. The same global charge value is obtained as that obtained by considering the surface charge Π_{BV}, which makes it possible to consider this topological singularity indifferently as a twist disclination loop or as a screw pseudo-dislocation loop. Considering the loop as a screw pseudo-dislocation loop then makes it possible to show, in a rather complicated way, that there is a local rotation field of toric shape around the loop, which is confined up to a distance of the order $r_B \approx 2R_{BV}$ relative to the center of the loop, where R_{BV} is the radius of the loop. Outside this toric confinement space, the far field becomes equal to the divergent field of rotation due to the global charge $\boldsymbol{q}_{\lambda BV}$ of rotation of the loop.

The distortion energy of a twist disclination loop is the energy which is stored by the rotations generated by the screw pseudo-dislocation of radius R_{BV} in a torus whose central fiber is the disclination loop and whose radius of the section roughly corresponds to R_{BV}, to which is added the energy of the external field of rotation of spherical symmetry for distances greater than $r \geq 2R_{BV}$. The calculation of the exact value of this energy is obviously very complex, in particular because the field of rotation cancels out exactly in the center of the loop. However, we can try to approximate the actual distortion energy of the loop, using the energy of a straight dislocation to calculate the energy of the curved dislocation. In the case where the radius R_{BV} of the loop is enormously larger than the core radius a of the screw pseudo-dislocation vis ($R_{BV} >> a$), this approximation must approach the real value of the energy of distortion within the torus surrounding the loop, and we can correct it by introducing a constant A_{BV} correcting the value of the external radius of the torus to best approach the real value of the energy. We will therefore write the energy of distortion $E_{dist\,tore}^{BV}$ of the toric field from the energy of a screw dislocation per unit of length, like the energy contained in the torus surrounding the twist disclination loop. This value is reported in figure 5.5, in which a is the core radius of the screw pseudo-dislocation, of the order of magnitude of the step of the cosmological lattice in the presence of any expansion field τ, $A_{BV}R_{BV}$ is the range of the toric field of the loop and A_{BV} is a constant which can only be obtained by the exact calculation of the energy of the loop, but which must be very close to unity according to our previous discussion. To simplify the rest of our presentation, as the ratio $A_{BV}R_{BV}/a$ does not depend almost on the background expansion, we will consider it to be approximately constant, and introduce a constant ζ_{BV}

specific to the twist disclination loop, and being equal to $\zeta_{BV} = \ln\left(A_{BV} R_{BV} / a\right) \cong cste$ with $A_{BV} \approx 1$ so to be able to write the energy of the toric field in the form shown in figure 5.5.

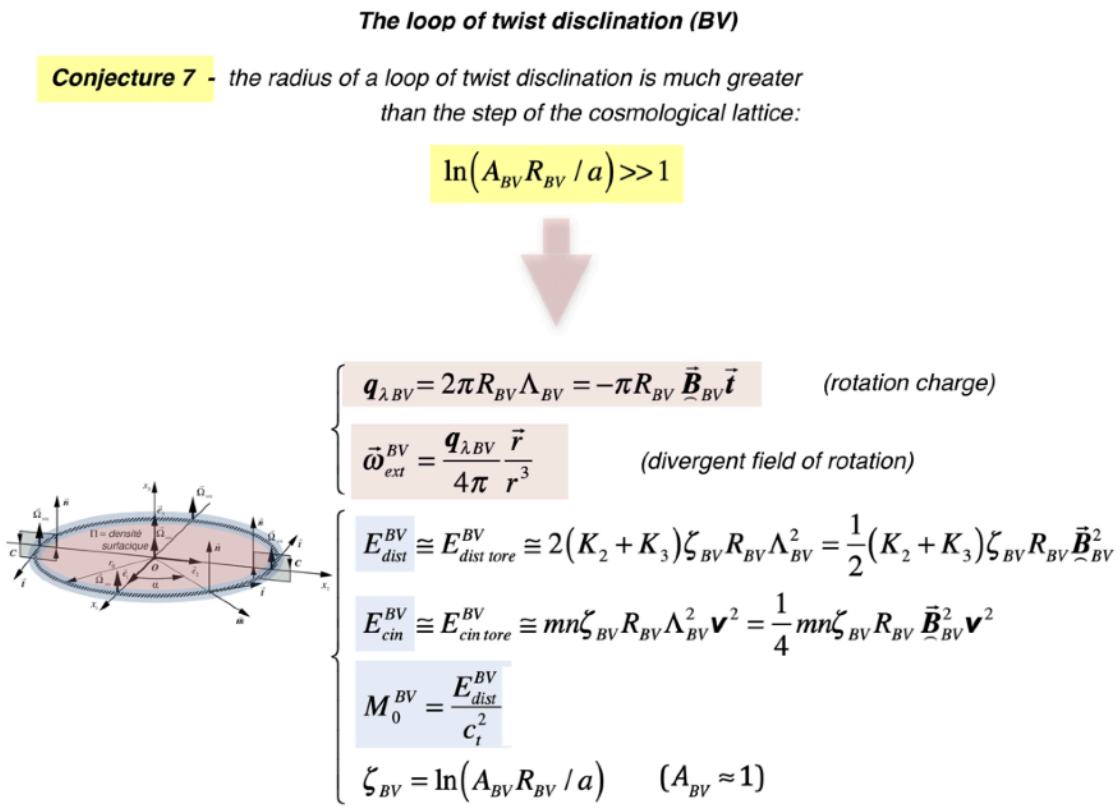


Figure 5.5 *- Charge, fields, energies and mass of a twist disclination loop*

We can then compare this energy of the toric field of the loop with the energy associated with the spherical field of rotation at great distance from the loop, which occurs beyond the distance $2R_{BV}$ of the loop, which is due to its rotation charge $\boldsymbol{q}_{\lambda BV}$, and which is simply worth $E_{dist\,ext}^{BV} \cong \pi K_3 R_{BV} \vec{\boldsymbol{B}}_{BV} / 4$. By comparing this value with the energy of the toric field reported in figure 5.5, we obtain the ratio $E_{dist\ tore}^{BV} / E_{dist\,ext}^{BV} \cong 2\ln\left(A_{BV} R_{BV} / a\right) / \pi$. If we admit here a new and seventh conjecture, reported in figure 5.5, namely that *the radius of a twist disclination loop is much larger than the step of the cosmological lattice*, therefore that $\ln\left(A_{BV} R_{BV} / a\right) >> 1$, the energy associated with the spherical external field of rotation becomes perfectly negligible with respect to the energy of the toric field of the loop. Therefore, the energy E_{dist}^{BV} of the twist disclination loop is essentially contained in the toroidal field of the loop, and we can write that $E_{dist}^{BV} \cong E_{dist\ tore}^{BV}$.

The non-relativistic kinetic energy of a moving twist disclination loop is the energy that is stored by the lattice movements generated by the moving screw pseudo-dislocation. Using the relation obtained in the case of a screw dislocation, and admitting the seventh conjecture, the kinetic energy E_{cin}^{BV} of the loop is fairly easily calculated, which is shown in figure 5.5. Again, the kinetic energy of the external rotational field is negligible compared to this kinetic energy, so we can consider that the kinetic energy of the loop is essentially confined to the toric field of the

loop. We therefore deduce that Einstein's relation applies perfectly to the twist disclination loop in the form $M_0^{BV} = E_{dist}^{BV} / c_t^2$.

We know from the separability of Newton's equation described at the beginning of this chapter that the existence of elastic distortion fields induces, via their energy, a perturbation field of expansion. We will return later in detail to this expansion perturbation field associated with the twist disclination loop.

"Coulomb-type" interaction between localized topological singularities with rotation charges

Assume first of all two loops of twist disclinations with rotation charges $\boldsymbol{q}_{\lambda BV(1)}$ and $\boldsymbol{q}_{\lambda BV(2)}$. There is an interaction force between these two loops, of electric type, and this interaction force can be deduced very generally using the Peach and Koehler force.

Indeed, the spherical external field of rotation generated by a charge $\boldsymbol{q}_{\lambda BV(1)}$ located at the center of the coordinate system is given by the relation of figure 5.5. If a twist disclination of rotation charge $\boldsymbol{q}_{\lambda BV(2)}$ is then at the position marked by a vector $\vec{r} = \vec{d}$ in the coordinate system, the interaction force acting on this charge on the part of the charge $\boldsymbol{q}_{\lambda BV(1)}$ is the Peach and Koehler force, which is exerted in the direction of the vector $\vec{d}$ and whose intensity is worth $\boldsymbol{F}_{PK(2)}^{BV} = \left[(K_2 + K_3) / \pi \right] \boldsymbol{q}_{\lambda BV(1)} \boldsymbol{q}_{\lambda BV(2)} / d^2$.

Thus, the reciprocal force between the two charges is repulsive if $\boldsymbol{q}_{\lambda BV(1)} \boldsymbol{q}_{\lambda BV(2)} > 0$ and attractive if $\boldsymbol{q}_{\lambda BV(1)} \boldsymbol{q}_{\lambda BV(2)} < 0$. This force of interaction between the rotation charges of twist disclination loops is the perfect analog of the force of interaction $\vec{\boldsymbol{F}}^{\textit{électrique}} = \boldsymbol{q}_{(1)} \boldsymbol{q}_{(2)} \vec{d} / 4\pi\varepsilon_0 d^3$ between two electric charges $\boldsymbol{q}_{(1)}$ and $\boldsymbol{q}_{(2)}$ in electromagnetism, and thus fits perfectly with the analogy developed in the previous chapter with the equations of Maxwell. As the previous relation of the force of Peach and Koehler is perfectly independent of the size of the loops, it can be generalized without problem to two macroscopic clusters of topological singularities which would have macroscopic charges of rotation $\boldsymbol{Q}_{\lambda(1)}$ and $\boldsymbol{Q}_{\lambda(2)}$ which would be distant from d, under the form $\boldsymbol{F}_{PK(2)} = \left[(K_2 + K_3) / \pi \right] \boldsymbol{Q}_{\lambda(1)} \boldsymbol{Q}_{\lambda(2)} / d^2$. In this case of two macroscopic clusters, the "electrical" interaction force between them therefore does not depend on the respective radii $R_{amas(1)}$ and $R_{amas(2)}$ of the two clusters.

Charge, fields, energies and mass of a loop of prismatic edge dislocation (BC)

If we consider a prismatic loop of edge dislocation *(**BC** = Boucle Coin in French)* with a radius R_{BC} (figure 2.28), the distortions induced in the lattice are those of an edge dislocation. We can therefore calculate approximately the elastic distortion energy of this loop as the energy which is stored in the lattice by the elastic distortions generated by the edge dislocation in a torus centered on the loop.

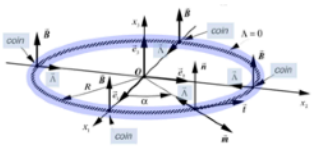
By using the same arguments as for the twist disclination loop, we deduce that, in a perfect cosmological lattice, the elastic energy of distortion of a prismatic loop is essentially contained in the toric fields surrounding the loop, and reported in the figure 5.6, in which A_{BC} is a constant close to unity, which should be calculated exactly by the exact integration of the energy of the fields within the torus, and where $\zeta_{BC} = \ln\left(A_{BC} R_{BC} / a \right)$ is a constant proper to the edge dislocation loop.

The prismatic loop of edge dislocation (BC)

Conjecture 7 - *the radius of a prismatic loop of edge dislocation is much greater than the step of the cosmological lattice:*

$$\ln\left(A_{BC}R_{BC}/a\right)>>1$$

$$\begin{cases} q_{\theta BC} = -2\pi\vec{n}\left(\vec{t}\wedge\vec{\Lambda}_{BC}\right) = 2\pi\vec{\Lambda}_{BC}\vec{m} = -2\pi\vec{n}\vec{B}_{BC} & \text{(flexion charge)} \\ \vec{\chi}_{ext}^{BC} = \dfrac{q_{\theta BC}}{4\pi}\dfrac{\vec{r}}{r^3} & \text{(divergent field of flexion)} \end{cases}$$



$$\begin{cases} E_{dist}^{BC} \cong E_{dist\,tore}^{BC} \cong \left(\dfrac{K_2}{K_3}\right)^2 K_3\zeta_{BC}R_{BC}\vec{\Lambda}_{BC}^2 \cong \left(\dfrac{K_2}{K_3}\right)^2 K_3\zeta_{BC}R_{BC}\vec{B}_{BC}^2 \\ E_{cin}^{BC} \cong E_{cin\,tore}^{BC} \cong \dfrac{1}{2}\left(\dfrac{K_2}{K_3}\right)^2 mn\zeta_{BC}R_{BC}\vec{\Lambda}_{BC}^2\boldsymbol{v}^2 = \dfrac{1}{2}\left(\dfrac{K_2}{K_3}\right)^2 mn\zeta_{BC}R_{BC}\vec{B}_{BC}^2\boldsymbol{v}^2 \\ M_0^{BC} = \dfrac{E_{dist}^{BC}}{c_t^2} \\ \zeta_{BC} \cong \ln\left(A_{BC}R_{BC}/a\right) \quad (A_{BC}\approx 1) \end{cases}$$

Figure 5.6 *- Charge, fields, energies and mass of a prismatic loop of edge dislocation*

Outside the loop, the fields due to the edge dislocation loop are reduced to a divergent flexion field of spherical symmetry. It is clear that this flexion field must be associated with a perturbation in the volume expansion field which must have a certain energy. We will come back to this problem later, and we will show that the energy associated with this flexion field is perfectly negligible compared to the distortion energy reported in figure 5.6, so that the energy of the edge dislocation loop is essentially contained in the toric fields in the immediate vicinity of the loop.

The non-relativistic kinetic energy of this loop is essentially the kinetic energy stored in the lattice by the dynamic distortions generated by the edge dislocation in the torus centered on the loop. Using the relations deduced previously for the edge dislocation, we deduce the approximate value of this kinetic energy, and we note that Einstein's relation applies perfectly to the non-relativistic kinetic energy of the prismatic dislocation loop since $M_0^{BC} = E_{dist}^{BC}/c_t^2$. As for the expansion perturbation field associated with this loop, we will come back to this in detail later.

Charge, fields, energies and mass of a slip loop of dislocatiopn (BM)

The slip loop of mixed dislocation *(**BC** = Boucle Mixte in French)* with a radius R_{BC} (figure 2.28), of a “vector” nature, is obtained by gliding (parallel translation to the plane of the loop) in the direction of the Burgers vector, so that the lattice does not present any "extra-matter" in this

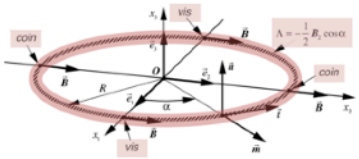
case (figure 2.28). On the other hand, the presence of a screw component in the regions where $\vec{B}_{BM} \,||\, \vec{t}$ induce a dipolar rotational field $\vec{\omega}^{BM}_{dipolaire}(r,\theta,\varphi)$ in the vicinity of the slip loop.

The slip loop of mixed dislocation (BM)

Conjecture 7 *- the radius of a slip loop of mixed dislocation is much greater than the step of the cosmological lattice:*

$$\ln\left(A_{BM}R_{BM}/a\right)>>1$$

$$\begin{cases} q_{\lambda BM}=0 \;\;\&\;\; q_{\theta BM}=0 \\ \exists \text{ an external dipolar field of rotation } \vec{\omega}^{BM}_{dipolar}(r,\theta,\varphi) \end{cases}$$



$$\begin{cases} E^{BM}_{dist} \cong E^{BM}_{dist\,tore} \cong \dfrac{1}{4}\left(K_2+K_3\right)\zeta_{BM}R_{BM}\vec{B}^2_{BM} \\ E^{BM}_{cin} \cong E^{BM}_{cin\,tore} \cong \dfrac{1}{8}mn\zeta_{BM}R_{BM}\vec{B}^2_{BM}\boldsymbol{v}^2 \\ M^{BM}_0 = \dfrac{E^{BM}_{dist}}{c_t^2} \cong \dfrac{1}{4c_t^2}\left(K_2+K_3\right)\zeta_{BM}R_{BM}\vec{B}^2_{BM} \\ \zeta_{BM}=\ln\left(A_{BM}R_{BM}/a\right) \qquad (A_{BM}\approx 1) \end{cases}$$

Figure 5.7 *- Charge, fields, energies and mass of a slip loop of mixed dislocation*

If we consider a slip loop with a radius R_{BM}, the distortions induced in the short distance lattice are those of a screw dislocation for the angles $\alpha=0$ and $\alpha=\pi$, and those of an edge dislocation for the angles $\alpha=\pi/2$ and $\alpha=3\pi/2$. We can therefore consider that we pass continuously as a function of the angle α from a screw dislocation to an edge dislocation via mixed intermediate states. The distortion energy associated with the bent string is stored mainly in the torus centered on the loop. However, since the two edge parts and the two screw parts of the loop are respectively of opposite charges, the fields associated with the edge parts and the screw parts of the loop decrease very quickly at great distance from the loop. For example, the modulus of the rotation field in the plane of the loop and over a diameter passing through the screw parts of the loop behaves approximately as follows $\left|\vec{\omega}^{BM}_{dist}\right| \propto \left|\vec{B}_{BM}\right| R_{BM}/(4\pi r^2)$ at great distance $(r>>R_{BM})$. If the radius R_{BM} of the loop is very much greater than the step of the lattice, we can roughly take into account this rapid decrease in the dipole field by imagining that the field in the vicinity of the string is that of a dislocation. We can thus roughly calculate the rest energy of such a loop by integrating the energies per unit length of string within the torus for the screw and edge components of the string as a function of the angle α. It therefore comes

approximately, in the perfect cosmological lattice, the expression of the energy reported in figure 5.7. An exact calculation of the energy should lead to the value A_{BM} of the constant proper to the geometry of the mixed loop, and which must approach the value 1.

It would also be necessary to take into account the energy of distortion associated with the dipolar field of rotation outside the loop. However, this is obviously lower than the distortion energy associated with the external field of rotation of a twist disclination loop, so that this energy can be perfectly neglected in comparison with the distortion energy contained in the torus. This again means that the energy of the mixed dislocation loop is essentially contained in the immediate vicinity of the dislocation loop.

The non-relativistic kinetic energy of the slip loop of dislocation is calculated approximately in the same way as its elastic distortion energy.

It can be seen that the energies E_{dist}^{BM} and E_{cin}^{BM} are in fact those supplied by the screw parts of the slip loop, and that these are essentially contained in the immediate vicinity of the dislocation loop. Einstein's relation therefore applies perfectly to the slip dislocation loop since $M_0^{BM} = E_{dist}^{BM} / c$. As for the expansion perturbation field associated with this loop, we will come back to this later in detail in chapter 24, where we will see that the energy associated with this field is negligible compared to the distortion energy contained in the torus.

"Topological bricks" to build the world of elementary particles

In Figures 5.4 to 5.7, we have reported all the results obtained for the three most basic types of loops that can be found in the perfect cosmological lattice. In our analogy with the real world, the three loops of disclination and dislocation which appear there could well constitute the most elementary topological bricks of the cosmological lattice, which could make it possible to work out loops of more complex structures which could be analogues of elementary particles of the Standard Model.

The twist disclination loop is the most basic topological singularity at the origin of an electrical charge. At a certain distance from the center of a twist disclination loop, greater than approximately $2R_{BV}$, the external rotation field of the disclination loop behaves exactly like the external field of a spherical charge of value $\boldsymbol{q}_{\lambda BV} = 2\pi R_{BV}\Lambda_{BV}$.

One can then wonder what should be the radius R_{ch} of the spherical charge so that it has an elastic energy of global distortion equal to the energy of distortion of the loop. With the charge value $\boldsymbol{q}_{\lambda BV}$ ensuring a long distance field similar to that of the twist disclination loop, the energy of a spherical charge of radius R_{ch} is worth $E_{dist}^{q_\lambda} \cong 12K_3\pi R_{BV}^2\Lambda_{BV}^2/(5R_{ch})$. For this global energy of the spherical charge to be equal to that of the distortion loop of radius R_{BV} and linear charge Λ_{BV}, that is to say that $E_{dist}^{q_\lambda} \cong E_{dist}^{BV}$, the radius R_{ch} of the charge must satisfy the following relation $R_{ch} \cong R_{BV} 6\pi / \left[5\ln(A_{BV}R_{BV}/a)\right]$, obtained by recalling that in the perfect cosmological lattice $K_2 << K_3$.

By using conjecture 7, we note that the radius of a spherical charge which would have an energy of the rotation field equal to the energy of the toric field of a twist disclination loop should be considerably smaller than the radius of the twist disclination loop. As the twist disclination loop is the most basic microscopic lattice singularity that it is possible to find which has a non-zero rotation charge $\boldsymbol{q}_{\lambda BV}$, the twist disclination loop therefore corresponds to the most elementary structure of an electric charge in our analogy with the real world.

The prismatic dislocation loop is the most basic topological singularity responsible for a spatial curvature charge. When we compare the elastic distortion energy of a prismatic loop with the elastic distortion energy of a twist disclination loop, with the same radii and the same modules of their Burgers vector, we see that in the perfect cosmological lattice with $K_2 << K_3$, we have $M_0^{BC} \cong 2\left(K_2 / K_3\right)^2 M_0^{BV} <<< M_0^{BV}$. Thus, *the mass of inertia of the prismatic edge dislocation loop is considerably lower than the mass of inertia of the twist disclination loop*.

On the other hand, as the prismatic dislocation loop has a nonzero charge of curvature $\boldsymbol{q}_{\theta BC} = -2\pi \vec{\boldsymbol{n}} \vec{\boldsymbol{B}}_{BC}$, which can be positive (loop of the lacunar type) or negative (loop of the interstitial type), it is necessarily associated with a flexion field $\vec{\chi}_{ext}^{BC}$ at long distance by lattice curvature, given by $\vec{\chi}_{ext}^{BC} = \boldsymbol{q}_{\theta BC} \vec{r} / (4\pi r^3)$. Thus, the prismatic dislocation loop is the most basic microscopic lattice singularity which is the source of spatial curvature of the lattice by the divergent flexion field which is associated with it, while the twist disclination loop is the most basic microscopic lattice singularity which is a source of spatial torsion of the lattice by the divergent field of rotation associated with it.

As one tried at first sight an analogy between the rotation charge of the twist disclination loop and the electric charge of the electron of the physics of particles, then the loop of prismatic edge dislocation, which does not present a field of rotation and which is of rest mass much weaker than the twist disclination loop, could very well, at first glance, be identified by analogy *with the real-world neutrino*, which is actually an electrically neutral particle and of much lower mass than the electron.

If we accept this analogy, the neutrino would in this case be the source of a spatial curvature by flexion of the perfect cosmological lattice, in other words the source of a field of curvature of space, while the charge of the electron would be the source of a spatial torsion by rotation of the perfect cosmological lattice, corresponding to the electric field of electromagnetism. This analogy with the two basic leptons of particle physics is obviously very sketchy at the moment, and it could very well intervene in fact more complex combinations of these elementary loops in the form of loops of dispiration of complex structures to explain the different elementary particles of the real world.

The slip dislocation loop is the most basic topological singularity at the origin of an electric dipolar moment. Unlike the twist disclination loop and the prismatic dislocation loop, the slip dislocation loop has no field at a long distance like a divergent rotation field or a divergent flexion field. However, this loop has a dipolar moment of rotation $\vec{\omega}_{dipolar}^{BM}(r,\theta,\varphi)$ in its vicinity, linked to the two opposite rotation charges located on either side of the loop. Thus, the slip dislocation loop is the most basic microscopic lattice singularity that can be the source of a dipolar moment of rotation.

In our analogy with the real world, a slip dislocation loop in the perfect cosmological lattice could correspond to the most elementary structure which could generate an electric dipolar moment for an elementary particle. However, it turns out that the research and measurement of an electrical dipole moment of elementary particles is currently an important research subject of the Physics of elementary particles.

The various physical properties transported by loop singularities

From the previous discussion, it would therefore seem that the twist disclination loop could

transport the electric charge, the prismatic edge dislocation loop the curvature charge and the slip mixed dislocation loop the electric dipolar moment. We can add to these three properties another property which could be of enormous interest. In our analogy with the real world, it is quite difficult to imagine, to find the analog of the spin of a charged particle and the magnetic moment associated with it, that a symmetrical spherical singularity of rotation charge like that described in figure 5.4 can turn on itself. However, if we consider that the analog of an electrical charge is indeed the twist disclination loop shown in figure 5.5, the topology of this singularity, consisting of a screw pseudo-dislocation, makes it possible to imagine very naively that it can rotate around one of its diameters. In this case, the distribution of the rotation charge, analogous to a distribution of the electric charge in the form of a ring along the perimeter of the twist disclination loop, would necessarily impose the appearance of a magnetic moment of the loop associated with this real movement of rotation. We will come back to this subject later.

There is still a fifth fundamental and very important property of elementary particles which could be explained with our analogy. It is the fact of being able to calculate the elastic distortion energies E_{dist}^{loop} and the kinetic energies E_{cin}^{loop} of the loops, and to be able to deduce therefrom their inertia masses M_0^{loop}, and that these are contained essentially in the immediate vicinity of the loops. But it is also and above all the fact that they all satisfy, in the perfect cosmological lattice, the famous relation of Einstein, which is *a fundamental property of these loops which has been demonstrated without in any way appealing to a principle of special relativity*.

On the other hand, the mass of inertia of the loops is a property linked to the mass of inertia of the cosmological lattice in the absolute reference frame of the external observer ***GO***. In an analogy with the real world, the mass of inertia of the topological lattice would then correspond to *the famous Higgs field* that had to be introduced into the Standard Model to explain the mass of elementary particles, and *the Higgs particle* would then be the only one real particle of the real world since it would correspond to a constituent particle of the perfect cosmological lattice, while the other elementary particles of the Standard Model would correspond to topological singularities of the perfect cosmological lattice.

There is certainly still a huge way to go to find an analogy which would provide, by judicious combination of the different elementary topological loops in the form of different dispirations of more or less complex structures, the set of elementary particles of the Standard Model and their physical properties. But the major problem that we will address in the following will be above all to find the analogies which explain the gravitational behavior of real world objects on a macroscopic scale (Newton's gravitation, General Relativity), as well as the quantum behavior of the real world at the microscopic scale (Quantum Physics).

We will retain for the moment in this chapter that several of the fundamental properties of elementary particles in our real world find a very simple and perfectly classic explanation using the analogy with the elementary loop singularities of a perfect cosmological lattice.