Chapter 13

Standard model of particles and strong force

We have previously shown that the perfect cosmological lattice presents strong analogies with all the major theories of modern physics, namely the equations of electromagnetism, special relativity, general relativity, black holes, cosmology, dark energy and quantum physics, including the notion of spin and magnetic moment, and that there can exist three types of loops of basic topological singularities respectively having the attributes of an electric charge, an electric dipolar moment or a load of curvature by bending (which is the exclusive prerogative of our approach of the perfect cosmological lattice, and which explains quite simply several mysterious phenomena at the present time, like the weak force of coupling of two topological loops, the dark matter, the galactic black holes and the disappearance of anti-matter).

In this chapter, we will focus on finding and describing the ingredients that could explain, on the basis of loops of basic topological singularities, the existence of the current standard model of elementary particles. In other words, we will try to find what mechanisms could generate the families of fundamental particles such as leptons and quarks, what could be the origins of the existence of three generations of these elementary particles, and where could the strong force come from with asymptotic behavior which binds quarks together to form baryons and mesons.

This chapter does not pretend at all to provide an elaborate theory or a definitive and quantitative solution to explain the standard model of particle physics, but rather to show by some specific arguments that it is certainly the choice of a particular microscopic structure of the perfect cosmological lattice which could provide an answer to the various questions which arise concerning the standard model. This chapter will therefore bring some elements of reflection by showing that it can appear in a solid of well chosen structure a whole "zoology" of loops of topological singularities which can have a strange family resemblance with the elementary particles of the standard model. It will also make it possible to present behaviors very similar to the behaviors of elementary particles, such as the presence of a strong asymptotic force which can participate in a coupling between topological loops.

The current Standard Model of elementary particles

At present, particle physics explains the intimate structure of matter using a model called the *Standard Model of Elementary Particles* (figure 13.1). This model reveals *fermions*, particles of matter that have two fairly different families, the *lepton family* and the *quark family*, as well as three types of interactions that can occur between these fermions: electromagnetic interaction, weak interaction and strong interaction.

The interactions between the fermions of matter take place through the exchange of particles called *gauge bosons*, corresponding to the quanta of the quantum fields of interaction concerned. The electromagnetic interaction uses the photon γ , the weak interaction with three gauge bosons Z^0 , W^+ et W^- , and the strong interaction with 8 gauge bosons called *gluons*.

As for the mass of particles, it is introduced into the standard model by a new interaction associated with the Higgs quantum field, the mediating particle of which is called the *Higgs boson.*

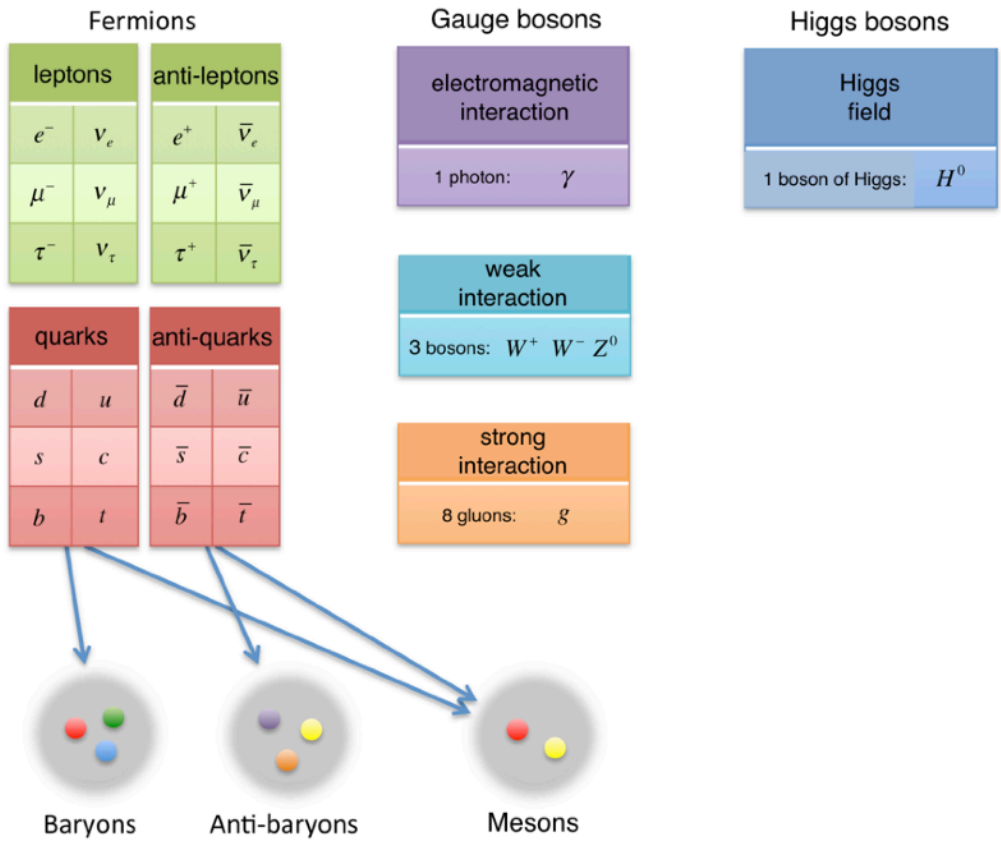


Figure 13.1 *- The particles of Standard Model*

Leptons and quarks

The *family of leptons* (figure 13.1) is made up of three generations of two types of particles: three electrically neutral particles called *electron neutrino* (ν_e), *muon neutrino* (ν_μ) and *tau neutrino* (ν_τ), and three electrically charged particles, called *electron* (e^-), *muon* (μ^-) *and tau* (τ^-). Each of these six particles has in principle an anti-particle ($\bar{\nu}_e$, $\bar{\nu}_\mu$, $\bar{\nu}_\tau$, e^+, μ^+ and τ^+) which is essentially characterized by an opposite electric charge, which already raises a question regarding the existence of anti-particles of neutrinos. Leptons are quasi-point particles that are sensitive to electromagnetic interaction and weak interaction, but not strong interaction. It has long been thought that neutrinos do not have mass, but recent measurements show that this is not the case.

The *family of quarks* is also composed of three generations of two types of electrically charged particles: a first generation is formed of the quarks *down (d)* and *up (u)*, respectively of electrical charges -1/3 and +2/3 of the electric charge of the electron, a second generation composed of the quarks *strange (s)* and *charm (c)*, of electric charges -1/3 and +2/3 respectively of the electric charge of the electron, and a third generation composed of the

bottom (b) and *top (t)* quarks, respectively of electrical charges -1/3 and +2/3 of the electrical charge of the electron. Each quark has its electric charge anti-particle of opposite sign ($\overline{d}$, $\overline{u}$, $\overline{s}$, $\overline{c}$, $\overline{b}$ and $\overline{t}$). The quarks are sensitive to both electromagnetic, weak and strong interaction. Quarks are not free particles, but they exist as a collection of quarks called *hadrons*. Quarks are linked within hadrons by strong force.

Hadrons come in two forms: *mesons* made up of a quark and an anti-quark, like particles $\Pi^{+}(u\overline{d})$, $\Pi^{-}(d\overline{u})$ or $\Pi^{0}(u\overline{u})$, and *baryons* made up of three quarks, like *proton* (uud) and *neutron* (ddu), or of three anti-quarks.

Each particle of matter, whether a lepton or a quark, has a non-zero mass and a spin 1/2, which gives it the *fermion* status.

Fundamental interactions and gauge bosons

In the Standard Model, we consider the following three possible interactions between particles: *electromagnetic interaction, weak interaction* and *strong interaction*. These interactions are described by quantum field theories, except the gravitational interaction which could never be introduced in the Standard Model, despite an intensive search for the *graviton* gauge boson which would be associated with it. Each interaction therefore calls upon a field which is specific to it, and is then carried out by the exchange of a particle called a *gauge boson*, corresponding to the quantum of the field concerned. The electromagnetic interaction uses the *photon* (γ), a boson of zero mass gauge. The weak interaction uses the three gauge bosons Z^{0}, W^{+} and W^{-}, particles of non-zero mass and zero, positive or negative electrical charge respectively. As for the strong interaction, it uses 8 gauge bosons called *gluons*, in fact particles of zero mass.

The gauge bosons associated with these interactions are spin 1 particles, which explains their name as *bosons*.

Electromagnetic interaction and quantum electrodynamics

The quantum theory that describes electromagnetic interaction is called *quantum electrodynamics*. It is a quantification of the electromagnetic field: the charged particles interact there by the exchange of quanta of the field, the *photons*. It is a relativistic theory, because it takes into account the propagation time of the interaction, namely the speed of the vector boson, the photon. In this theory, we can represent an interaction in a simple and convenient way, thanks to *Feynman diagrams.* In figure 13.2, the example of the interaction between two electrons is represented by the exchange of *a virtual photon*, qualified here as virtual because it cannot be detected experimentally.

Weak interaction and electroweak theory

The weak interaction acts between all elementary fermions, whether they are leptons or quarks (Figure 13.3). This is the only interaction that acts on neutrinos. It is responsible for *nuclear decay*. This interaction has two aspects: the weak interaction by *charged currents*, whose vectors are the gauge bosons W^{+} and W^{-}, and the weak interaction by *neutral*

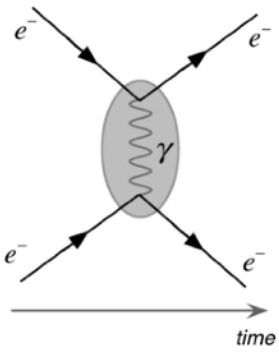


Figure 13.2 *- Feynman diagram of the interaction between two electrons via a photon*

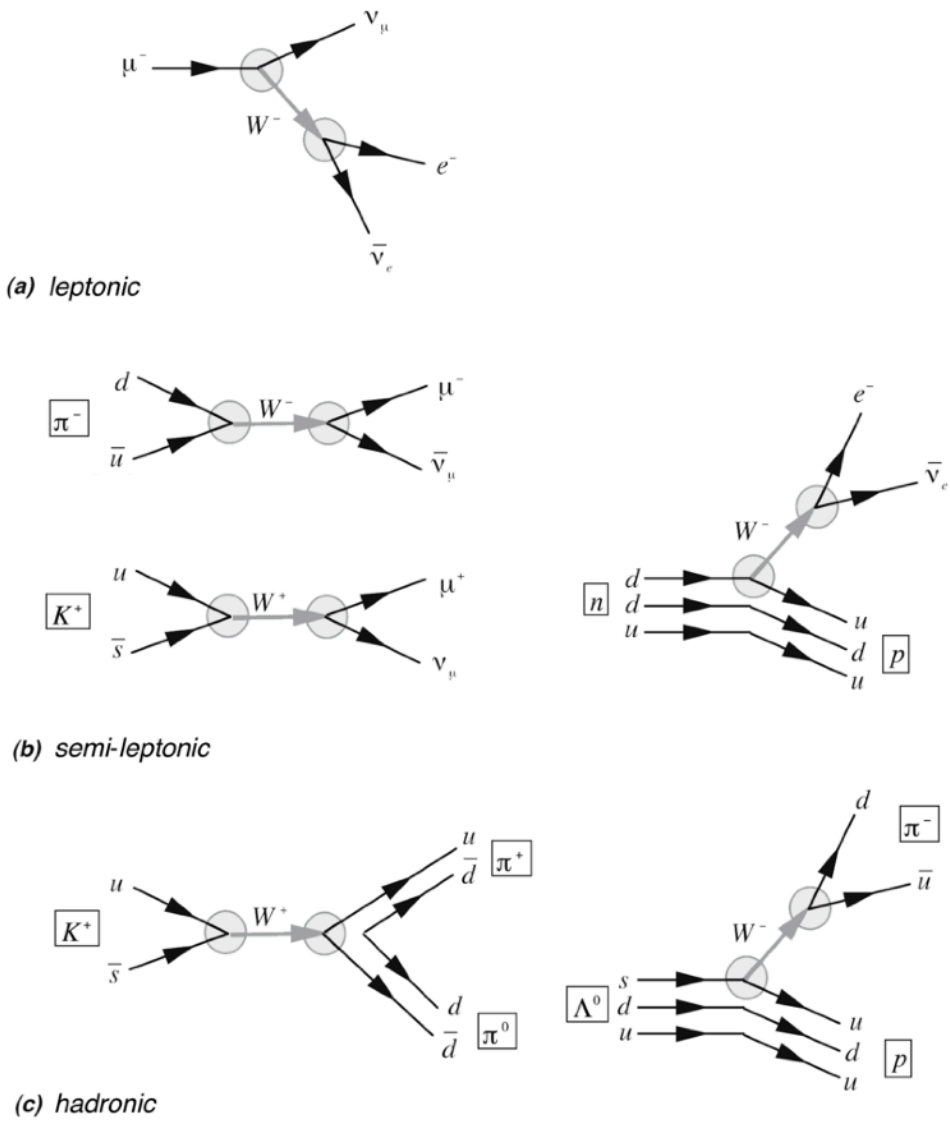


Figure 13.3 *- Examples of Feynman diagrams leptonic, semi-leptonic and hadronic weak interactions*

current, whose vector is the gauge boson Z^0 . The gauge bosons are the only ones which present masses, and these are very high, which imposes, by combining the relation $\Delta E \bullet \Delta t \approx \hbar$ of uncertainty of Heisenberg and the relation $\Delta E = mc^2$ of Einstein, a very short lifespan Δt of these bosons, and consequently, since the speed of light is an insurmountable limit, an extremely small range of the interaction via these bosons (of the order of $10^{-15}[m]$), which explains why this interaction does not manifest itself than at the scale of the atomic nucleus.

As the gauge bosons W^+ et W^- have a non-zero electric charge, fermions can change electric charge during an interaction by exchange of W^+ or W^-, which changes their *flavor* (we call flavor of a fermion its nature: electron, neutrino, quark u, quark d, etc.). For example, beta radioactivity is explained by the emission of a W^- by a quark *d* of the neutron, which then changes flavor and becomes quark *u*. Then, the W^- materializes in the form of an electron and an electronic anti-neutrino (figure 13.3, b).

The gauge boson Z^0 has no electrical charge, and therefore cannot induce a change in flavor during a weak interaction. The weak interaction by neutral current is quite similar to the exchange of a photon. Two fermions which can exchange a photon can also exchange a Z^0, with the exception of the neutrino which can exchange a Z^0 but cannot exchange a photon since it is a neutral particle.

There are several types of weak interactions according to the fermions which interact: leptonic interactions, semi-leptonic interactions and hadronic interactions, of which examples of Feynman diagrams are reported in figure 13.3.

Note that the electromagnetic interaction and the weak interaction were unified in a quantum theory which was called *electroweak theory*.

Strong interaction and quantum chromodynamics theory

The strong interaction is a short-range interaction between quarks via gluons, gauge bosons that are vectors of this interaction. It is this interaction which explains not only the *mesons* composed of a quark and an anti-quark and the *baryons* composed of three quarks, but also how neutrons and protons can bond to form atomic nuclei.

To develop a quantum theory of strong interaction, it was necessary to call upon a new type of charges, called *charges of color*, from where the name of *theory of quantum chromodynamics*. Each quark has a charge of color, red *(R=rouge)*, green *(V=vert)* or blue *(B=bleu)*, and anti-quarks have a charge of one of the complementary colors($\overline{R}$), ($\overline{V}$) or ($\overline{B}$).

The strong interaction is then explained by the exchange of "colored" gluons between elementary fermions with a color charge, which allows the color charges to be exchanged between fermions. There are 8 gluons of different colors, corresponding to 8 different combinations of a color and an anti-color. Thus, when exchanging a gluon between two quarks, they exchange their respective colors. In addition, since gluons carry a charge of color, they can also interact with each other, which is not the case with other gauge bosons. Leptons do not have a color charge and therefore do not undergo strong interaction.

Although the mass of the gluons is zero, the strong interaction is of very short range, of the order of $10^{-15}[m]$, and it has a rather strange characteristic: the more the quarks are distant from each other, the more the force of interaction between them is strong. And if they are

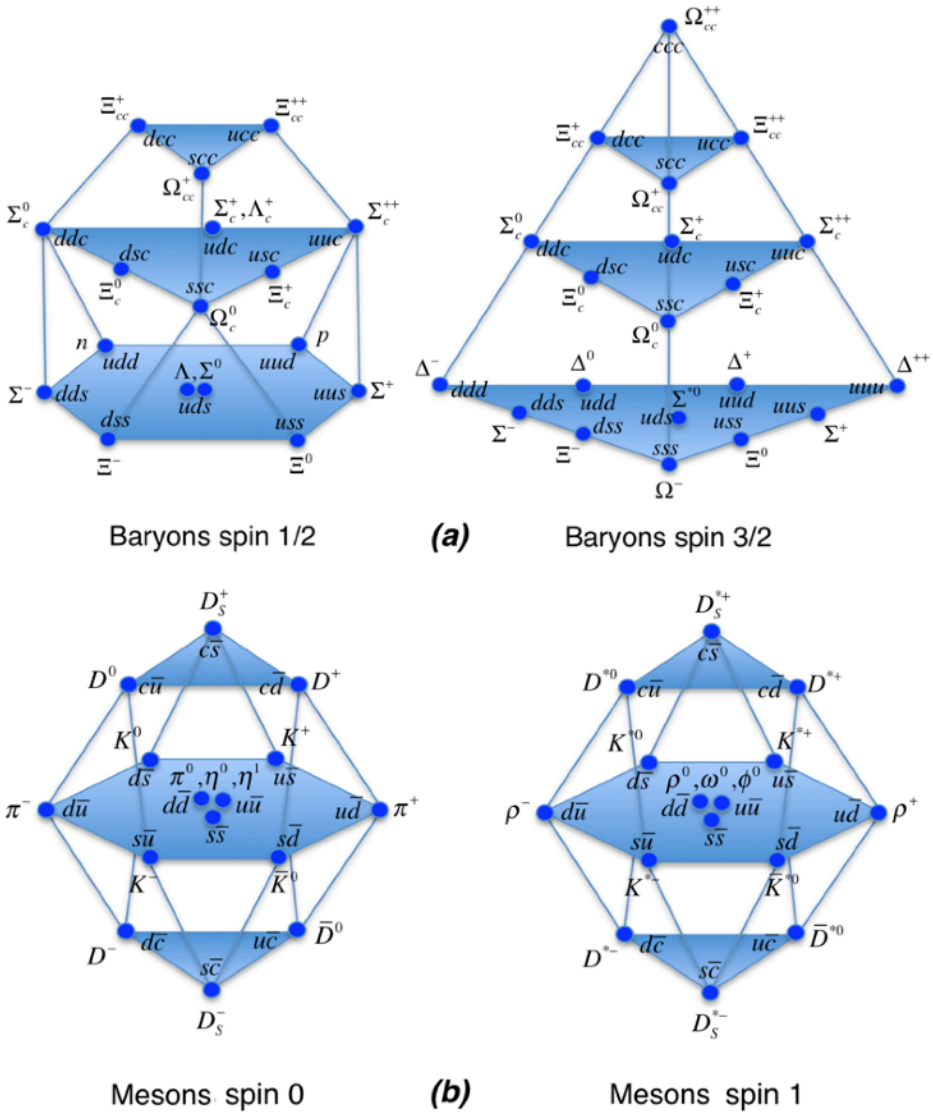


Figure 13.4 *- **(a)** baryons composed of triplets of quarks (u, d, s or c), **(b)** mesons composed of quark-antiquark doublets (u, d, s or c)*

infinitely close, they no longer interact at all. This property is called *asymptotic freedom*, and it is responsible for what is known as *the confinement of quarks inside hadrons*: this implies that *quarks cannot exist in the free state.*

The particles formed from quarks are therefore hadrons, that is to say bound states of several quarks via gluons. Hadrons must necessarily be "white", that is to say have a zero color combination. We can therefore consider:

- *the baryons*, combinations of three red, green and blue quarks respectively, or else anti-baryons, combinations of three anti-red anti-green, and anti-blue, respectively. The triplets formed of three quarks (among the quarks *u, d, s or c*) are represented in the diagrams of figure 13.4 (a), in the cases of global spin of $1/2$ and $3/2$ with the name given to the particle corresponding to this triplet,
- *the mesons*, which contain a colored quark (red, green or blue) and an anti-quark of the

corresponding anti-color (anti-red, anti-green or anti-blue). The doublets formed by a quark and an anti-quark (among the quarks *u, d, s* or *c*) are represented in the diagram of figure 13.4 (b), in the case of global spin of 1 and 0, with the name given to the particle corresponding to this doublet.

Particle masses and Higgs boson

In a first version of the Standard Model, all the particles described (leptons and quarks) had to be of zero mass, which is obviously false as the table in figure 13.5 clearly shows. To make up for this gap in the initial Standard Model, theorists have imagined a fifth interaction, different from the other four (electromagnetic, weak, strong and gravitational), and calling on a field whose quantum is a particle of spin 0: *the boson of Higgs* H^0 (figure 13.1). It is then the

Fermions *(spin 1/2)*		**Electric charge** *(q_e)*	**Mass** *(MeV/c²)*
lepton electron	e^-	-1	0,51
lepton muon	μ^-	-1	106
lepton tau	τ^-	-1	1777
lepton neutrino electron	ν_e	0	< 0,0000022
lepton neutrino muon	ν_μ	0	< 0,17
lepton neutrino tau	ν_τ	0	< 15,5
quark Up	*u*	+2/3	2,55
quark Down	*d*	-1/3	5,04
quark Charm	*c*	+2/3	1270
quark Strange	*s*	-1/3	105
quark Top	*t*	+2/3	173100
quark Bottom	*b*	-1/3	4200

Jauge bosons *(spin 1)*		**Electric charge** *(q_e)*	**Mass** *(MeV/c²)*
photon	γ	0	0
boson	W^+	-1	80398
boson	W^-	+1	80398
boson	Z^0	0	90187
8 gluons	*g*	0	0

Jauge bosons *(spin 0)*		**Electric charge** *(q_e)*	**Mass** *(MeV/c²)*
boson Higgs	H^0	0	125000

Figure 13.5 *- The charges and masses of the various particles*

interactions between the elementary fermions of zero mass and the Higgs field via the Higgs bosons which provide a mass to the fermions of the Standard Model. The existence of the Higgs boson has been verified experimentally at CERN, quite recently.

The problems of the standard model which already have solutions in the theory of the perfect cosmological lattice

The standard particle model, despite its undeniable success, leaves many questions unanswered. In the rest of this chapter, we will try to see if an approach to the standard model by our approach of the perfect cosmological lattice can provide an answer to these various questions. It will not be a question here of giving a complete and quantitative answer to all these problems, but of sketching, in a very qualitative way, in other words "with the hands", how the cosmological lattice could provide a solution to these problems. Some of the problems raised by the standard model already contain a sketch of an explicit solution in the previous chapters.

So let's take a tour of the problems posed by the standard model which already have an explanation in the approach of the cosmological lattice and explain how the cosmological lattice answers, at least partially, to these various problems:

- the absence of gravitational interaction in the standard model:

The gravitational interaction is directly part of the results obtained with the cosmological lattice, as a static solution of Newton's second partial equation, and it is moreover this same equation in its dynamic form which made it possible to introduce and give a simple explanation of quantum physics and the notion of spin of loop topological singularities.

- the need for the Higgs boson and the impossibility of calculating the masses of the various fermions and bosons in the standard model:

In the basic standard model, fermions have no mass, and theorists had to introduce an ad-hoc mechanism, the interaction with the Higgs field via the Higgs boson, which provides the mass of inertia to the elementary particles. However, in the standard model, it is not possible to obtain quantitative values of the inertia masses of the particles, which must therefore be "calibrated" on the values obtained experimentally. The theory of the cosmological lattice actually contains a mechanism fairly analogous to the Higgs field: it is the field of the masses of inertia of the "corpuscles" of the network (which are therefore a kind of analog of the spin 0 Higgs bosons) as well as the elastic energy of distortion of the lattice, which are responsible together for the relativistic properties of inertia of topological singularities, and which allow a quantitative calculation of the masses of inertia of topological singularities, without having to “calibrate” these values on results experimental.

- the physical nature of the electromagnetic interaction in the standard model:

The electromagnetic interaction, as well as its vector boson, the photon, with its various quantum properties, are an integral part of the theory of the cosmological lattice, and have there a simple and well-defined physical explanation based on the field of rotation within the cosmological lattice.

- the physical nature of the weak interaction in the standard model:

A weak interaction presenting an analogy with the weak interaction of the standard model has been obtained in the theory of the cosmological lattice (chapter 9), in the form of a very

short-range bonding force binding "topological fermions" between them (twist disclination loops to edge dislocation loops), by coupling their rotation and curvature charges.

- violation of the CP invariance (charge / parity) in the standard model:

In the current universe, there is a violation of the invariance ***CP*** (charge / parity) that theorists believe to be the probable cause of the matter / anti-matter asymmetry and of the matter / anti-matter imbalance in the current universe. In the theory of the cosmological lattice, this weak asymmetry between matter and anti-matter exists well, and is explained perfectly by the existence of the charge of curvature by bending of the edge dislocation loops, charge which has absolutely no equivalent in the standard particle model. This same phenomenon is also behind the explanation of the famous dark matter of astrophysicists and the disappearance of anti-matter during the cosmological evolution of the universe.

- the absence of explanation of the dark energy and the dark matter in the standard model:

These two concepts invented by theorists to provide explanations for the acceleration of cosmological expansion and the gravitational behavior of galaxies both have a direct explanation in the theory of the cosmological lattice: the energy of elastic distortion with regard to dark energy and the repulsive gravitational force of the neutrino sea with respect to black matter.

The problems of the standard model which have not yet been explained in the theory of the perfect cosmological lattice

Among the problems of the standard model of elementary particles, there are some for which plausible explanations have not yet appeared in the theory of the cosmological lattice. These include:

- the existence of fermions in the form of three generations of leptons and quarks:

If the fermions correspond to topological singularities in the theory of the cosmological lattice, the existence of fermions in the form of leptons and quarks, as well as the existence of three generations of these fermions, should probably be explained by a judicious choice of the structure of the cosmological lattice and of the constitution of elementary particles as topological singularities in the form of dispiration loops, judicious assemblies of loops of twist disclination, of edge disclination, of edge dislocation and of mixed dislocation .

- the existence of three massive gauge bosons in the weak interaction:

Since the weak interaction has already appeared in our approach as the force linking the twist disclination loops to the edge dislocation loops, it remains to find out what the massive gauge bosons, vectors of this interaction, are in cosmological lattice theory.

- the existence of a strong interaction linking quarks by a color confinement mechanism:

The strong interaction, with its color confinement mechanism and its vector bosons, the gluons, is the only interaction that has not yet appeared in the framework of cosmological lattice theory. But we have already encountered mechanisms which could be very interesting potential candidates to explain this force and its asymptotic behavior, such as for example the mechanisms generating a fault energy within the lattice, such as the dissociation of a dislocation by example.

- the existence of quantified electrical charges, of relative values 1, 1/3 and 2/3:

The electrical charges of fermions have relative values 1, 1/3 and 2/3 between the charge of the electrons and the charges of the quarks. These quantified values have absolutely no explanation in the standard model, but it is a safe bet that the choice of a particular structure of the cosmological lattice could provide an explanation for this problem.

In the rest of this chapter, we will try to find answers and explanations to these questions of the standard model, playing exclusively on the structure of the cosmological lattice and on the properties of the topological singularities that it can contain. In the standard model, 26 different parameters are required in the case where the neutrinos are massive to obtain a functional theory, such as the masses of the particles and the intensities of the various forces, and these parameters must necessarily be “calibrated” on the values of experimental results. It is a safe bet that the model of the cosmological lattice can make it possible to greatly reduce the number of parameters to be adjusted, simply by the fact that it can provide new physical explanations for phenomena that do not have any in the standard model.

A "colored" face centered cubic lattice with specific stacking and rotation rules to explain the first family of quarks and leptons of the standard model

In the perfect cosmological lattice, we have seen that the simplest topological singularity for explaining the electric charge is the twist disclination loop. As we saw in chapter 8, for the gravitational interaction of twist disclination loops to satisfy behaviors similar to experimentally observed behaviors (time dilation, curvature of wave rays), it is sufficient that the coefficients α_{BV} and β_{BV} in the expressions $R_{BV} = R_{BV0}\, e^{\alpha_{BV}\tau}$ and $\Omega_{BV} = \Omega_{BV0}\, e^{\beta_{BV}\tau}$ giving the dependence of the radius and the torsion angle of the twist disclination loop as a function of the background expansion of the lattice satisfy the relation $3\alpha_{BV} + 2\beta_{BV} = 1/8$. This implies that the angle of twist Ω_{BV} could

(i) either be a constant independent of the expansion, in which case $\alpha_{BV} = 1/24$ and $\beta_{BV} = cste$, which allows the existence of a topological reason for the explanation of the existence of discrete values, independent of the expansion, for the angle Ω_{BV},

(ii) either depend in fact on the volume expansion, in which case Ω_{BV} cannot take a discrete

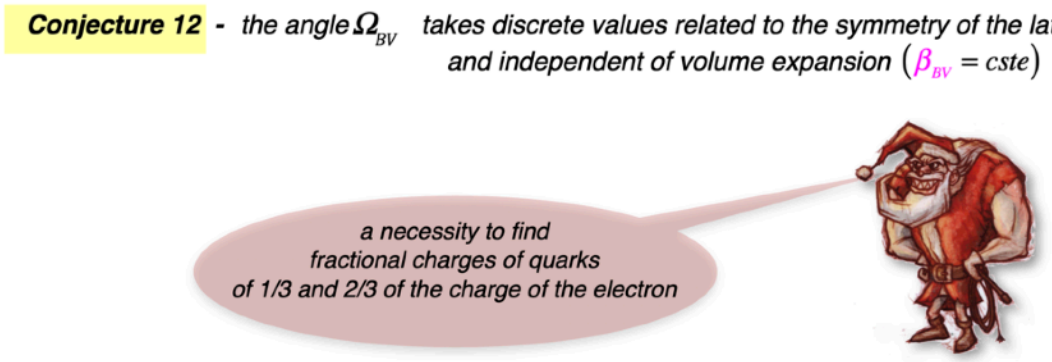


Figure 13.6 - *The twelfth conjecture on the quantification of the angles of rotation of the twist disclination loop*

value which is directly linked to the structure of the lattice since this angle would then depend continuously on the volume expansion.

Thus, so that it appears quantified charges like the charge of the electron, but also fractional charges of 1/3 and 2/3 of the charge of the electron as it is the case of the quarks of the standard model, the screw loops should be obtained by rotating the two planes inside the loop by an angle *corresponding to the symmetry of the lattice*, for example $\pi/2$, π, $3\pi/2$, ... in the directions perpendicular to the planes of a simple cubic lattice, or $\pi/3$, $2\pi/3$, π, ... in the directions perpendicular to the compact planes of a compact hexagonal or face-centered cubic lattice.

We will therefore choose hypothesis in the form of the conjecture 12 explained in figure 13.6 to try to find a cosmological lattice which could explain the standard model of elementary particles.

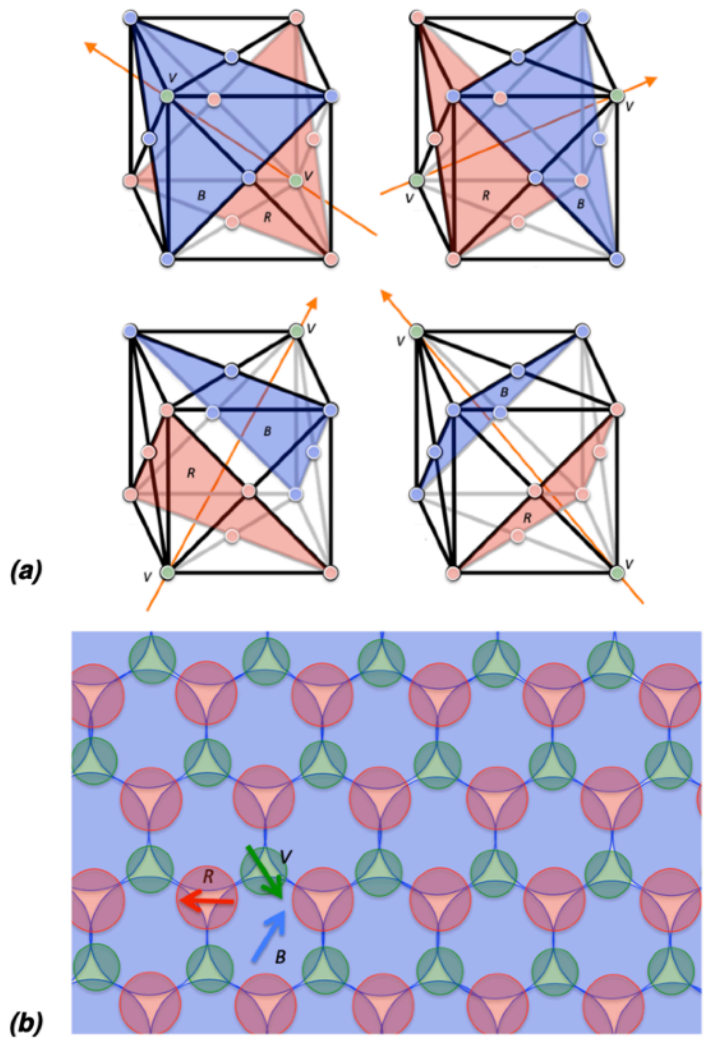


Figure 13.7 - *An imaginary, "axial", face-centered cubic cosmological lattice:*
(a) *CFC cell with the dense planes* ***R,B,V*** *showing a regular compact stacking in the four directions of space perpendicular to the four families of dense planes,*
(b) *plane representation of the* ***R,B,V*** *stacking of three successive dense planes, with the preferred directions of the layers associated with the axial properties of the lattice.*

To satisfy this assumption, it seems a priori preferable to choose a compact stacking lattice, namely a compact hexagonal lattice or a face-centered cubic lattice. For reasons that will be explained later, we will choose the face-centered cubic (*FCC*) lattice, as illustrated in figure 13.7.

In the *FCC* cell, there are four families of dense planes, shown in figure 13.7(a). The four axes perpendicular respectively to these four families of dense planes are third-order rotational symmetry axes passing through two opposite vertices of the *FCC* cell. Only rotations of $2\pi/3$, $4\pi/3$, 2π, ... about these axes respect the dense stacking of the *FCC* cell.

Let us imagine a priori that this *FFC* lattice is moreover an axial lattice, i.e. that each plane of "corpuscles" has a preferential direction represented in figure 13.7(b) by arrows making an angle of $2\pi/3$ between each dense layer. This axial property can be represented by *"colored planes of corpuscles"* with alternating three fundamental colors ***R, B, G***. Each of these colors represents one of the three preferred directions of the dense planes, as shown in figure 13.7(b). These imaginary "colors" are chosen only for convenience, and *so far* have no relation to the

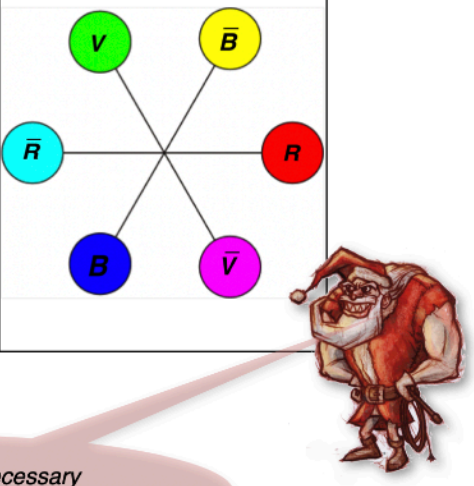
Conjecture 13 - the stacking of the ***R, B, V*** planes follows three basic rules *with respect to the axial properties of the CFC lattice:*

Rule 1: the alternation of the planes ***R, B, V*** cannot be broken, either by impossibility, or by penalty of *an extremely high stacking fault surface energy*,

Rule 2: there may appear a shift in the succession of ***R, B, V*** planes according to a connecting fault plane perpendicular to the dense planes, and this shift has *a non-zero connecting fault surface energy* γ_0,

Rule 3: if a plane of a given color is rotated by an angle $\pm 2\pi/3$, $\pm 4\pi/3$ ou $\pm 2\pi$, *it changes color* according to the table below

rotation angle Ω_{BV}	color change	colors R, V, B and anti-colors $\bar{R}$, $\bar{V}$, $\bar{B}$
$+2\pi$	$R \to R$	
0	$V \to V$	
-2π	$B \to B$	
$+2\pi/3$	$R \to V$	
	$V \to B$	
$-4\pi/3$	$B \to R$	
$+4\pi/3$	$R \to B$	
	$V \to R$	
$-2\pi/3$	$B \to V$	



three heuristic rules necessary to create an ad hoc "axial" cosmological lattice

Figure 13.8 - *The thirteenth conjecture on the stacking and rotation rules of the **R, B, V** planes of the axial CFC cosmological lattice*

"colors" used in the standard model to explain the color charge of quarks and gluons. Even if we do not know the physical reason for the existence of this axial property represented by these "colored planes", we can suppose that this alternation of colors of the corpuscular planes can be a condition for the existence of a perfect cosmological lattice in the absence of topological singularities, and that, if the ***R, B, V*** alternation of the lattice planes is broken by the presence of a topological singularity, fault energies can appear if a "corpuscular" plane does not follow the ***R, B, V*** arrangement. Let us then postulate *a priori* rules of stacking and rotation of the colored planes in this very particular lattice, in the form of a thirteenth conjecture reported in figure 13.8. In this conjecture, there are three rules which are all three associated with *the axial property of the FCC lattice* that we have postulated:

- *The first rule* stipulates that the ***R, B, V*** alternation of the dense planes of the lattice cannot be broken, under penalty of an important stacking fault energy, i.e. the preferential directions associated with the "corpuscles" must *if possible* alternate with an angle of $\pm 2\pi/3$ from one dense layer to the other.
- *The second rule* states that there may be planes perpendicular to the dense planes that separate two domains of the lattice with a shift in the succession of planes ***R, B, V***. These joints thus correspond to sorts of connecting fault planes, and it is assumed that these joints have *a non-zero connecting fault surface energy* γ_0.
- *The third rule* states that if a dense plane is rotated by an angle $\pm 2\pi/3$, $\pm 4\pi/3$ or $\pm 2\pi$ about an axis perpendicular to this family of dense planes, and thus leaves the *FCC* structure intact, it is the preferred direction of this dense plane represented by the arrows in figure 13.7(b) that changes, and thus it is the "color" of this plane that changes since the color represents this preferred direction.

Existence of quarks due to combining a screw disclination loop with an edge dislocation loop

We can introduce a screw disclination loop in our particular lattice, shown symbolically in figure 13.10d, with a rotation angle of the lower plane of $\pm 2\pi/3$ or $\pm 4\pi/3$ or $\pm\pi$. But according to rule 3, a rotation of $\pm 2\pi/3$ or $\pm 4\pi/3$ will change the color of the inner plane of the screw disclination loop. In this way, rule 1 would no longer be satisfied. Therefore, on the one hand, an interstitial or lacunar edge loop must be added to satisfy rule 1 with the upper dense plane, and on the other hand, a cylinder must be induced in which all dense planes below the screw disclination loop change color to satisfy rule 1. Then, according to rule 2, *a cylinder of connecting faults with fault surface energy* γ_0 is generated, as schematically represented in figures 13.9a to 13.9d.

The intercalated plane in the case of the interstitial edge loop has one of the three colors ***R, B, V*** (red, blue, green), whereas the missing plane in the case of the lacunar edge loop has the anti-color of the color of the interrupted plane, namely one of the colors $\bar{\boldsymbol{R}}$, $\bar{\boldsymbol{B}}$ or $\bar{\boldsymbol{V}}$. One uses indeed in the figures the complementary colors of ***R, B, G***, which are the colors cyan, magenta and yellow, as represented in figure 13.8. In the four cases (figures 13.9a to 13.9d), the screw disclination loop is obviously linked to the edge dislocation loop by the weak force described in chapter 9, but also by the necessity to introduce the edge loop to ensure the succession of the colors of the planes at the level of the screw disclination loop.

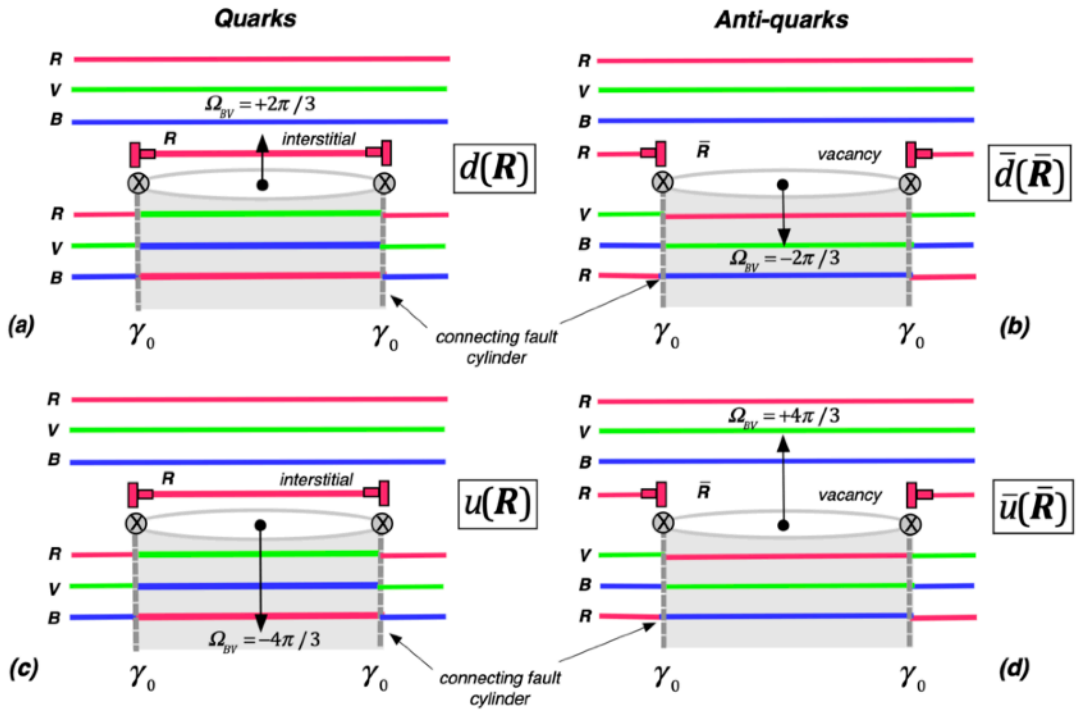


Figure 13.9 *- quarks and antiquarks formed by combinations of screw disclination loops of quantized angles with edge dislocation loops which ensure the continuity of succession of planes* ***R,B,V***

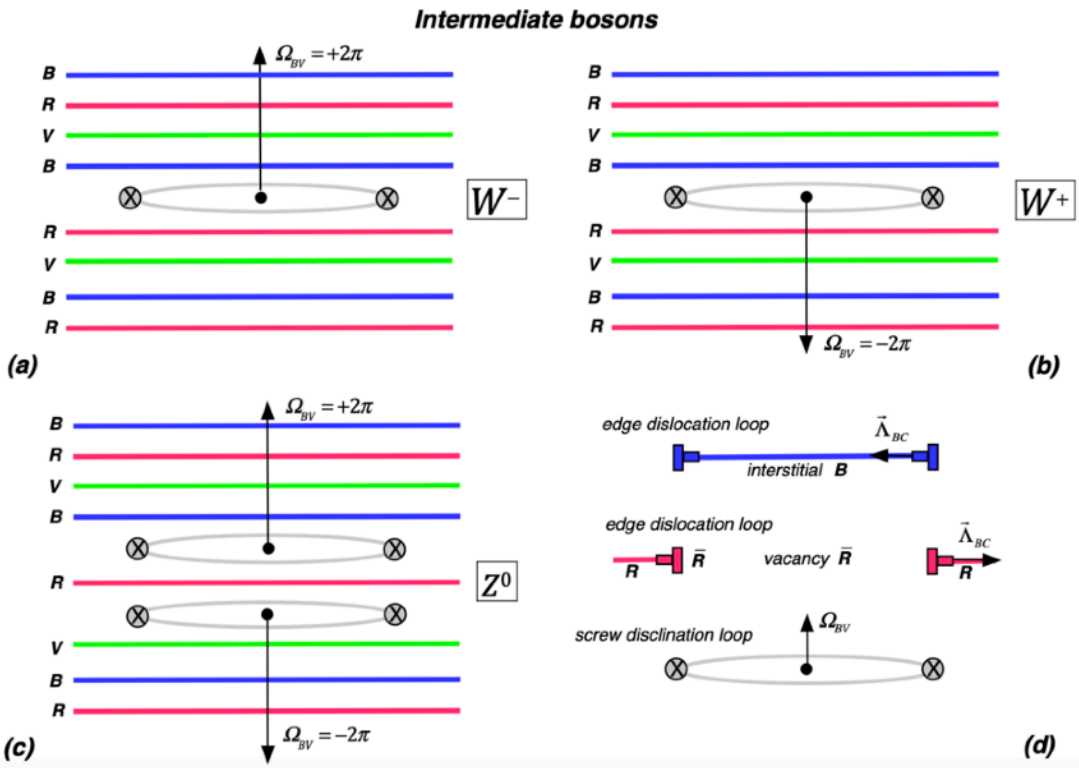


Figure 13.10 *- Intermediate bosons formed by screw disclination loops of angle* $\pm 2\pi$ *which do not need edge dislocation loops to ensure the continuity of succession of* ***R,B,V*** *planes*

The dispirations thus formed have a "color", which corresponds to the color of the interstitial loop plane or to the anti-color of the lacunar loop plane (the anti-color or complementary color of the corpuscular plane in which the lacunar loop appears).

Existence of intermediate gauge bosons

As for disclination loops of angle $\pm 2\pi$ (figures 13.10a to 13.10c), they do not need to be combined with edge loops since these rotations do not cause any color change in the lower planes, and therefore also no connecting fault cylinder below the loop.

In the table of figure 13.11, we have reported the properties of the different topological singularities thus formed, giving them, as in figures 13.9 and 13.10, a name chosen *"by chance"*, and using the fact that the two dispirations on the right (a and c) in figure 13.9 are clearly the anti-loops of the loops on the left (b and d).

name	Ω_{BV}	$q_{\lambda BV}$	**edge loop**	$q_{\theta BC}$	**color**
d	$+2\pi/3$	$-2\pi^2 R_{BV}^2/3$	*interstitial*	$-2\pi a$	***R***, ***V*** ou ***B***
u	$-4\pi/3$	$+4\pi^2 R_{BV}^2/3$	*interstitial*	$-2\pi a$	***R***, ***V*** ou ***B***
$\overline{d}$	$-2\pi/3$	$+2\pi^2 R_{BV}^2/3$	*vacancy*	$+2\pi a$	$\overline{\boldsymbol{R}}$, $\overline{\boldsymbol{V}}$ ou $\overline{\boldsymbol{B}}$
$\overline{u}$	$+4\pi/3$	$-4\pi^2 R_{BV}^2/3$	*vacancy*	$+2\pi a$	$\overline{\boldsymbol{R}}$, $\overline{\boldsymbol{V}}$ ou $\overline{\boldsymbol{B}}$
W^-	$+2\pi$	$-2\pi^2 R_{BV}^2$	-	0	-
W^+	-2π	$+2\pi^2 R_{BV}^2$	-	0	-
Z^0	$(+2\pi)+(-2\pi)$	0	-	0	-

Figure 13.11 - *The seven singularities composed of a screw disclination loop combined or not with interstitial or lacunar edge dislocation loops*

In table 13.11, we then see that the rotation charges $q_{\lambda BV}$, analogous to the electric charge, have three different values, corresponding respectively to 1/3x, 2/3x and 1x the charge of the loops W^- or W^+. On the other hand, only the dispirations d, u, $\overline{d}$ and $\overline{u}$ present a non-zero curvature charge $q_{\theta BC}$, and the sign of these charges, positive in the case of the lacunar edge loop and negative in the case of the interstitial edge loop, implies, as we have already postulated with conjecture 8, that the particles d and u c correspond by analogy to matter and that their anti-particles $\overline{d}$ and $\overline{u}$ correspond to anti-matter. The parameter a is in this

case the distance between two dense planes of the lattice. As for the particles W^-, W^+ and Z^0 which do not have a curvature charge, they must certainly have a large mass since they are loops of screw disclination with a very high rotation angle $\Omega_{BV} = -2\pi$.$

Weak interaction between quarks via intermediate bosons

It is interesting to note here that the combination of two dispirations d and $\overline{u}$, or $\overline{d}$ and u contributes to create a pure screw disclination loop W^- or W^+, which can again be transformed into a pair d and $\overline{u}$, or $\overline{d}$ and u . One can also imagine an exchange of an W^- or W^+ loop between two dispirations d and $\overline{u}$, or $\overline{d}$ and u, which will change their nature, or to put it more colorfully or poetically, their *"taste"* or *"flavor"*.

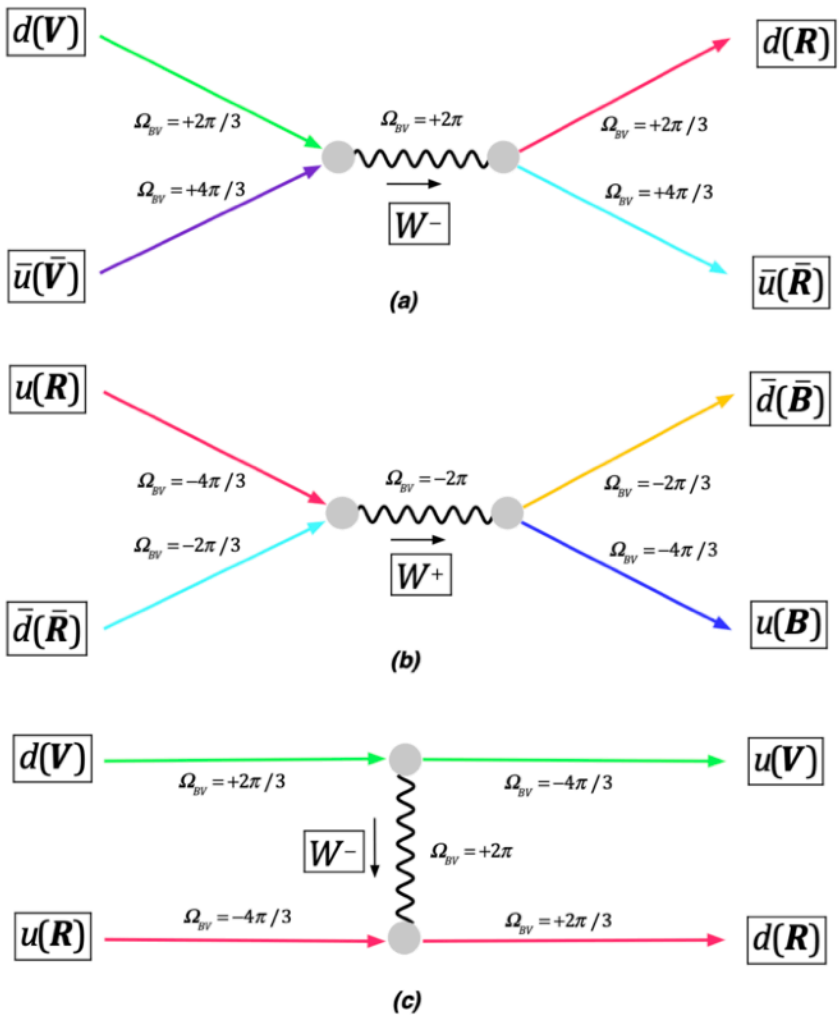


Figure 13.12 - *Feynman diagrams of mechanisms of combinations and exchanges of intermediate bosons between quarks of the table 13.10*

These combinations and exchanges are illustrated in figure 13.12 as *Feynman diagrams*. They are characterized by the fact that the total rotation Ω_{BV} is conserved, which ensures at the same time the conservation of the rotation charge $q_{\lambda BV}$. We also see that the total charge

$q_{\theta BC}$ is also conserved in these reactions. It is then undeniable that these reactions have a strange similarity with the weak interactions of the standard model reported in figure 13.3.

Existence of localized "baryons" and "mesons", formed by 3 and 2 dispirations

Each of the dispirations in figures 13.9a to 13.9d generates a connecting fault cylinder that has an energy proportional to the lateral surface of the cylinder. Consequently, it is impossible for these dispirations to appear in isolation, because the connecting fault cylinder would then be of gigantic length $\sim R_{\infty}$, and consequently of gigantic energy. One can then ask how to generate singularities composed of such dispirations, and which are of reasonable energy.

In fact, there are three ways to combine the four dispirations in figure 13.9 so that the resulting topological singularity is perfectly localized, namely that the connecting fault tube is of finite

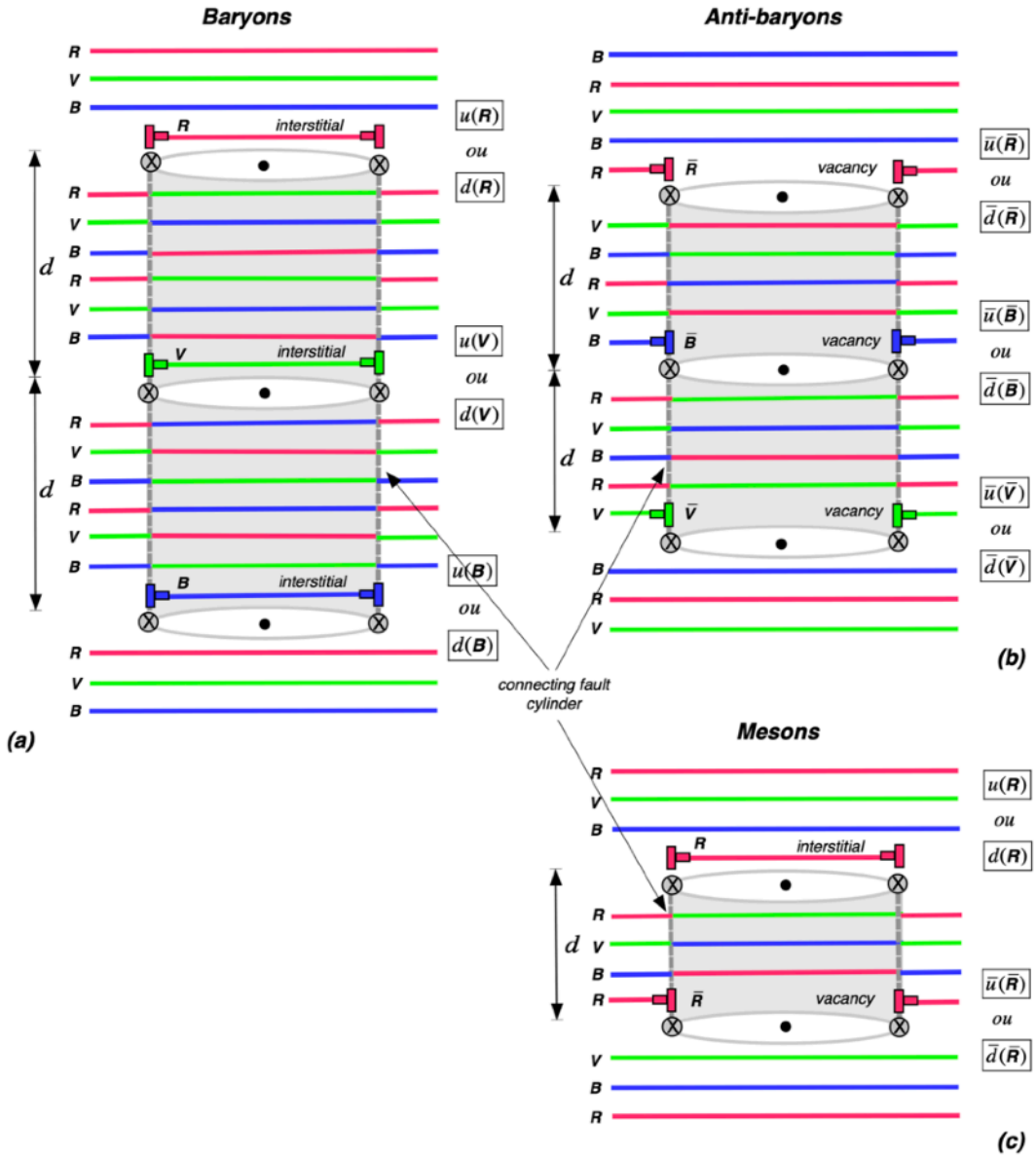


Figure 13.13 - *The three possible combinations of 2 or 3 dispirations allowing to form perfectly localized topological singularities*

length:

- *the combination of three singularities* u *or* d represented in figure 13.13a,
- *the combination of three anti-singularities* $\overline{u}$ *or* $\overline{d}$ represented in figure 13.13b,
- *the combination of one singularity* u *or* d *with one anti-singularity* $\overline{u}$ *or* $\overline{d}$ represented in figure 13.13c.

In order for the three rules previously stated to be all perfectly satisfied in these various combinations, it is necessary that:

- *the sum of the angles of rotation* Ω_{BV} *of all the dispirations of the combination is zero or a multiple of* 2π, which allows the connecting fault tube to be of finite length,
- *the color of the assembly thus formed is "white"*, thus that the assembly presents the sum of the 3 colors ***R, G, B*** (figure 13.13a), or the sum of the 3 anti-colors $\overline{\boldsymbol{R}}$, $\overline{\boldsymbol{V}}$, $\overline{\boldsymbol{B}}$ (figure 13.13b), or the sum of one of the colors ***R, G, B*** with its respective anti-color $\overline{\boldsymbol{R}}$, $\overline{\boldsymbol{V}}$, $\overline{\boldsymbol{B}}$ (figure 13.13c).

In the table of figure 13.14, the 8 different possible combinations of 3 dispirations of the table

combinations	***symbol spin 1/2***	***symbol spin 3/2***	Ω_{BV}	$q_{\lambda BV}$	***edge loop***	$q_{\theta BC}$
$d\,d\,d$	e^- (?) *electron*	Δ^-	$+2\pi$	$-2\pi^2 R_{BV}^2$	*interstitial*	$-6\pi a$
$d\,u\,d$	n *neutron*	Δ^0	0	0	*interstitial*	$-6\pi a$
$u\,d\,u$	p *proton*	Δ^+	-2π	$+2\pi^2 R_{BV}^2$	*interstitial*	$-6\pi a$
$u\,u\,u$	e^{++} (???) *lepton ?*	Δ^{++}	-4π	$+4\pi^2 R_{BV}^2$	*interstitial*	$-6\pi a$
$\overline{d}\,\overline{d}\,\overline{d}$	$\overline{e}^+$ (?) *positron*	$\overline{\Delta}^+$	-2π	$+2\pi^2 R_{BV}^2$	*vacancy*	$6\pi a$
$\overline{d}\,\overline{u}\,\overline{d}$	$\overline{n}$ *antineutron*	$\overline{\Delta}^0$	0	0	*vacancy*	$6\pi a$
$\overline{u}\,\overline{d}\,\overline{u}$	$\overline{p}$ *antiproton*	$\overline{\Delta}^-$	$+2\pi$	$-2\pi^2 R_{BV}^2$	*vacancy*	$6\pi a$
$\overline{u}\,\overline{u}\,\overline{u}$	$\overline{e}^{--}$ (???) *anti-lepton ?*	$\overline{\Delta}^{--}$	$+4\pi$	$-4\pi^2 R_{BV}^2$	*vacancy*	$6\pi a$

Figure 13.14 - *The "white" baryons formed by 3 dispirations, and the four leptons obtained by collapsing combinations of quarks* ddd, $\overline{ddd}$, uuu *and* $\overline{u}\,\overline{u}\,\overline{u}$

of figure 13.11 have been reported with their property, giving them a symbol and calling them baryons by analogy with the standard model.

In this table, the analogy with the baryons of the standard model of elementary particles, composed of triplets of quarks u and d or triplets of anti-quarks $\overline{u}$ and $\overline{d}$, is flagrant and perfect. Not only do we see particles composed of quarks with fractional rotation charges $q_{\lambda BV}$ corresponding to the electric charges of the standard model, but we also add here the curvature charge $q_{\theta BC}$ which has no equivalent in the standard model, and which corresponds perfectly with our conjecture 8, namely that *the singularities of lacunar nature correspond by analogy to anti-matter and the singularities of interstitial nature to matter.* The fact that the particles of the standard model appear with two different symbols in this table for the combinations $d\,u\,d$, $u\,d\,u$, $\overline{d}\,\overline{u}\,\overline{d}$ and $\overline{u}\,\overline{d}\,\overline{u}$ is explained by the notion of spin of the screw disclination loops, developed in chapter 12. Indeed, if each quark has a spin $\pm 1/2$, then the spin composition can create a global spin of $\pm 1/2$ in the case of particles *(neutron)* and *(proton)* and anti-particles *(anti-neutron)* and *(anti-proton),* or a spin $\pm 3/2$ in the case of particles Δ^0 and Δ^+ and anti-particles $\overline{\Delta}^0$ et $\overline{\Delta}^-$. In the case of the combinations $d\,d\,d$, $u\,u\,u$, $\overline{d}\,\overline{d}\,\overline{d}$ and $\overline{u}\,\overline{u}\,\overline{u}$, the spins of the 3 quarks are obligatorily aligned (for a reason which remains to be explained, but which is most probably linked with the exclusion principle) and the composition of the spins can then only provide a global spin of $\pm 3/2$ in the case of the particles Δ^- and Δ^{++} and anti-particles $\overline{\Delta}^+$ and $\overline{\Delta}^{--}$. In the case of the combinations $d\,d\,d$ and $\overline{d}\,\overline{d}\,\overline{d}$, the complete collapse of the quarks with spin $\pm 1/2$ then presents exactly the configuration of the leptons "electron" and "positron" as represented in figure 13.17. We will come back to this subject in the rest of this chapter.

In the table of figure 13.15, the different possible combinations of 2 dispirations of the table of figure 13.11 have been reported with their property, giving them a symbol and calling them *mesons* by analogy with the standard model.

combinations	***symbol spin 0***	***symbol spin 1***	Ω_{BV}	$q_{\lambda BV}$	***edge loop***	$q_{\theta BC}$
$d\,\overline{d}$	π^0	ρ^0	0	0	-	0
$d\,\overline{u}$	π^-	ρ^-	$+2\pi$	$-2\pi^2 R_{BV}^2$	-	0
$\overline{d}\,u$	π^+	ρ^+	-2π	$+2\pi^2 R_{BV}^2$	-	0
$u\,\overline{u}$	η^0	ω^0	0	0	-	0

Figure 13.15 - *The mesons of "white" color formed by 2 dispirations*

In this table, the analogy with the mesons of the standard model of elementary particles, composed of quarks doublet u or d with anti-quarks $\overline{u}$ or $\overline{d}$, is flagrant and perfect. One

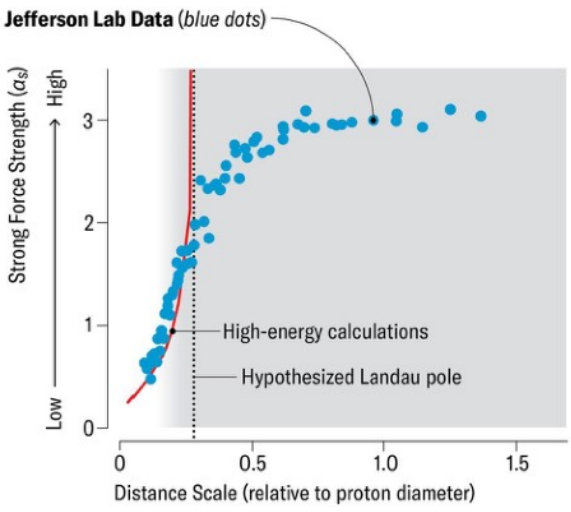
can see particles composed of quarks with fractional rotation charges $q_{\lambda BV}$, which correspond to the mesons of the standard model, but with a zero curvature charge $q_{\theta BC}$, which means that these topological singularities cannot be catalogued as anti-matter (singularities of lacunar nature) or matter (singularities of interstitial nature).

The fact that the particles of the standard model appear with two different symbols in this table is also explained by the notion of spin of the screw disclination loops, developed in chapter 12. Indeed, if each quark has a spin $\pm 1/2$, then the spin composition can create a global spin of 0 in the case of particles π^0, π^-, π^+ and η^0, or a spin ± 1 in the case of particles ρ^0, ρ^-, ρ^+ et ω^0.

The strong force and its asymptotic behavior

The quarks making up the particles in the tables of figures 31.9 and 31.10 are linked by a cylinder of connecting faults, so that the energy of the topological singularity increases as $E_\gamma \sim \gamma_0 2\pi R_{BV} d \sim \alpha d$ if the distance d separating two dispirations increases. On the other hand, when we try to bring together the quarks making up the particles in the tables in figures 31.9 and 31.10, a repulsive force appears. For example, in the case of the particle π^-, quarks d and $\overline{u}$ are electrically charged $-2\pi^2 R_{BV}^2/3$ and $-4\pi^2 R_{BV}^2/3$, respectively, of the same sign, so the electrical interaction energy between the two quarks increases as $E_{élect} \sim \beta/d$. The total interaction energy due to the stacking fault cylinder and the electrical repulsion between the quarks, $E_{\text{int}} = E_\gamma + E_{élect} \sim \alpha d + \beta/d$, therefore has a minimum at $d_{\min} = (\beta/\alpha)^{1/2}$, which corresponds to the equilibrium distance between the quarks. The strong interaction force is deduced by deriving the interaction energy with respect to d as $F_{forte} = \partial E_{\text{int}}/\partial d \sim \alpha d - \beta/d^2$. This force is therefore repulsive below $d_{\min}$, zero for $d = d_{\min}$ and attractive above $d_{\min}$.

The binding force of dispirations is therefore a strong force, in the sense that the binding force increases if we try to separate the dispirations. This is similar to the case of the stacking fault energy between two partial dislocations in a *FCC* lattice, or the case of the connection fault energy between three partial dislocations in an axial cubic lattice (see Chapter 2). The equilibrium distance $d_{\min}$ between the dispirations is then controlled by a competition mechanism between the repulsive interaction energy between the loops making up the particle and the stacking fault energy between the loops, a mechanism quite similar to the one described in the case of figure 2.16.



Remarkably, the attractive interaction force above $d_{\min}$ increases until it tends towards a constant limit value equal to $F_{forte} \to \alpha$. This original "asymptotic" behavior of the strong force has indeed been measured at the Thomas Jefferson

Lab in Virginia[1], and is plotted in the figure above. We can see that the measured behavior of the strong force corresponds perfectly to the existence of a cylinder of stacking faults!

Strong interaction between quarks via the gluon gauge bosons

In the standard model, the quantum treatment of the "colors" of quarks is provided by *quantum chromodynamics,* in which there are 8 colored gauge bosons, carriers of the strong force, called *gluons*.

And it is the exchange of a colored gluon between two quarks that allows then to exchange the color of these two quarks, by an interaction that can be represented, as in figure 13.16, in the form of a *Feynman diagram* illustrated by the configuration of the topological singularities involved.

The colored gluons then correspond to two associated edge dislocation loops, one of inter-

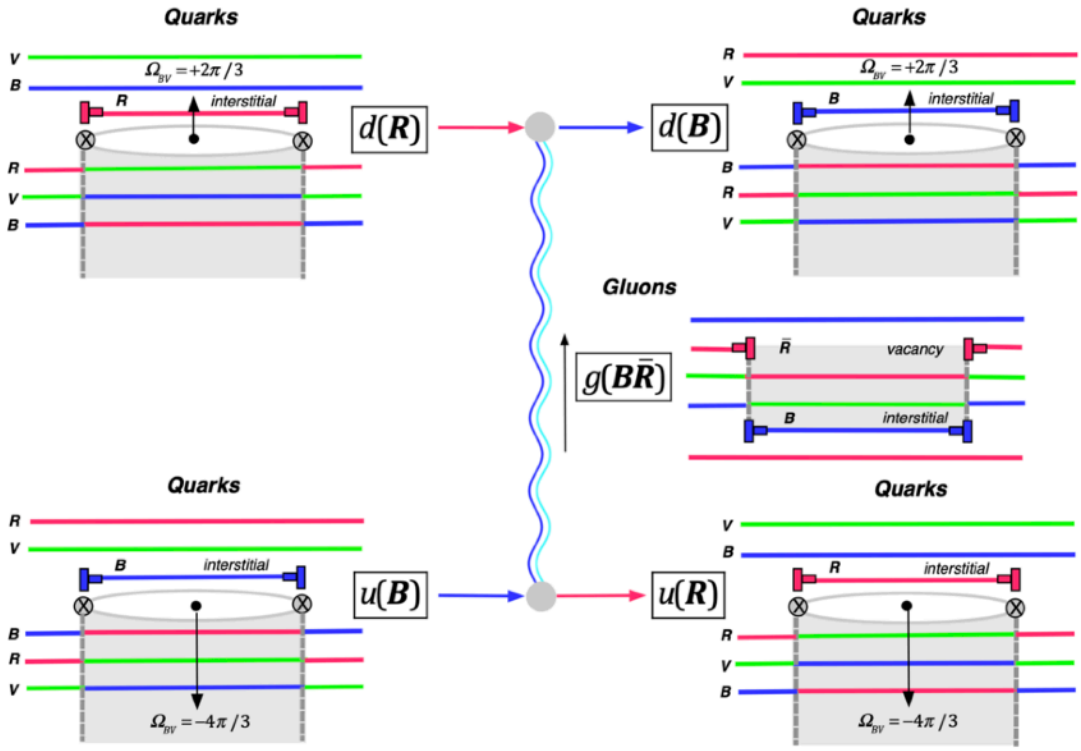


Figure 13.16 *- Feynman diagram of the color exchange of two quarks by the exchange of a bicolor gluon*

stitial nature and one of lacunar nature, and their rotation charge $q_{\lambda BC}$ is zero. The edge loops are linked together by the existence of a connecting fault cylinder, and are therefore subject to the strong force. As for their curvature charge $q_{\theta BC}$, it is null since we have $q_{\theta BC} = (+2\pi a) + (-2\pi a)$, so that *the energy associated to the distortions of this pair of loops must be extremely low*, and that, consequently, *the mass of the gluons must be almost null, while it has a non null energy coming from the connecting fault cylinder*. From this point of

[1] *S. J. Brodky, A. Deur, C.D. Roberts, «The secrets of the Strongest Force in the Universe» Scientific American Magazine, Vol. 330, No. 5, May 2024, p. 32*

view, gluons are similar to photons.

In quantum chromodynamics, it is thought that it is this mechanism of exchange of gluons between neutrons and protons of the atomic nucleus that explains the cohesion of atomic nuclei. It is therefore a side effect of the strong force since these exchanges of colored gluons disturb the distances between the dispirations composing the neutrons and protons, and consequently disturb the energies of the protons and neutrons.

The constitution of neutrino and anti-neutrino leptons

In the standard model, there is also a first family of quasi-punctual particles called leptons, represented by the electron e^-, the anti-electron or positron e^+, the electron neutrino ν_e and

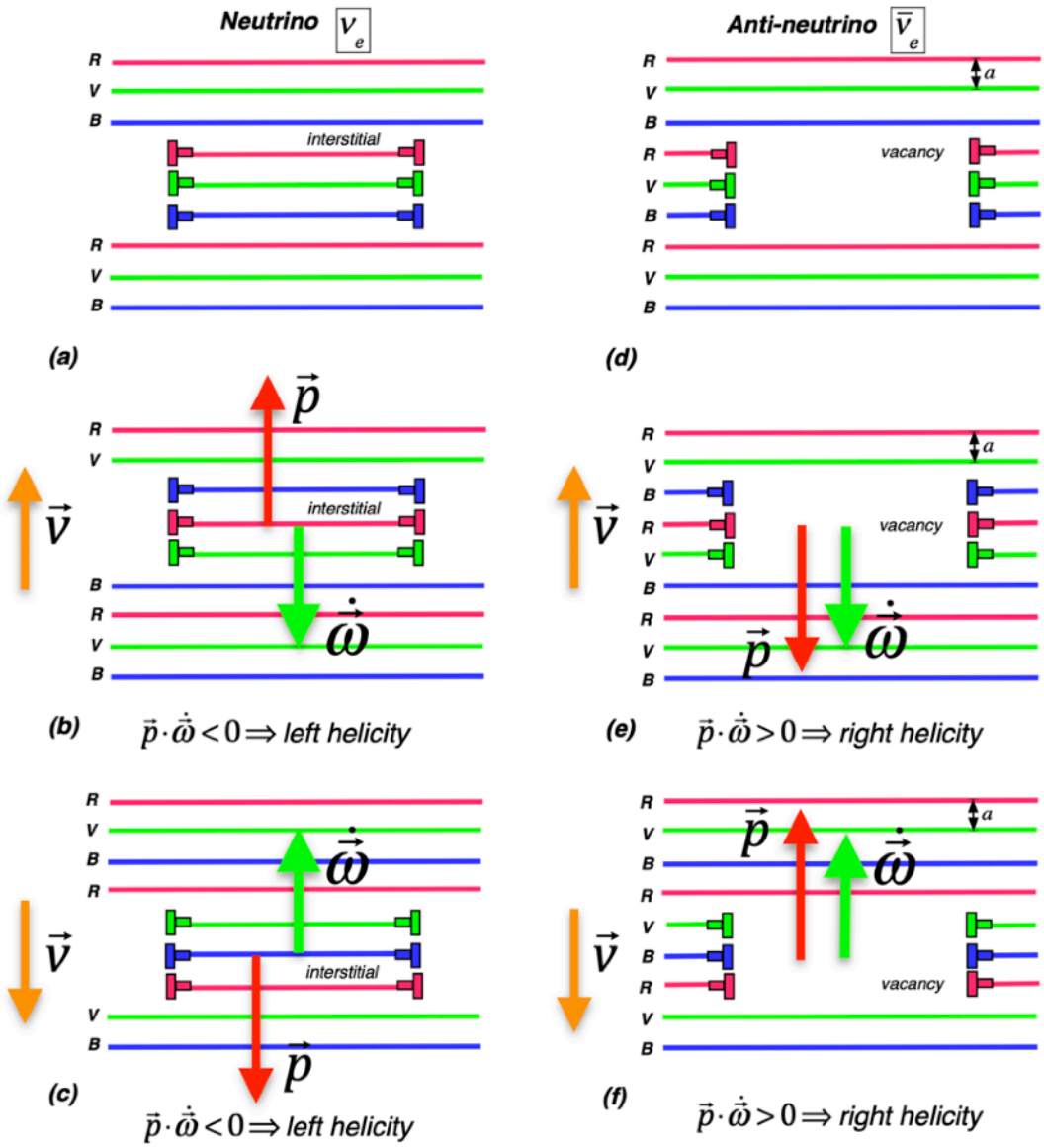


Figure 13.17 - *The neutrino and the antineutrino and their negative and positive helicity as the scalar product of their momentum $\vec{p}$ and the speed of rotation $\dot{\vec{\omega}}$ of their axial planes*

the electron anti-neutrino $\overline{\nu}_e$.

In the cosmological lattice, we have already postulated the existence of the neutrino in the form of an edge dislocation loop of interstitial nature, while the anti-neutrino corresponded to an edge dislocation loop of lacunar nature. This is what allowed us to deduce exceptional repulsive gravitational properties for the neutrino, due to its curvature charge which largely dominates the attractive gravitational effects due to its inertial mass. In the case of the "colored cosmological lattice" of figure 13.7, in order to respect the three rules that this lattice must satisfy, the neutrino can only correspond to the insertion of three consecutive planes of color ***R, G, B***, and the anti-neutrino to the subtraction of three consecutive planes $\overline{\boldsymbol{R}}$, $\overline{\boldsymbol{V}}$, $\overline{\boldsymbol{B}}$, as represented in figures 13.17a and 13.17d, so as to form an inclusion or a hole that has no color, i.e. white color. In this form, neutrinos and anti-neutrinos have exactly the properties that we deduced in the previous chapters for prismatic edge dislocation loops, provided that their Burgers vector has a norm such that $\left|\vec{B}_{BC}\right| = 3a$, so that their curvature charge by flexion has a norm equal to $\left|\boldsymbol{q}_{\theta BC}\right| = 6\pi a$.

In particle physics, the *helicity* $\vec{S}\cdot\vec{p}/\left|\vec{p}\right|$ *of a particle* is defined as the projection of its spin $\vec{S}$ on the direction $\vec{p}/\left|\vec{p}\right|$ of its momentum $\vec{p}$ (this projection corresponds to the component of the spin along the direction of propagation). We say that a *particle's helicity is right (positive) or left (negative)* depending on whether its spin is oriented in the same direction or in the opposite direction to its motion. In the case of the neutrino and the anti-neutrino, experimental observation shows that *all neutrinos always have a left helicity*, and that *all antineutrinos always have a right helicity*. And the fact that neutrinos are always left-handed is very important, because it explains *the phenomenon of parity violation in the weak interaction*.

An explanation of this helicity behavior can be given here by considering classically the motion of neutrinos and anti-neutrinos in figure 13.17. Indeed, if we consider that these particles move in the lattice perpendicularly to the dense planes at velocity $\vec{v}$ as illustrated in figures 13.17, we find that the direction of momentum $\vec{p}$ associated with the displacements of the massive planes is in the direction of the neutrino's velocity $\vec{v}$, but in the opposite direction to the direction of the velocity $\vec{v}$ of displacement in the case of the anti-neutrino. As for the direction of rotation of neutrinos and anti-neutrinos, represented by the angular velocity vector $\dot{\vec{\omega}}$ of the "corpuscle" planes concerned, it can be seen that it is always opposite to the direction of the velocity $\vec{v}$. If we classically qualify the helicity of these motions by the sign of the scalar product $\vec{p}\cdot\dot{\vec{\omega}}$ of the momentum $\vec{p}$ and the angular velocity $\dot{\vec{\omega}}$, we can see that the helicity of the neutrino is always negative, so that *the motion of the neutrino is always of left-handed helicity*, while this same product in the case of the anti-neutrino is always positive, so that *the motion of the anti-neutrino is always of right-handed helicity.*

The constitution of electron and positron leptons

As for the electron and the anti-electron or positron, we have already hypothesized that the screw disclination loop is a good candidate to represent them. In this case, to ensure that the rotation charge matches well, the rotation angle $\boldsymbol{\Omega}_{BV}$ between two consecutive planes must be equal to $\pm 2\pi$, so that the norm of the rotation charge satisfies the relation $\left|\boldsymbol{q}_{\lambda BV}\right| = 2\pi^2 R_{BV}^2$. However, in this pure form, the screw disclination loop has already been identified as the particle W^- or W^+ in figures 13.10a and 13.10b. Moreover, the electron and the positron must

present the dissymmetry between matter and anti-matter, and they must satisfy the weak leptonic interactions of figure 13.3. To satisfy these desiderata, one must again use a combination of a screw disclination loop of angle $\pm 2\pi$, which satisfies rule 3 and therefore has no color, with an edge dislocation loop corresponding to the insertion of three consecutive planes of color ***R, G, B***, or the subtraction of three consecutive planes $\overline{\boldsymbol{R}}$, $\overline{\boldsymbol{V}}$, $\overline{\boldsymbol{B}}$.

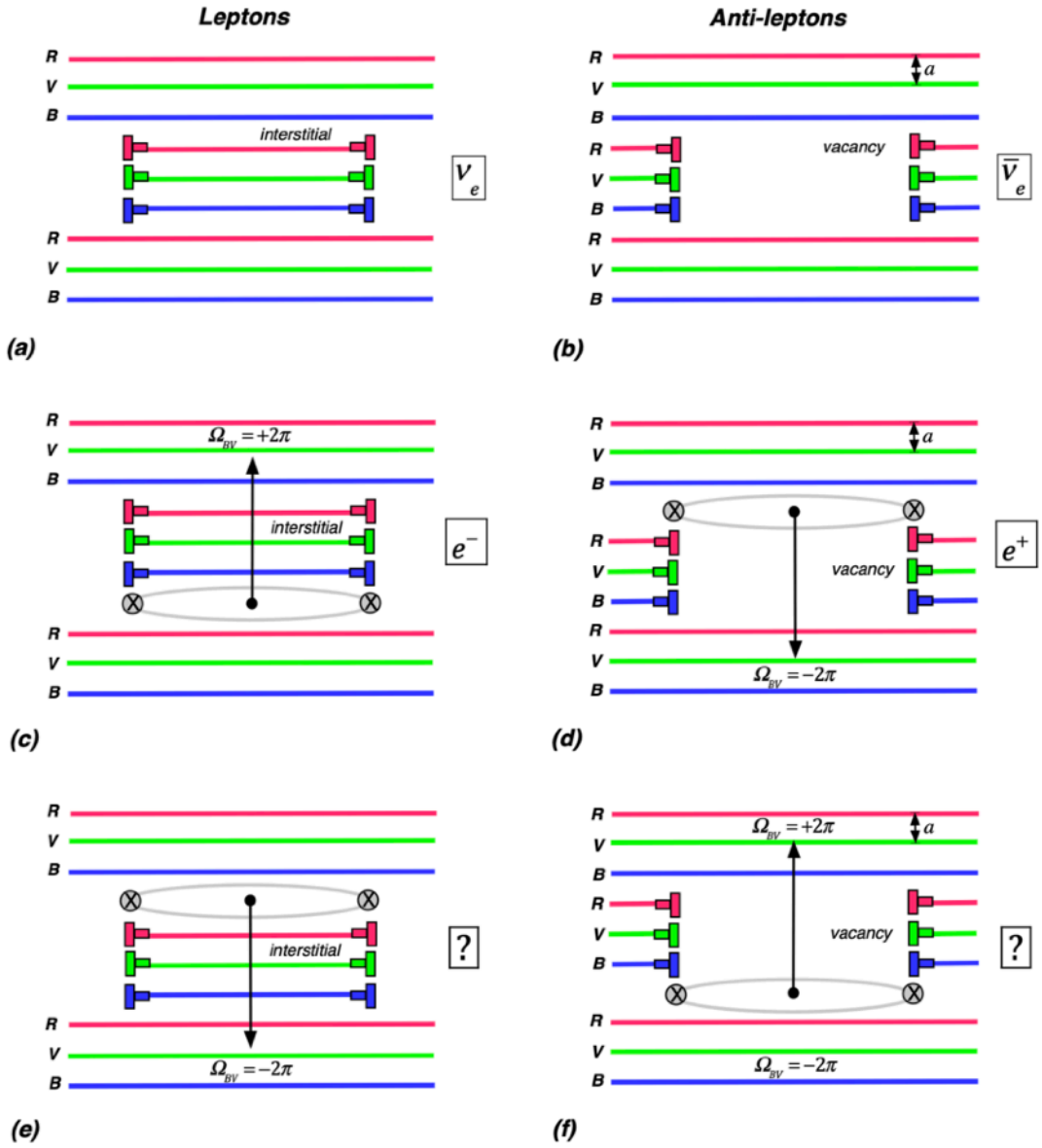


Figure 13.18 - *Structure of the neutrino, the anti-neutrino, the electron, the positron, and two "unknown leptons", as assemblies of edge dislocation loops and screw disclination loops*

In principle, there should thus be four different electrons, of charges $\boldsymbol{q}_{\lambda BV} = \pm 2\pi^2 R_{BV}^2$ and $\boldsymbol{q}_{\theta BC} = \pm 6\pi a$ as represented in figures 13.18c to 13.18f. But in reality, one observes in nature only *the electron* e^- *and the anti-electron or positron* $\overline{e}^+$. The "unknown leptons" represented in figures 13.18e and 13.18f could be considered in fact as a positive electron of matter and a

negative anti-electron, but they are not observed in nature, whereas nothing seems a priori to show the reason in figures 13.17.

However, there could be a rather simple explanation, although difficult to justify. One could imagine that the charged leptons are in fact the results of collapses of three-quark baryons. Let us consider the simplest case, namely the compression of assemblies of quarks $d\,d\,d$ and $\overline{d}\,\overline{d}\,\overline{d}$, so as to collapse the three screw loops into one, and to collapse the three edge loops into one. We then obtain directly the electron and the positron represented in figures 13.18c and 13.18d. But it would be necessary that these collapses lead to leptons of spin 1/2 since the electron and the positron are of spin 1/2. However, in table 13.14, we see that the assemblies of quarks $d\,d\,d$ and $\overline{d}\,\overline{d}\,\overline{d}$ lead exclusively to baryons Δ^- and $\overline{\Delta}^+$ of spin 3/2, and that there are no baryons $d\,d\,d$ and $\overline{d}\,\overline{d}\,\overline{d}$ with a spin 1/2. One can therefore imagine that the assemblies of quarks $d\,d\,d$ and $\overline{d}\,\overline{d}\,\overline{d}$ with spin 1/2 must necessarily become leptons, thus electrons and positrons, as suggested in table 13.14.

By admitting this explanation, it becomes quite simple to explain the non observation of the "unknown leptons" of figures 13.18e and 13.18f. Indeed, it is enough to note that there is no assembly of three quarks in the table 13.14 which could lead by collapse to the two "imaginary" leptons of figures 13.18e and 13.18f, hence the explanation of the non-existence of these two leptons.

Looking at the table of figure 13.14, we also see that there are no spin 1/2 baryons obtained by combining quarks $u\,u\,u$ and $\overline{u}\,\overline{u}\,\overline{u}$, and we could then ask ourselves if there would not exist a positive lepton e^{++} of spin 1/2 and double charge coming from the collapse of the quark assembly $u\,u\,u$ and a negative anti-lepton $\overline{e}^{--}$ of spin 1/2 and double charge coming from the collapse of the quark assembly $\overline{u}\,\overline{u}\,\overline{u}$. The existence of these two leptons would have the advantage of filling the two gaps left in table 13.14. Note that in the literature[2], doubly charged leptonic states appear in type II flip-flop mechanisms, in strong electroweak symmetry breaking models, in some extensions of supersymmetric models, in models of flavors in extra distorted dimensions, and in even more general models, in string theory inspired models and in 3-3-1 models. In addition, doubly charged stable leptons are also considered by some as an acceptable candidate for cold dark matter.

Weak interaction of leptons and intermediate bosons of the standard model

In the standard model, the weak interactions correspond to exchange of intermediate bosons $W^{\pm}$ ou Z^0, which allow to exchange the electric charge between two particles, as reported in figures 13.3 and 13.11. For the Feynman diagrams of these figures to work with the dispirations of our model, it is necessary that the intermediate bosons are pure screw disclination loops of rotation angles $\boldsymbol{\Omega}_{BV}$ worth respectively $\pm 2\pi$ or 0, as represented in figure 13.9e to 13.9g.

The intermediate bosons are then the only massive gauge bosons, which is understandable if they are indeed pure loops of screw disclination. Experimentally, it has been found that their mass is much higher than that of the electron and the positron, which could be explained by the fact that the rotation of $\pm 2\pi$ must be entirely done on a distance of a in the case of the inter-

[2] *A. Ozansoy, «Doubly Charged Lepton Search Potential of the FCC base Energy-Frontier Electron-Proton Colliders», Advances in High Energy Physics, Volume 2020, Article ID 9234130, 13 pages, https://doi.org/10.1155/2020/9234130*

symbol	Ω_{BV}	$q_{\lambda BV}$	edge loop	$q_{\theta BC}$
ν_e	0	0	interstitial	$-6\pi a$
e^-	$+2\pi$	$-2\pi^2 R_{BV}^2$	interstitial	$-6\pi a$
$\bar{\nu}_e$	0	0	vacancy	$6\pi a$
e^+	-2π	$+2\pi^2 R_{BV}^2$	vacancy	$6\pi a$
W^-	$+2\pi$	$-2\pi^2 R_{BV}^2$	-	0
W^+	-2π	$+2\pi^2 R_{BV}^2$	-	0
Z^0	$(+2\pi)+(-2\pi)$	0	-	0

Figure 13.19 - *The leptons of the first family and the intermediate gauge bosons*

mediate bosons, whereas in the case of the electron and the positron, the rotation of $\pm 2\pi$ can be distributed on 3 successive planes, thus on a distance of $3a$, which must decrease very considerably the local distortions of the lattice, and thus the energy of the particle. This could also be the reason why a gauge boson would associate extremely quickly with 3 interstitial or lacunar edge loops to strongly decrease its energy, which would perfectly explain the weak interactions of figure 13.3.

Note also that, in the standard model of particles, the gauge bosons W^+ and Z^0 are of spin 1, and therefore they do not satisfy the exclusion principle, which means that two gauge bosons can occupy the same state, and thus superimpose, which creates a loop of screw disclination of angle Ω_{BV} equal to for example $\pm 4\pi$. On the other hand, the electron and the positron are particles of spin 1/2, which satisfy the Pauli exclusion principle. They cannot therefore occupy the same state, which means that they cannot be superimposed, which becomes naively almost an evidence if we consider the loop structure of electrons and positrons represented in figure 13.15. One can then plot the properties of the leptons and the gauge bosons in the table of figure 13.19.

An attempt to explain the three families of quarks and leptons of the standard model

In the Standard Model, there are not only the quarks and leptons just described, but there are also two additional families of quarks and leptons (figure 13.1), distinguished mainly by the

much higher masses observed experimentally each time one moves from one family to the next. The progression of masses within the table of elementary particles of the standard model is plotted in figure 13.20, giving the approximate multiplicative factor of the masses, in the horizontal direction of the table and in the vertical direction of the table. It can be seen that the average multiplicative factors reported outside the table are indeed very high when moving from one family to another, while the multiplicative factors for moving from one particle to another within each family are not so high, except in the case of the neutrino to electron transition, which would

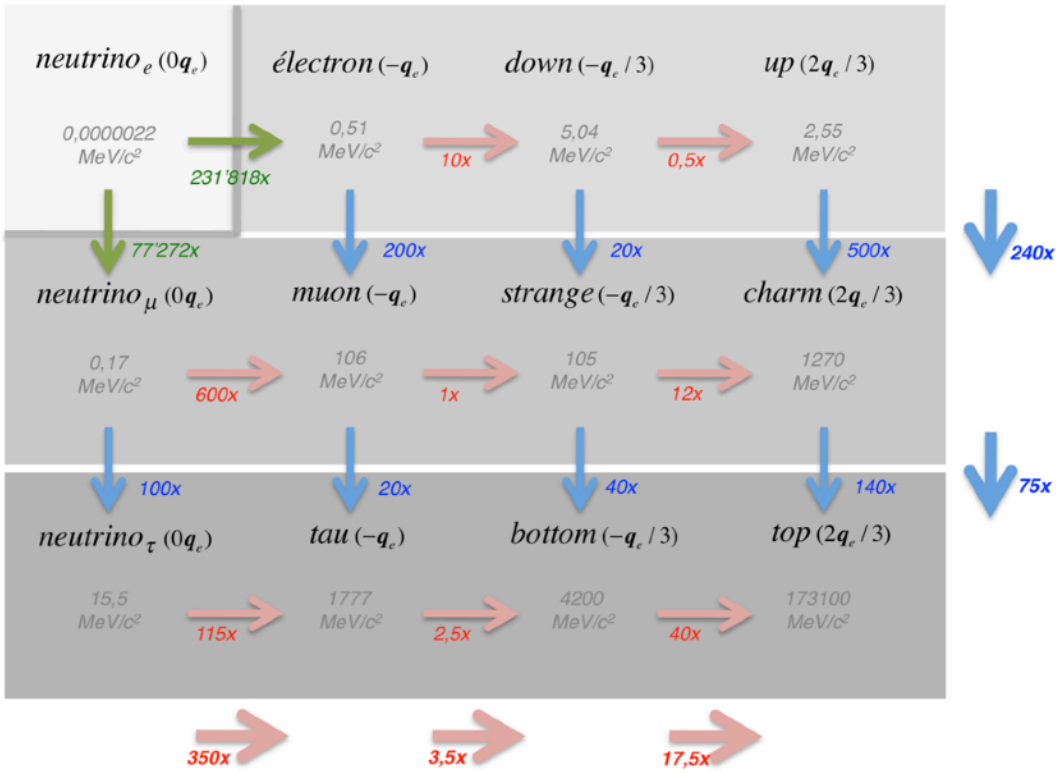


Figure 13.20 - *The masses of the particles of the standard model, measured experimentally and expressed in MeV/c2, with the approximate multiplicative factors*

tend to suggest that the topological structure responsible for the large mass increase most likely changes from one family to another but most likely remains the same within the same family. It is also remarkable that the multiplicative factors associated with the neutrino ν_e are colossally higher than all other factors, which tends to make one think that it is probably the structure of the edge loops that change from one family to another.

As for the colossal multiplicative factor to go from neutrino ν_e to electron e^-, it is explained by the huge energy difference between an edge dislocation loop and a screw disclination loop, as we have explained in chapter 5.

About the possibility of involving the stacking fault energy between axial dense planes

The fact that there are two additional families with much higher energies could perhaps be

attributed to the appearance of stacking faults between dense axial planes, faults that were initially eliminated by rule 1 in conjecture 13. In fact, we constructed the first family of particles taking this rule into account, i.e., by ensuring that the ***R, V, B*** sequence of dense planes is never violated. To do this, we had to introduce edge dislocation loops of the correct color to describe quarks, and introduce a triple edge loop of three colors to describe leptons.

Let us imagine that there could be stacking faults between the dense planes of the lattice. There are only two types of stacking faults that are possible: either a faulty alternation of planes of the type ***X-Y-X***, or a faulty alternation of the type ***X-X***. Let us assume that the defect energies associated with these two types of stacking faults are essentially due to the axial properties of these planes, and therefore have axial surface defect energies γ_{1a} *and* γ_{1b} respectively. The defect energy γ_{1a} is associated with an ***X-Y-X*** type stacking fault, while the defect energy γ_{1b} is due to an ***X-X*** type stacking fault. The fault energy γ_{1a} is therefore related to a stacking error with the second neighboring plane, while γ_{1b} is related to a stacking error with the first neighboring plane. There is therefore a strong possibility that the energy γ_{1b} will be significantly higher than the energy γ_{1a}, and therefore that $\gamma_{1b} >> \gamma_{1a}$.

On the possible constitution of neutrino families

Let's take the case of neutrinos, which we know exist in three different states or three “flavors,” as physicists say: electron, muon, and tau. By removing or adding one or two planes to the electron neutrino and antineutrino in figures 13.18a and 13.18b, we can construct the six neutral leptons shown in figure 13.21.

The addition or removal of two axial dense planes corresponds to two fault energies γ_{1a} and could therefore correspond to the muon neutrinos and antineutrinos of the second family, while the addition or removal of one axial dense plane corresponds to fault energies γ_{1b} and could therefore correspond to the tau neutrinos and antineutrinos of the third family.

Experimentally, it has been found, surprisingly, that neutrinos are capable of spontaneously changing from one flavor to another during their movement. They are even the only elementary particles with this property, called “oscillation.” The major result of these experiments is that this transformation of neutrinos can only be explained by the fact that they have different masses, which is the case since they differ from one family to another (from one flavor to another) in terms of their lattice deformation energy and their axial dense plane stacking fault energy.

As for the mechanism that leads to this oscillation, it is assumed that at the moment of creation and emission of neutrinos or antineutrinos by weak interaction (for example, in the beta decay of radioactive nuclei), the mass states cannot be separated. A coherent superposition of defined mass states is then formed, and the wave function now contains all types of neutrinos. There is then a probability of observing each type of neutrino that can be deduced from the wave function, and this probability function exhibits a magnificent oscillatory behavior. Neutrino oscillations can only be observed if the masses *m1, m2*, and *m3* are not all identical, which leads to slightly different speeds from one flavor to another, hence the phenomenon of oscillation, and if the initial neutrino (emitted in a weak interaction process) is created in a coherent superposition of mass eigenstates.

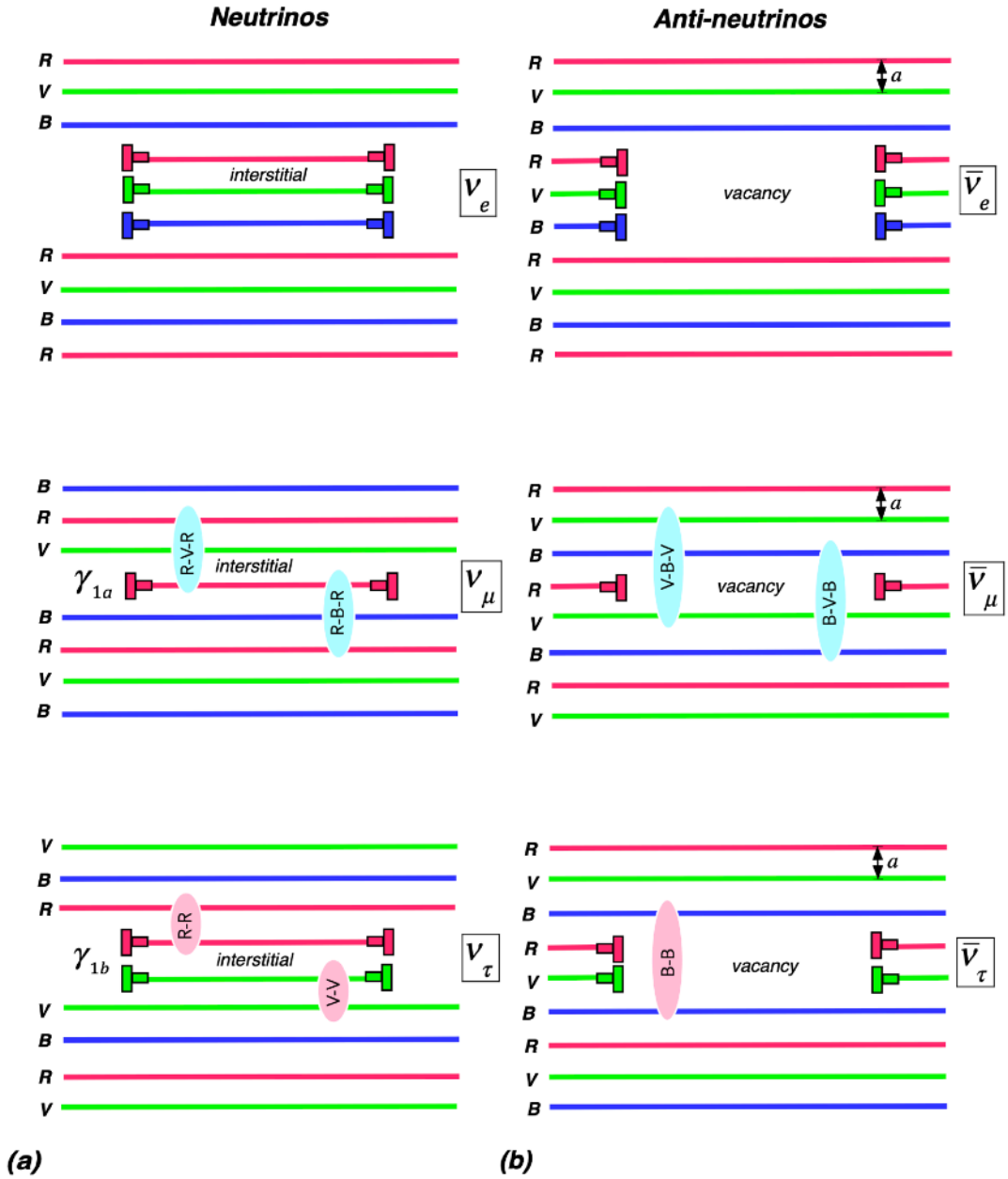


Figure 13.21 - *the three families of neutrinos and anti-neutrinos, obtained by removing or adding one or two dense planes, with the appearance of stacking faults of type X-Y-X and X-X.*

On the possible constitution of electron families

In the case of electrons and antielectrons in figures 13.18c and 13.18d, it suffices to add to the neutrinos in figure 13.21 the screw disclination loops with a rotation angle Ω_{BV} of $\pm 2\pi$ respectively. In these cases, we obtain the electrons and anti-electrons of the first family, the muons and anti-muons of the second family, and the taus and anti-taus of the third family shown in figure 13.22

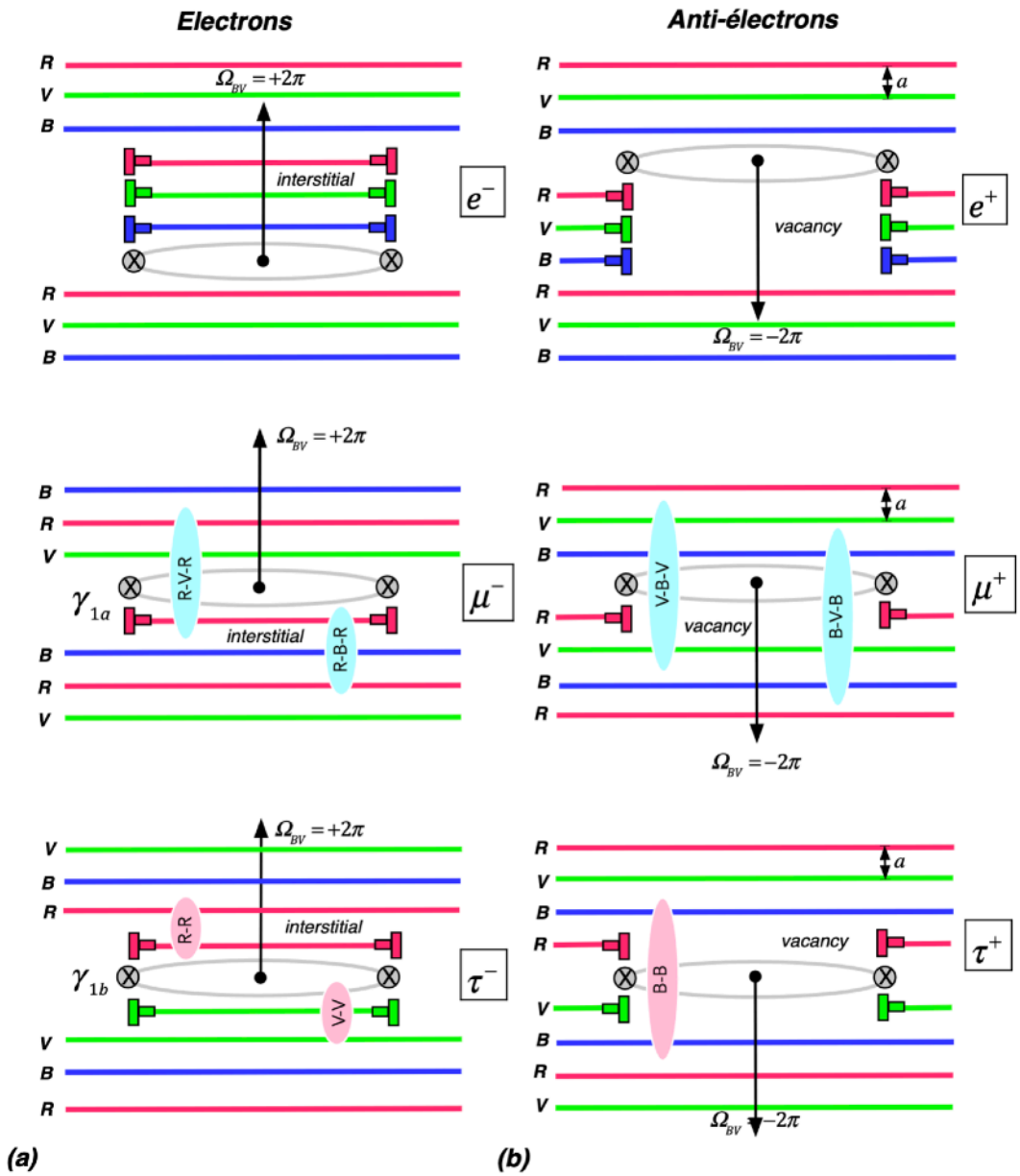


Figure 13.22 - *the three families of electrons and anti-electrons, obtained by removing or adding two or one dense plane, in combination with the screw disclination loop*

On the possible constitution of quark families

In the case of quarks, we can add or subtract 1 or 2 axial dense planes to quarks u and d and/or anti-quarks $\overline{u}$ eand $\overline{d}$, so as to reveal stacking faults in the axial dense planes with energies γ_{1a} or γ_{1b}. This gives us the family of *quarks* shown in figure 13.24, which is also composed of three generations of two types of electrically charged particles: the first generation consists of *down (d)* and *up (u)* quarks, with electric charges of -1/3 and +2/3 of the electric charge of the electron, respectively; a second generation composed of *strange (s)* and *charm (c)* quarks, with electric charges of -1/3 and +2/3 of the electric charge of the electron, respecti-

vely, and a third generation composed of *bottom (b)* and *top (t)* quarks, with electric charges of -1/3 and +2/3 of the electric charge of the electron, respectively. Each quark also has its own antiparticle with the opposite electric charge ($\overline{d}$, $\overline{u}$, $\overline{s}$, $\overline{c}$, $\overline{b}$ et $\overline{t}$).

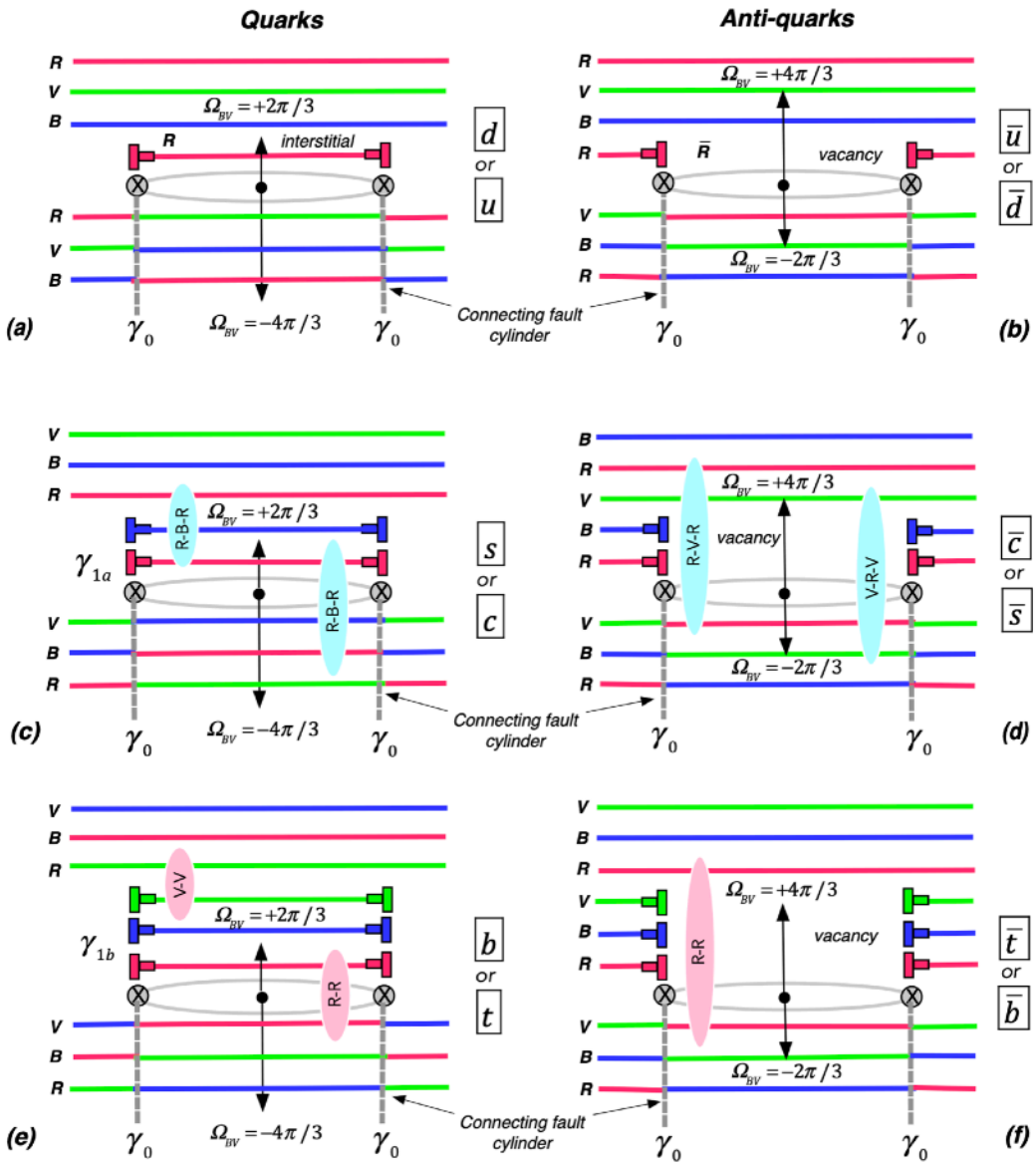


Figure 13.23 - *the three families of quarks and anti-quarks, obtained by adding or removing one or two dense planes, in combination with a screw disclination loop*

Quark decay via weak interaction

According to this hypothetical model describing the three families of quarks and their respective flavors *d, u, s, c, b,* and *t*, based on the existence of ***X-Y-X*** and ***X-X*** stacking faults between dense planes, we can deduce the pathways through which quarks should decay. The diagram of possible decays is shown in figure 13.24.

With this hypothetical model, we find the usual pure decays via weak interaction during the transformations *u-> d, c-> s*, and *t-> b* within the same family. On the other hand, the decays from one family to another *c-> d, s-> u, t-> s, b-> c, t-> d*, and *b->u* do not correspond exactly to the decays described in the literature since, in addition to the emission of a usual boson W^+ or W^-, *the emission of a lepton* ν_μ *ou* ν_τ *must be added to respect the number of axial planes during the decay.*

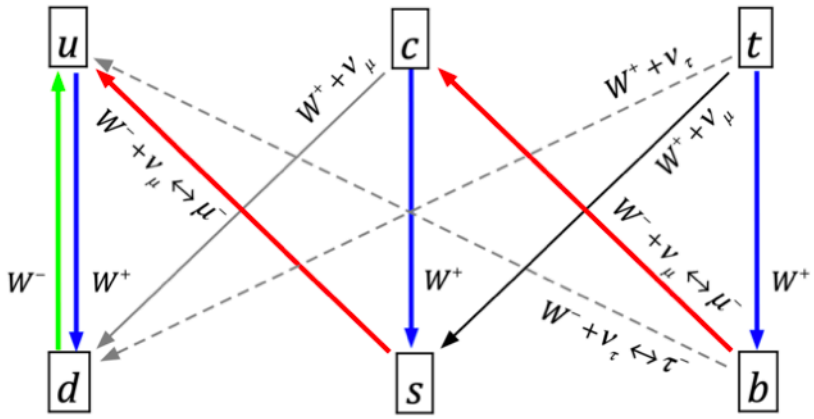


Figure 13.24 - *Diagram of possible quark decays via weak interaction, with particles produced according to each decay pathway.*

This discrepancy with the usual theory of the standard model should make it possible to experimentally verify or refute the idea that the existence of three families of elementary particles could be due to energies γ_{1a} and γ_{1b} of stacking faults of dense planes in a “colored” *FCC* lattice.

About the interest of the analogy between the "colored" cosmological lattice and the standard model

The analogy between our "colored" cosmological lattice model, with the elementary topological singularities it may contain, and the standard model of elementary particles is excellent, and it is very fruitful to provide explanations to several rather mysterious facets of the standard model that we are going to list here.

- *The structure of the Standard Model particles in three families of quarks and leptons:*

The topological structures of edge dislocation loops and screw disclination loops introduced in a "colored" *FCC* lattice having strict rules of arrangement and rotation of the "colored" corpuscular planes, with connecting and stacking fault energies γ_0, γ_{1a} and γ_{1b}, allow to reconstitute all the particles of the standard model of elementary particles, namely quarks and leptons. These particles present a structure in three families whose very different masses can be explained by the stacking fault energies γ_{1a} and γ_{1b}. These various quarks and leptons also satisfy *all the properties of the weak interaction and the strong interaction* using respectively the intermediate gauge bosons $W^\pm$ and Z^0 and the gluons, which also have their own topological structures in the "colored" cosmological lattice, *except for the addition of lepton emission* ν_μ *or* ν_τ *during the decay of quarks from one family to another* (figure 13.24). As for the strong force, it has good asymptotic properties due to the fact that it is generated by a cylinder of connecting

faults whose fault energy γ_0 increases if it is lengthened, and it is responsible for the existence of baryons and mesons, which are localized and "uncolored" topological structures that it is possible to form on the basis of quarks. In this way, one can reconstruct all the particles of the standard model, such as the baryons and mesons of figure 13.4, composed of the quarks and anti-quarks u, d, s and/or c.

- The weak and strong force interaction fields:

As for the force fields acting between the topological loops, they have simple topological explanations:

(i) the weak force is essentially due to the decrease in the formation energy of a dispiration loop when an edge dislocation loop is associated with a screw disclination loop, as discussed in chapter 9. It is the very weak range of the capture interaction potential of this force that then explains the radio-active decay of elementary particles, by the crossing of the interaction potential by quantum tunneling. In fact, *the weak force is an interaction between the rotation charge of a screw disclination loop with the curvature charge of an edge dislocation loop.*

And there are indeed gauge bosons exchanged during the weak interaction: these are the intermediate bosons $W^{\pm}$ et Z^0, which have a well defined topological structure, reported in figure 13.10.

(ii) the strong force, which binds two or three quarks together, is due to *the connecting fault cylinder generated by the fact that the screw disclination loops associated with the quarks have charges* $\boldsymbol{q}_{\lambda BV}$ *that are only 1/3 or 2/3 of the charge of the perfect screw disclination loop associated with the electron*. The dissociation distance between loops of a doublet or a triplet of quarks depends essentially *on the energy of connecting faults per unit area*. If this energy is very high, one can imagine that the loops will be very close, as illustrated in the figures of this chapter. But if this energy is low, one could also imagine fault tubes constituting membranes whose diameter (equal to the diameter of the topological loops) is much smaller than their length, so that the topological singularities in doublet and triplet could then have the aspect of *"long strands"* terminated at each end by topological loops.

And there are indeed gauge bosons exchanged during the strong interaction: these are the bicolor gluons, which have a well-defined topological structure, shown in figure 13.16.

- The possibilities of calculating the energy of the particles of the standard model:

A first very interesting consequence of this explanation of the Standard Model particles is related to the fact that, in the case of dispiration loops and their interactions via the weak and strong forces, the energies involved in the formation of loop multiplets has a known origin since it is in fact the sum of the following various energies:

(i) the formation energies associated with the very strong local lattice distortions generated by these objects, and stored in the lattice in the vicinity of these objects,

(ii) the energies of connection faults (related to) and stacking faults (related to and) appearing due to the fact that the imaginary cosmological lattice considered here is a "colored" lattice which must have axial properties,

(iii) the energies involved by *the weak force* in the gravitational couplings between the edge dislocation loops and the screw disclination loops, as described in chapter 9,

(iv) the longer range stored energies, which are due to the long range distortions of the lattice related to the global charge $\boldsymbol{q}_{\theta}$ of curvature by flexion and the global charge $\boldsymbol{q}_{\lambda}$ of rotation by

torsion of loop multiplets, which are contained in the calculations of energies that we made in the previous chapters, as well as the proper vibration and proper rotation energies of the loops that we obtained in chapters 11 and 12, respectively.

The total energy of formation of the loop multiplets could thus be calculated in a rigorous way, provided that the exact elastic properties (the moduli K_0, K_1, K_2 and K_3) as well as the surface energies of fault γ_0, γ_{1a} and γ_{1b} of the cosmological lattice in which these objects appear are known. This energetic aspect is very important because, in the case of the standard model of particles, the origin and the value of the energy of elementary particles (their mass) still remain very mysterious, and are introduced as parameters of the standard model, which must be measured experimentally.

- *The "elementarity" of the particles of the standard model:*

Another interesting consequence of our conception of the standard model is the existence of a difference in *"elementarity"* between the topological loops of dispiration of our imaginary cosmological lattice and the leptons and quarks of the standard model. Indeed, the dispiration loops that we have described, contrary to the elementary leptons and quarks of the standard model, are not strictly speaking elementary particles, but are already assemblies of screw disclination loops and lacunar or interstitial edge dislocation loops.

To judge the other potentialities of this idea of the constitution of the Standard Model particles, one would have to check whether this approach would allow to justify and explain the complicated set of selection rules that had to be introduced in particle physics to describe all the experimentally observed interactions. This is obviously only a suggestion, and its detailed development is beyond the scope of this treatise. Note that other similar approaches to decompose the Standard Model particles have already been proposed in particle physics, but in different forms, such as the model based on pre-quarks called *"rishons".* But these models have proved to be unsuccessful.

- *The role of the curvature charge in the standard model:*

The curvature charge $\boldsymbol{q}_\theta$ plays an important role in the development of a model of "elementary topological singularities" to explain the standard model of particles. It is quite easy to see that this charge, for which we do not see a direct analogy in the standard model, satisfies a conservation principle during the interactions between loops, both during weak and strong interactions.

But this charge has another major interest related to the bosonic or fermionic nature of particles. Indeed, we find that *all particles with a curvature charge (leptons, quarks and baryons) are fermions with a half-integer spin*, *which satisfy the Pauli exclusion principle*, while *all particles without a curvature charge (photons, gauge bosons, gluons and mesons) are bosons with an integer spin, not subject to the Pauli exclusion principle*. There is most probably a crucial role played by the curvature charge, which remains to be elucidated, but which is not within the scope of this treatise.

The question is also to know if the charge $\boldsymbol{q}_\theta$, which is conserved during the loop interactions, has a correlation with one of the characteristic quantities or with one of the conservation relations of the standard model, such as the Gell-Mann-Nishijima relation for example. The answer to this question could certainly present very important potentialities for particle physics, especially since we have already shown many times that *it is the curvature charge* $\boldsymbol{q}_\theta$ *that is*

responsible for the weak asymmetry between matter and anti-matter, and consequently for the cosmological evolution of matter and anti-matter in the universe, and for the presence of a *"dark mass"* in the form of a sea of repulsive neutrinos surrounding the galaxies.

Still open questions about the "colored" cosmological lattice model and its analogy with the standard model

The analogy developed in this chapter between the topological loops of dispiration in an imaginary "colored" cubic cosmological lattice and the standard model of elementary particles proves to be very fruitful to try to understand some points still unclarified in particle physics, such as the topological nature of elementary particles, as well as of the strong and weak forces, or the origin of the mass of elementary particles.

However, there are still several unanswered questions, which deserve to be studied in detail, among which the main ones are the following:

- The application of the concept of spin:

As we have already mentioned in chapter 12, the notion of spin seems to correspond to a real rotation of topological loops. But there are still many questions that need to be studied in detail.

The first question is obviously to try to imagine how an edge dislocation loop, and/or a screw disclination loop can rotate on itself in a "colored" *FCC* cosmological lattice, knowing moreover that there is a stacking fault tube responsible for the strong force in the case of baryons and mesons. Is there a possible topological explanation for such a spinning motion, or should we imagine a lattice with "even stranger" properties?

The second question is obviously related to the value to be assigned to the spin of a topological loop. For example, why does the electron, which would correspond to a weak coupling between an edge dislocation loop and a screw disclination loop, have a spin 1/2, while the gauge boson, which would correspond to an isolated screw disinclination loop, has a spin 1? This is where the important observation that we have made is likely to play an essential role in explaining the value of the spin of a particle, namely that all particles with a curvature charge (leptons, quarks and baryons) are fermions with a half-integer spin, while all particles without a curvature charge (photons, gauge bosons, gluons and mesons) are bosons with a whole spin.

The third question would be how to apply more carefully the concept of spin developed in chapter 12 to the "colored" cosmological lattice model that we described in this chapter. The answer to this question could allow to find an explanation for the existence of particles composed of the same quarks, but of different spins, like mesons π^+ and ρ^+ composed both of quarks $u\bar{d}$, but of respective spins 0 and 1, or baryons p (proton) and Δ^+ composed both of quarks uud, but of respective spins 1/2 and 3/2. Such a study would perhaps also make it possible to explain the exact origin of the spin 1/2 of the baryons and the spin 1 of the mesons, which is still a rather obscure point of the standard model of the particles, but which could perhaps find an explanation in the case of the "colored" cosmological lattice by supposing that it is the existence or not of a curvature charge which imposes a behavior of boson or fermion to a given particle.

- The theory of quantum chromodynamics:

It would obviously be very instructive and interesting to develop a much more detailed study

of the application of the wave equation calculations, of the concepts of bosons and fermions, of the Pauli exclusion principle developed in chapter 11, as well as of the notion of spin introduced in chapter 12, to the topological loop singularities analogous of the particles of the standard model, and to try to see if such a study would not finally lead us to a comprehensible physical explanation of the famous theory of "quantum chromodynamics"?

- The existence of supersymmetric models:

A more detailed study of the existence of the curvature charge could not only (perhaps) explain why there are fermions (spin 1/2 particles like quarks and leptons) and bosons (spin 1 particles like intermediate gauge bosons and gluons) in the Standard Model, but it could also answer the question of whether (by chance) it would be possible to create a zoology of particles identical to those we have obtained in this chapter, but whose spins 1/2 and 1 would be inverted, which could lead to a "supersymmetric model". But we note that in the framework of our model of particles, it appears very difficult, if not impossible, to imagine such supersymmetric particles.

- The existence of "exotic" leptons:

In our description of the quarks of figure 13.24, the fact that the quarks possess electric charges -1/3 and +2/3 of the charge of the electron, whereas the anti-quarks possess electric charges +1/3 and -2/3 of the charge of the electron is easily explained by the rules of succession of the colors of the corpuscular planes that we have emitted. On the other hand, for the leptons that we have introduced in figures 13.22 and 13.23, we have chosen arbitrarily to associate to the neutrino an electric charge -1 to obtain *the electron of matter* and to associate to the anti-neutrino an electric charge +1 to obtain *the positron of anti-matter*. But in fact the rules of color that we introduced would not prevent a priori to associate an electric charge +1 to the neutrino to obtain *an exotic positron of matter* and an electric charge -1 to the anti-neutrino to obtain *an exotic electron of anti-matter*, as reported in figure 13.18. There is a subject of reflection there that we have already approached by commenting on the table 13.14, where we proposed that the electron and the positron could be considered as the result of the compression of assemblies of quarks $d\,d\,d$ and $\overline{d}\,\overline{d}\,\overline{d}$, which would explain the existence of the electrons of matter and the positrons of anti-matter and the absence of the electrons of anti-matter and the positrons of matter. But this "explanation" of being able to collapse the assemblies of three identical quarks $d\,d\,d$ and $\overline{d}\,\overline{d}\,\overline{d}$ to form electrons and positrons also led us to wonder if it was also possible to collapse in the same way three identical quarks $u\,u\,u$ and $\overline{u}\,\overline{u}\,\overline{u}$, to form exotic leptons, namely *a positive lepton* e^{++} of spin 1/2 and of double charge and *a negative anti-lepton* $\overline{e}^{--}$ of spin 1/2 and of double charge. The existence of these two exotic leptons would have the advantage of filling the two gaps left in table 13.14.

There is matter to think about to confirm or deny the formation of leptons by collapse of three identical quarks.

- Conclusion :

To conclude this section, we must note that our model of a "colored" cosmological *FCC* lattice still raises many unresolved questions, and that it could thus be the origin of a new exciting field of research, especially if we try to elucidate the preponderant role that the new and original element of our approach, namely the curvature charge, must surely play.