Chapter 6

Lorentz transformation and special relativity

Thanks to *Newton's first partial equation in the presence of topological singularities*, it was possible to obtain *the elastic distortion fields associated with the various elementary singularities of the cosmological lattice*. In this chapter, we will show that these elastic distortion fields satisfy *the Lorentz transfomation*, and that they reveal *a new interpretation of the special relativity.*

We have deduced the kinetic energy associated with the movement of a dislocation or of a dislocation or disclination loop within the perfect cosmological lattice, by implicitly supposing that the distortion perturbations due to the moving charge are transmitted within the lattice with almost infinite speed compared to the speed of the charge within the lattice. However, it is well known that perturbations within a solid lattice are actually transmitted at the finite speeds of transverse or longitudinal perturbations. To take into account the propagation effects of perturbations with finite speed within the solid lattice when the speed of displacement of the charge becomes significant in comparison with the speed of propagation of transverse and / or longitudinal waves, we demonstrate here the Lorentz transformation to go from a stationary reference frame in the lattice to the mobile reference frame associated with the moving charge. This transformation is then applied to the singularities in movement at relativistic speed within a perfect topological lattice, namely the screw and edge dislocations, the localized charge of rotation, the twist disclination loop, the prismatic dislocation loop and the slip dislocation loop. We calculate their total energy, due to the sum of the potential energy stored by the lattice distortions generated by the presence of the charge and the kinetic energy stored in the lattice by the movement of their charge, and we show that those satisfy *a relativistic dynamic*. In addition, there is a very elegant explanation of the famous *«electron energy paradox»* which says that the mass associated with the electromagnetic fields of the electron does not satisfy the principles of special relativity.

We then show that the Lorentz transformation also reveals *a term of relativistic force* acting on the rotation charges in motion, a term which is perfectly analogous to *the Lorentz force in electromagnetism*.

On these bases, we discuss the analogy between our approach and *the theory of Special Relativity*. We note that the cosmological lattice behaves in fact like *an ether*, in which the topological singularities satisfy exactly the same properties as those of Special Relativity, not only concerning *the contraction of the measuring rods and the dilation of time*, but also concerning *the Michelson-Morley experience* and *the Doppler-Fizeau effect.* But the existence of the cosmological lattice then makes it possible to interpret the concept of special relativity quite differently, and to explain for example very simply some somewhat obscure sides of special relativity, such as the famous «paradox of twins».

Mobile charges and Lorentz transformations

When topological singularities of charge densities $\vec{\lambda}_i$, $\vec{\lambda}$ or λ move in the frame $\boldsymbol{O}x_1x_2x_3$ fixed to the solid lattice at significant speeds compared to the celerities of propagation of transverse and / or longitudinal waves, it would obviously be very useful to be able to find the dynamic fields $\tau(\vec{r},t)$, $\vec{\omega}(\vec{r},t)$ and $\vec{\alpha}_i(\vec{r},t)$ generated by these singularities in the frame $\boldsymbol{O}x_1x_2x_3$. Finding a solution of differential equations for singularities moving in the reference frame $\boldsymbol{O}x_1x_2x_3$ is not at all easy. On the other hand, using a mobile referential with the singularities, in which the singularities seem immobile, should allow us to calculate the static fields in $\boldsymbol{O}'x_1'x_2'x_3'$ much more simply, then to obtain the dynamic fields in $\boldsymbol{O}x_1x_2x_3$ using transformation laws which have yet to be defined.


Hendrik Anton Lorentz
(1853-1928)

Consider for example an infinite screw dislocation along the axis $\boldsymbol{O}x_1$ and suppose that it moves at velocity $\vec{\boldsymbol{v}}$ in the direction of the axis $\boldsymbol{O}x_2$. The choice of screw dislocation is not free, because it turns out that it is the only singularity which does not induce lattice distortions by volume expansion, but only a divergent field of rotation, which must greatly simplify the calculations. In the reference frame $\boldsymbol{O}'x_1'x_2'x_3'$ moving with the dislocation string, the displacement field $\vec{u}_{ext}^{\,screw\,\prime}$ must be that of a static screw dislocation, as shown in figure 6.1.

In order to transform this static field in $\boldsymbol{O}'x_1'x_2'x_3'$ into a dynamic field associated with the mobile screw dislocation in $\boldsymbol{O}x_1x_2x_3$, we must establish the transformation laws which will provide us with the dynamic fields in $\boldsymbol{O}x_1x_2x_3$. And the dynamic fields thus obtained must satisfy the space-time evolution equations in $\boldsymbol{O}x_1x_2x_3$. As there is translation of the coordinate system $\boldsymbol{O}'x_1'x_2'x_3'$ with respect to the coordinate system $\boldsymbol{O}x_1x_2x_3$, the transformation laws must transform the coordinate x_2' of $\boldsymbol{O}'x_1'x_2'x_3'$ into a coordinate which must depend on speed and time, in the form $(x_2-\boldsymbol{v}t)$, in the coordinate system $\boldsymbol{O}x_1x_2x_3$. We can *a priori* hypothesize that the transformation laws are written $x_2'=\alpha(x_2-\boldsymbol{v}t)$, $x_1'=\beta x_1$ and $x_3'=\beta x_3$ according to the three respective axes. With these transformation laws, the static displacement field $\vec{u}_{ext}^{\,screw\,\prime}$ becomes a dynamic field $\vec{u}_{ext}^{\,screw}(\vec{r},t)$ which depends on the factor $(x_2-\boldsymbol{v}t)$ and the constants α and β in $\boldsymbol{O}x_1x_2x_3$.

From the dynamic field $\vec{u}_{ext}^{\,screw}(\vec{r},t)$ thus obtained in $\boldsymbol{O}x_1x_2x_3$, one can directly calculate the fields of rotation $\vec{\omega}_{ext}^{\,screw}(\vec{r},t)$ and speed $\vec{\phi}_{ext}^{\,screw}(\vec{r},t)$ in $\boldsymbol{O}x_1x_2x_3$ via the rotational and the time derivative of $\vec{u}_{ext}^{\,screw}(\vec{r},t)$. But in the reference frame $\boldsymbol{O}x_1x_2x_3$, *the fields thus obtained must satisfy the spatio-temporal evolution equations, namely the second pair of Maxwell's equations*. For this requirement to be satisfied, the parameter α introduced into the transformation laws must necessarily be written $\alpha=\beta/(1-\boldsymbol{v}^2/c_t^2)^{1/2}=\beta/\gamma_t$, in which it appears the well-known factor $\gamma_t=(1-\boldsymbol{v}^2/c_t^2)^{1/2}$ of Lorentz transformations. By introducing this relation for α in the expressions obtained for $\vec{\phi}_{ext}^{\,screw}(\vec{r},t)$ and $\vec{\omega}_{ext}^{\,screw}(\vec{r},t)$, we obtain the expressions of the fields of the screw dislocation in $\boldsymbol{O}x_1x_2x_3$, as represented in figure 6.1. It is then remarkable that these fields, which perfectly satisfy the equations of spatio-temporal evolution in the reference frame $\boldsymbol{O}x_1x_2x_3$, do not depend absolutely on the parameter β, but only on the parameter γ_t of the

Lorentz transformations, so that the parameter β can be chosen freely, and we will admit here the value of 1, so that it is shown that the laws of spatial transformation are indeed the Lorentz laws represented in figure 6.1.

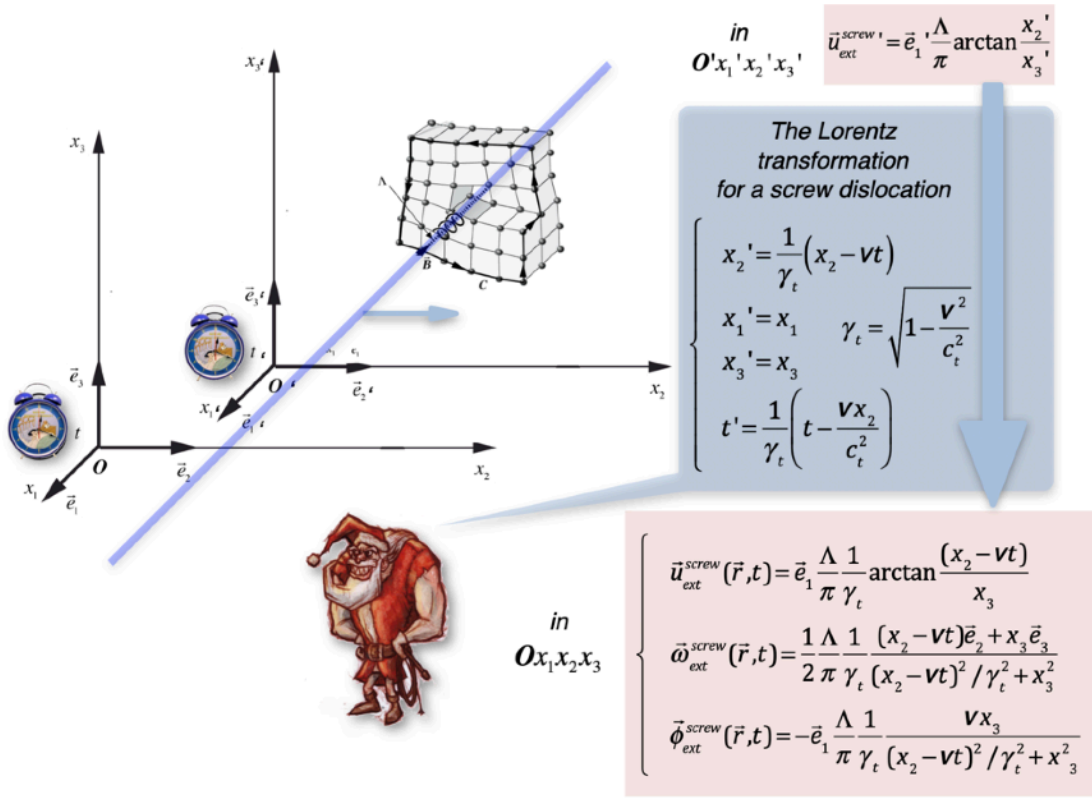


Figure 6.1 - *The Lorentz transformation deduced using a moving screw dislocation*

Contraction of lengths in the direction of movement

The expressions in figure 6.1 for dynamic fields $\vec{u}_{ext}^{screw}(\vec{r},t)$, $\vec{\omega}_{ext}^{screw}(\vec{r},t)$ and $\vec{\phi}_{ext}^{screw}(\vec{r},t)$ are effective solutions of topological equations and Newton's equation for a screw dislocation moving in the reference frame $Ox_1x_2x_3$. It is interesting to take a look at the behavior of these fields as a function of the velocity $\vec{v}$ of the dislocation. One can take for example the projection ω_2 of the external vector field of rotation in the direction of the movement of the dislocation, and report its value $\omega_2(t=0, x_3=0)$, taken at the instant $t=0$ and for the coordinate $x_3=0$, as a function of x_2 for different values of the ratio v/c_t, as illustrated in the figure 6.2. We then observe that the horizontal component of the rotation field seems to contract along the axis Ox_2. It is easy to calculate that a certain value of $\omega_2(t=0, x_3=0)$ is observed at a distance Δx_2 from the origin which depends on the velocity $\vec{v}$ of the dislocation, given by $\Delta x_2(v) = \Delta x_2(v=0)(1 - v^2/c_t^2)^{1/2}$, so that the field of rotation of the moving screw dislocation *is effectively contracted along the axis* Ox_2 *of a factor* γ_t.

Now imagine a cluster of rotation singularities which are linked to each other via their fields of rotation (it should be recalled here that the field of rotation corresponds to the electric field in

our analogy with the real world). If the cluster moves along the axis Ox_2 in the reference frame $Ox_1x_2x_3$ of the ***GO***, the fields of rotation associated with this cluster must contract along the axis Ox_2 with a factor γ_t in order to satisfy the topological equations and the Newton equation of the lattice. The consequence is then that the cluster itself, which is linked by these fields of rotation, must contract along the axis Ox_2. If this cluster represents an "object" for the great observer ***GO*** located outside the lattice, this "object" will contract along the axis Ox_2. But if it is observed in its own frame of reference by a hypothetical observer who would be located inside the lattice, this "object" will remain exactly the same as it is at rest in the absolute frame of reference $Ox_1x_2x_3$, and its shape will not change in the reference frame $O'x_1'x_2'x_3'$ regardless of the speed of this "object" in $Ox_1x_2x_3$.

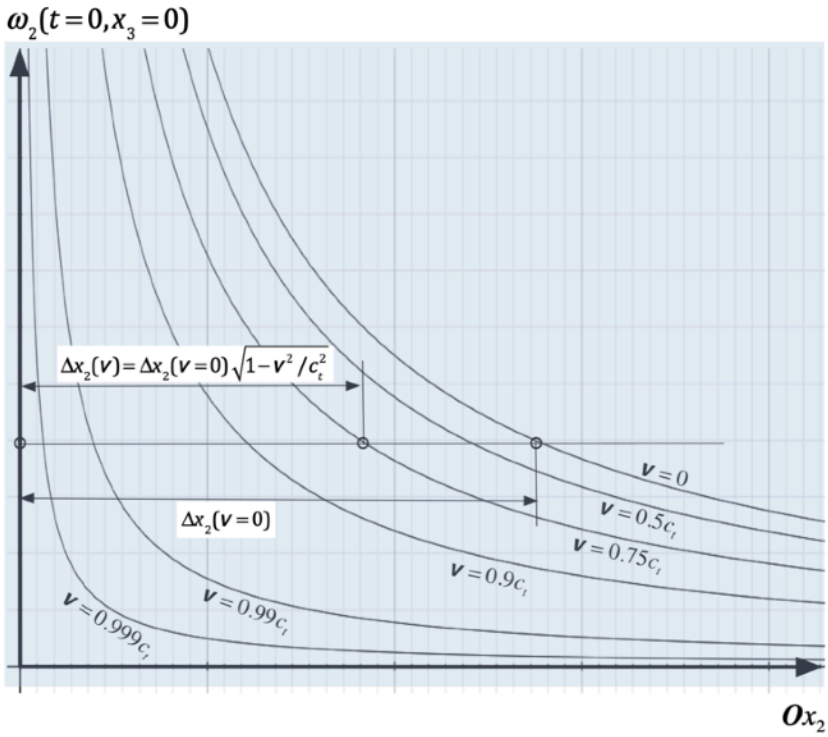


Figure 6.2 - *Contraction of the component $\omega_2(t=0,x_3=0)$ of the rotation vector of a screw dislocation in $Ox_1x_2x_3$ in the direction of its movement, depending on its velocity $\vec{v}$*

Time dilation of a mobile cluster of topological singularities

Now imagine that the observer measures the time T_0 it takes for a transversal wave to travel the distance d_0 in the absolute frame of reference $Ox_1x_2x_3$, be reflected on a mirror and return to its point of emission. It is clear that the observer measures a time equal to $T_0 = 2d_0 / c_t$. Such a time measurement system based on an "object" constituted by a cluster of singularities linked by the fields of rotation can be used by the observer ***GO*** as a time base, *a clock giving the basic time lapse T_0.*

Imagine that the clock system, based on the same "object", but now moving at a velocity $\vec{v}$ along the axis Ox_1 in the base reference frame $Ox_1x_2x_3$, is observed by the ***GO***. If the

transverse wave is emitted in the mobile reference frame $O'x_1'x_2'x_3'$ in the vertical direction within this frame of reference, this same wave is seen by the ***GO*** as a non-vertical wave in its frame of reference $Ox_1x_2x_3$, as illustrated in figure 6.3 (a). For the ***GO*** observer, the time T it takes for the wave to travel at celerity c_t, via the reflection on the mirror of the moving "object" is easily calculated using the triangle in the plane Ox_1x_3, and we just gets that $T = T_0 / \gamma_t$. This means that the base time of the mobile clock in the reference frame $O'x_1'x_2'x_3'$, measured by the ***GO*** in its own reference frame $Ox_1x_2x_3$ seems dilated as a function of the velocity $\vec{v}$ with a factor $1/\gamma_t$, and therefore that *the clock of the mobile "object" slows down compared to the **GO**'s absolute clock*.

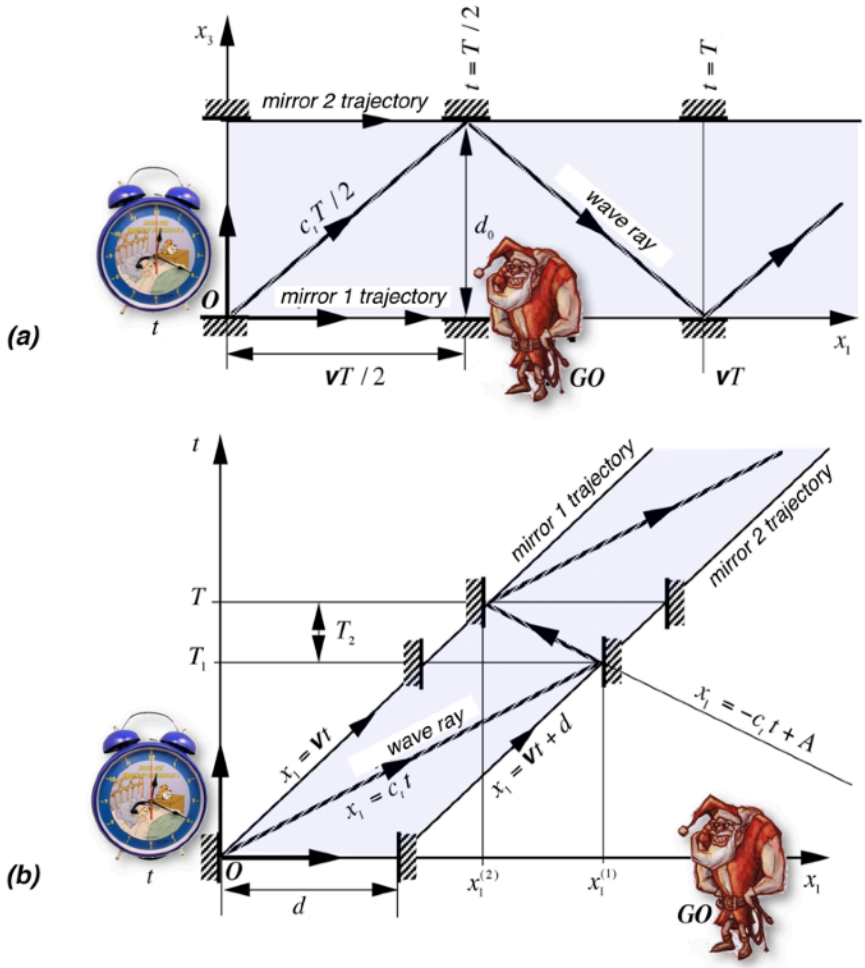


Figure 6.3 - (a) *the trajectory of the transverse wave emitted vertically by the local clock of the mobile «object» in the frame, as observed by **GO** in his reference frame*
(b) *the trajectory of the transverse wave emitted horizontally by the local clock of the mobile «object» in the frame, as observed by **GO** in his reference frame*

One can still wonder if the time in the reference frame $O'x_1'x_2'x_3'$ of the "object" remains isotropic in this reference frame, in other words if a clock based on a horizontal trajectory of the transverse wave, gives the same time as the vertical clock. If the horizontal clock is observed by the ***GO*** in its frame $Ox_1x_2x_3$, the wave path can be illustrated by the path diagram in figure 6.3

(b). In this diagram, the trajectories of the moving mirrors are represented by two lines with a slope $\boldsymbol{v}$, separated by a distance d in the direction $\boldsymbol{O}x_1$. The trajectories of the transverse wave lines are represented by two lines with slopes $+c_t$ and $-c_t$ respectively, for the two directions of propagation of the wave.

In this trajectory diagram, we can again geometrically calculate the time T required for the wave to travel a round-trip path via a reflection on a mirror of the mobile "object", knowing that the distance d between the two mirrors associated with the mobile "object" is contracted by a factor γ_t as we have seen previously, which provides the following relationship $d=\gamma_t d_0=d_0(1-\boldsymbol{v}^2/c_t^2)^{1/2}$ between the distance d and the distance d_0 at rest which separate the two mirrors, and we then obtain again $T=T_0/\gamma_t$ as result of this calculation.

The two diagrams in figure 6.3 clearly show that the two mobile clocks, operating respectively with a vertical and horizontal wave propagation in the frame $\boldsymbol{O}'x_1'x_2'x_3'$ provide exactly the same local time, meaning that *there is indeed a local time* t' *and that this local time* t' *remains isotropic in the mobile frame of reference* $\boldsymbol{O}'x_1'x_2'x_3'$, regardless of the direction of movement of the "object" in the lattice.

In the mobile frame $\boldsymbol{O}'x_1'x_2'x_3'$, the length the wave has to travel along $\boldsymbol{O}'x_1'$ or $\boldsymbol{O}'x_3'$ inside the clock system is measured as a length d_0, and the local time to go back and forth via reflection on a mirror is measured as being T_0 both in the case of a wave propagating vertically as horizontally. This means that the speed of the wave measured by an observer linked to the mobile frame of reference $\boldsymbol{O}'x_1'x_2'x_3'$ has exactly the same value c_t as that measured in the frame of reference $\boldsymbol{O}x_1x_2x_3$, regardless of the velocity $\vec{\boldsymbol{v}}$ of the frame of reference $\boldsymbol{O}'x_1'x_2'x_3'$ relative to the frame of reference $\boldsymbol{O}x_1x_2x_3$.
Imagine then that a transverse wave $\vec{\omega}'=\omega_0\vec{e}_3'\sin\left[\omega'(x_1'/c_t-t')\right]$ propagates along $\boldsymbol{O}'x_1'$ in the frame of reference $\boldsymbol{O}'x_1'x_2'x_3'$ moving at speed $\vec{\boldsymbol{v}}$ in the direction $\boldsymbol{O}'x_1'$ relative to the frame of reference $\boldsymbol{O}x_1x_2x_3$. To express this wave in the frame of reference $\boldsymbol{O}x_1x_2x_3$, we use the space transformation $x_1'=(x_1-\boldsymbol{v}t)/\gamma_t$ already obtained before and a new time transformation relation $t'=\varepsilon t+\delta x_1$, in which the parameters ε and δ have yet to be determined. By introducing these two relations in the expression of the wave in the frame $\boldsymbol{O}'x_1'x_2'x_3'$, this one must obligatorily take the simple form $\vec{\omega}=\omega_0\vec{e}_3\sin\left[\omega(x_1/c_t-t)\right]$ in the frame $\boldsymbol{O}x_1x_2x_3$, which implies that the constants must take the values $\delta=-\boldsymbol{v}/\gamma_t c_t^2$ and $\varepsilon=1/\gamma_t$, and that consequently the law of Lorentz for the transformation of time is written $t'=(t-\boldsymbol{v}x_1/c_t^2)/\gamma_t$, as it has already been reported in figure 6.1.

Lorentz transformation for a mobile "object" linked by the rotation fields

The fact that the fields of rotation, and therefore the mobile "objects" linked by the fields of rotation, are actually contracted in the direction of movement by a factor $\gamma_t=(1-\boldsymbol{v}^2/c_t^2)^{1/2}$, that the isotropic time measured by the clocks of the mobile "object" is really dilated by a factor $1/\gamma_t$ and that the velocities of the transverse waves measured in $\boldsymbol{O}x_1x_2x_3$ and in $\boldsymbol{O}'x_1'x_2'x_3'$ have exactly the same values c_t, mean that the transformation laws reported in figure 6.1, allowing to pass from one referential to the other, are *the same as the well-known Lorentz transformations of electromagnetism*.

It should be noted here that these transformations were used initially as simple mathematical tools making it possible to calculate with Maxwell's equations the electromagnetic fields

generated by mobile electric charges. Later, these transformations were used in special relativity by Einstein, by postulating that Lorentz relations are applicable *to any frame of reference moving at speed* $\boldsymbol{v}$ *relative to another*, hence the term *"relativity"* which corresponds in fact *to axiomatically admitting the constancy of the speed of light in any frame of reference*.

Here, in the case of a solid lattice, the Lorentz transformation is obtained by a quite different approach based on the existence of a solid lattice in the absolute frame of reference $\boldsymbol{O}x_1x_2x_3$ of ***GO***, which is *the support (we then speak of ether) for the propagation of transverse waves*. This approach makes it possible to demonstrate the reality of the physical consequences of the Lorentz transformation, such as the spatial contraction and the dilation of time measured in $\boldsymbol{O}x_1x_2x_3$ for mobile “objects” made up of topological singularities linked by fields of rotation. And this demonstration is based on the initial assumption that the ***GO*** can introduce a relative frame of reference $\boldsymbol{O}'x_1'x_2'x_3'$ associated with the mobile "object" into its absolute frame of reference $\boldsymbol{O}x_1x_2x_3$. The use of the Lorentz transformation in the case of the cosmological lattice is therefore limited only to transforming the fields between a mobile relative reference frame $\boldsymbol{O}'x_1'x_2'x_3'$ with respect to the lattrice and the absolute ***GO*** reference frame $\boldsymbol{O}x_1x_2x_3$, which is fixed to the lattice. Consequently, there is absolutely no axiomatic hypothesis of "relativity" here stipulating that the Lorentz transformation is applicable to any referential moving relative to another. We will see that this remark is very important, because it implies a point of view radically different from that of Einstein's special relativity.

Uniqueness of the Lorentz transformation according to the background expansion

In conjecture 6, we stipulated that the module K_1 must be necessarily positive for the edge dislocations to satisfy the same Einstein relation as the screw dislocations in the cosmological Lattice. This conjecture therefore implies that the existence of longitudinal waves is subject to the fact that the background expansion of the cosmological lattice satisfies the hypothesis $\tau_0 > \tau_{0cr}$. In this particular case, as transverse and longitudinal waves can propagate within the lattice with different celerities c_t and c_l respectively, the fields associated with a mobile “object” which would be made up of topological singularities like edge dislocations which are linked both by fields of rotation and expansion, would become immensely more complicated to calculate. Indeed, supposing that the displacement of the linked charges in the reference frame $\boldsymbol{O}x_1x_2x_3$ takes place at velocity $\vec{\boldsymbol{v}}$ in the direction $\boldsymbol{O}x_1$, one should define two mobile reference frames $\boldsymbol{O}'x_1'x_2'x_3'$ and $\boldsymbol{O}''x_1''x_2''x_3''$ which move with the charges, by assigning to each of these reference frames the Lorentz transformation laws with velocities c_t and c_l respectively, therefore with two Lorentz factors $\gamma_t = (1-\boldsymbol{v}^2/c_t^2)^{1/2}$ and $\gamma_l = (1-\boldsymbol{v}^2/c_l^2)^{1/2}$.

We can imagine quite easily that the complete resolution of this type of problem for any density $\vec{\lambda}_i$ of mobile charges in $\boldsymbol{O}x_1x_2x_3$ can prove to be extremely complex, especially if there is still a non-homogeneous expansion field within the lattice, and especially as longitudinal perturbations can propagate like waves.

This is why we will treat in the following only the particular case, which is in fact the really interesting case for our analogy with the universe, of topological singularities which move in the perfect cosmological lattice presenting a homogeneous and constant background volume expansion which satisfies the relationship $\tau_0 < \tau_{0cr}$. In this case, we know that *the longitudinal waves do not exist*, meaning that any disturbance of the distortion fields can only propagate at

the speed of the transverse waves, and that the problem of determining the fields generated by mobile singularities can be solved by applying the unique Lorentz transformation for the frame of reference $\boldsymbol{O}'x_1'x_2'x_3'$, the one shown in figure 6.1. The problem of expansion perturbation fields linked to topological singularities will be dealt with later, in the chapters dealing, on the one hand, with *"gravitational fields"* namely static perturbations of the expansion field due to topological singularities, and on the other hand *"quantum fields"* namely the dynamic perturbations of the expansion field due to mobile topological singularities when $\tau_0 < \tau_{0cr}$.

If we now consider mobile rotation charges, of charge density λ, which move within the lattice with velocity $\vec{\boldsymbol{v}}$ along the axis Ox_1, the fields $\vec{\omega}$ generated by these charges will be dynamic fields which will evolve according to the movements of the charges. As the transmission of information of the mobile charges at any point of the solid lattice is done in this case at the speed c_t of the transverse waves, one can use the transformation of Lorentz deferred to figure 6.1 by associating a mobile reference frame $\boldsymbol{O}'x_1'x_2'x_3'$ with the charges. It is interesting to show here the transformation relations concerning the pair of Maxwell equations managing the dynamics within the lattice, outside the charges, in the case where the volume expansion is homogeneous and constant ($n = cste$).

These relations of transformation of the fields of momentum $(n\vec{p})$ and torque $\vec{m}$ in the frame of reference $\boldsymbol{O}x_1x_2x_3$ in the fields $(n\vec{p})'$ and $\vec{m}'$ in the frame of reference $\boldsymbol{O}'x_1'x_2'x_3'$ are obtained by fairly simple calculation, and are reported in figure 6.4. Thanks to these transformation relationships, we will be able to calculate the fields associated with movement within a solid lattice of different types of rotation charges, as well as their total energy, composed of their elastic potential energy and their kinetic energy.

Relativistic energies of the screw and edge dislocations

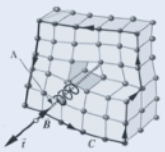
Let us consider an infinite cylindrical screw string and suppose that it moves at velocity $\vec{\boldsymbol{v}}$ in the direction of the axis $\boldsymbol{O}x_1$. In the reference frame $\boldsymbol{O}'x_1'x_2'x_3'$ in movement with the string, we can apply the transformation relations of figure 6.4 to find, from the expression of the static field $\vec{\omega}_{ext}$ of rotation of the dislocation as well as from the Lorentz transformation relations, the dynamic fields $\vec{\omega}_{ext}$ and $\vec{\phi}$ expressed in the reference frame $\boldsymbol{O}x_1x_2x_3$. We then deduce directly from these expressions the elastic energy density F_{dist}^{screw} of distortion and the kinetic energy density F_{cin}^{screw} in the frame of reference $\boldsymbol{O}x_1x_2x_3$. The total energy $E_{\boldsymbol{v}}^{screw}$ per unit length of the dislocation is obtained by integration of these energy densities in $\boldsymbol{O}x_1x_2x_3$. The total energy of the screw dislocation thus obtained is shown in figure 6.4, and its expression deserves a few comments:

- in fact, this expression is quite remarkable, because not only does it appear there the mass of inertia $M_0^{screw} \cong E_{dist}^{screw} / c_t^2$ at rest of the screw dislocation that we had already obtained in a completely classic manner, but also it allows better understand the true physical origins of the relativistic terms of distortion energy $E_{\boldsymbol{v}}^{dist}$ and kinetic energy $E_{\boldsymbol{v}}^{cin}$ which appear there. Indeed, in this form, the term $E_{\boldsymbol{v}}^{dist}$ corresponds to *the relativistic correction of the elastic distortion energy* E_{dist}^{vis} *at rest,* while the term $E_{\boldsymbol{v}}^{cin}$ corresponds to *the relativistic correction of the non-relativistic kinetic energy* $M_0^{vis}\boldsymbol{v}^2/2$,
- in this case of screw dislocation, that is to say when the density λ of scalar charge is distributed in *an infinite rectilinear string*, the behavior of the total energy $E_{\boldsymbol{v}}^{screw}$ is *a pure*

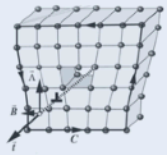
Relativistic transformations of the momentum and the torque

$$\begin{cases} m_1' = m_1 \\ m_2' = \left(m_2 - 2\boldsymbol{v} n p_3\right)/\gamma_t \\ m_3' = \left(m_3 + 2\boldsymbol{v} n p_2\right)/\gamma_t \end{cases} \qquad \begin{cases} np_1' = np_1 \\ np_2' = \left(np_2 + \boldsymbol{v} m_3/(2c_t^2)\right)/\gamma_t \\ np_3' = \left(np_3 - \boldsymbol{v} m_2/(2c_t^2)\right)/\gamma_t \end{cases}$$

Total relativistic energies of rectilinear screw and edge dislocations



$$E_{\boldsymbol{v}}^{vis} = \underbrace{\frac{1}{\gamma_t}\left(1-\frac{\boldsymbol{v}^2}{2c_t^2}\right)E_{dist}^{vis}}_{E_{\boldsymbol{v}}^{dist}} + \underbrace{\frac{1}{\gamma_t}\frac{1}{2}M_0^{vis}\boldsymbol{v}^2}_{E_{\boldsymbol{v}}^{cin}} = \frac{E_{dist}^{vis}}{\gamma_t} = \frac{M_0^{vis}c_t^2}{\gamma_t} = \frac{1}{\gamma_t}\frac{\left(K_2+K_3\right)\Lambda^2}{\pi}\ln\frac{R_\infty}{R}$$



$$E_{\boldsymbol{v}}^{coin} = \underbrace{\frac{1}{\gamma_t}\left(1-\frac{\boldsymbol{v}^2}{2c_t^2}\right)E_{dist}^{coin}}_{E_{\boldsymbol{v}}^{dist}} + \underbrace{\frac{1}{\gamma_t}\frac{1}{2}M_0^{coin}\boldsymbol{v}^2}_{E_{\boldsymbol{v}}^{cin}} = \frac{E_{dist}^{coin}}{\gamma_t} = \frac{M_0^{coin}c_t^2}{\gamma_t} = \frac{1}{\gamma_t}\left(\frac{K_2}{K_3}\right)^2\frac{K_3\vec{\Lambda}^2}{2\pi}\ln\frac{R_\infty}{R}$$

Figure 6.4 *- The relativistic transformations of the momentum and the torque, and the total relativistic energies of rectilinear screw and edge dislocations*

relativistic behavior, satisfying very exactly the famous relation of special relativity $E = E_0/\gamma$, whereas a localized scalar load of rotation does not satisfy such a relation as we will see in the continuation,

- the total energy associated with the moving charge tends to an infinite value when the speed $\boldsymbol{v}$ tends to the celerity c_t of the transverse waves as shown in figure 6.5. This behavior is generated by the presence of the term $\gamma_t = \left(1-\boldsymbol{v}^2/c_t^2\right)^{1/2}$ in the expression of energy, term which is due to the relativistic contraction of the field of rotation in the direction of the movement, imposed by the Lorentz transformation,

- the total energy $E_{\boldsymbol{v}}^{screw}$ associated with the moving charge is not at all energy stored in the singularity itself, but it is the movement of the singularity in the lattice which stores both potential energy $E_{\boldsymbol{v}}^{dist}$ of elastic distortion of the lattice and of the Newtonian kinetic energy $E_{\boldsymbol{v}}^{cin}$ of movement of the lattice in its vicinity,

- the fractions of the total energy being found in the form of potential elastic energy of rotation of the lattice and in the form of kinetic energy of the cells of the lattice depend on the value of the ratio $\boldsymbol{v}/c_t$ as shown in figure 6.6. We see, among other things, that the energy fractions in potential form and in kinetic form become perfectly equal when the speed $\boldsymbol{v}$ of a charge tends towards the celerity c_t of the transverse waves,

- the fact of obtaining exactly a relativistic behavior is due to the particularity that the term of kinetic energy $E_{\boldsymbol{v}}^{cin}$ is precisely compensated by an additional negative term in the potential energy $E_{\boldsymbol{v}}^{dist}$ in the case of a screw dislocation. We will see later that this compensation effect is not systematic, and that it essentially depends on the topology of the considered charge. We

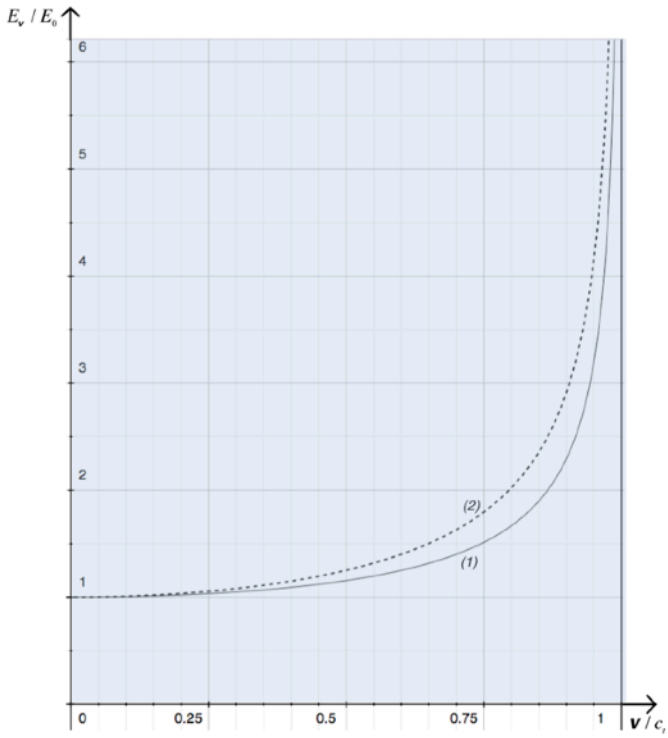


Figure 6.5 *- Total energy of the charge compared to its rest energy, as a function of* v / c_t *, in the case of a screw or edge dislocation (1) or a spherical charge of rotation (2)*

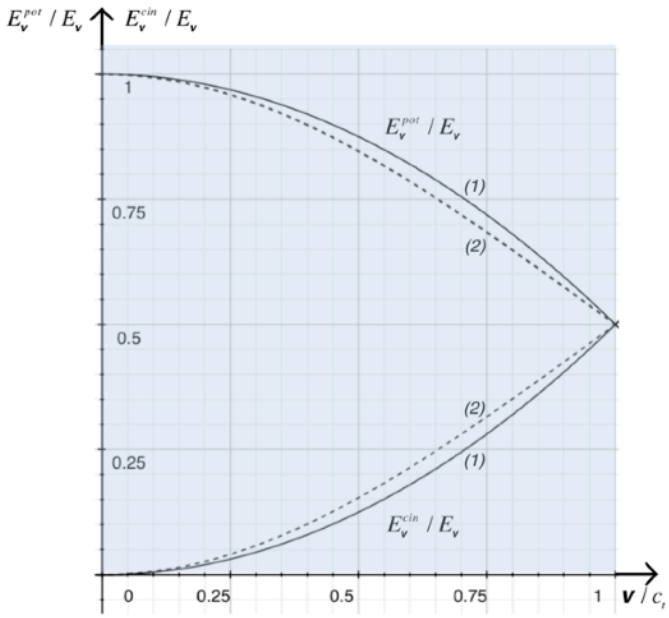


Figure 6.6 *- Fractions of the total energy in potential and kinetic form, as a function of* v / c_t *, in the case of a screw or edge dislocation (1) or a spherical charge of rotation (2)*

therefore have here a somewhat paradoxical situation, namely that *the relativistic dynamics of screw dislocations is a direct consequence of the purely Newtonian dynamics of the lattice* in the absolute space of ***GO,*** because it is the exact compensation of the term of Newtonian kinetic energy $E_{\boldsymbol{v}}^{cin}$ of the lattice by the additional negative term in the elastic potential energy $E_{\boldsymbol{v}}^{pot}$ which is responsible for it.

With regard to rectilinear edge dislocations, the supposition that the lattice is a perfect cosmological lattice satisfying conjecture 6, namely that $K_0 = K_3 > 0$, that $K_1 << K_0$ and that $K_2 << K_3$, and also satisfying the hypothesis $\tau_0 < \tau_{0cr}$, implies that edge dislocations in a perfect cosmological lattice are subject exactly to the same relativistic behaviors as screw dislocations. So we have in particular that $E_{\boldsymbol{v}}^{coin} = E_{dist}^{coin} / \gamma_t$ where the energy of distortion also satisfies a real Einstein relation $E_{dist}^{edge} \cong M_0^{edge} c_t^2$ as we have shown previously in a purely classical way. We thus obtain for the edge dislocation a completely similar expression of its total relativistic energy $E_{\boldsymbol{v}}^{edge}$ as in the case of the screw dislocation, as shown in figure 6.4.

Equations of the relativistic dynamics of a screw or edge dislocation

Suppose that a rectilinear screw or edge dislocation, which moves at high velocity $\vec{\boldsymbol{v}}$ in the perfect cosmological lattice, is subjected to *a Peach and Koehler force* $\vec{\boldsymbol{F}}_{PK}$ per unit of length. Due to the rectilinear geometry of the dislocation, the vectors $\vec{\boldsymbol{v}}$ and $\vec{\boldsymbol{F}}_{PK}$ can only be perpendicular to the line of dislocation. The power transmitted to the dislocation by the force $\vec{\boldsymbol{F}}_{PK}$ is obviously written $\vec{\boldsymbol{F}}_{PK}\vec{\boldsymbol{v}}$, and this power comes to increase the total energy $E_{\boldsymbol{v}}^{disloc}$ of the dislocation, so that the relativistic dynamic equation of the dislocation corresponds to equal the temporal variation of the total energy $E_{\boldsymbol{v}}^{disloc}$ taken along the trajectory with the power $\vec{\boldsymbol{F}}_{PK}\vec{\boldsymbol{v}}$ supplied to the dislocation by the Peach and Kohler force, as shown in figure 6.7.

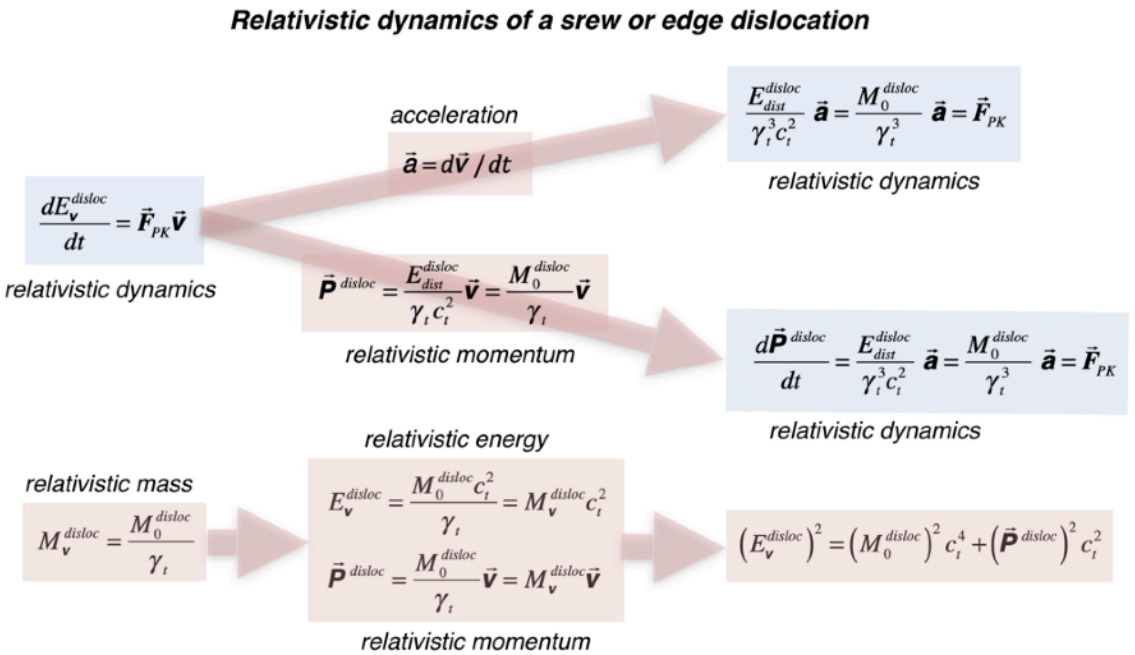


Figure 6.7 *- Relativistic dynamic equations, relativistic momentum and relativistic mass of a screw or edge dislocation*

But in the case of a rectilinear dislocation, the vectors $\vec{\boldsymbol{v}}$ and $\vec{\boldsymbol{F}}_{PK}$ are parallel, so that we can write a vector equation for the relativistic dynamics of the dislocation directly involving the acceleration $\vec{\boldsymbol{a}} = d\vec{\boldsymbol{v}} / dt$ of the dislocation. Note that the time derivative of the total energy, namely $dE_{\boldsymbol{v}}^{disloc} / dt = \left(\partial E_{\boldsymbol{v}}^{disloc} / \partial \boldsymbol{v}\right)\left(d\boldsymbol{v} / dt\right) = \boldsymbol{a}\,\partial\left(E_{dist}^{disloc} / \gamma_t\right) / \partial \boldsymbol{v}$, must take into account the fact that the Lorentz factor γ_t also depends on the norm of $\vec{\boldsymbol{v}}$. By introducing the relativistic momentume $\vec{\boldsymbol{P}}^{disloc}$ per unit length of the screw or edge dislocation, we can still write the relativistic dynamic equation in a different way which is shown in figure 6.7. The expression of the relativistic momentum $\vec{\boldsymbol{P}}^{disloc}$ allows us to introduce a generalized relativistic mass $M_{\boldsymbol{v}}^{disloc}$ of the dislocation in motion, which we can use to write the total energy $E_{\boldsymbol{v}}^{disloc}$ and the momentum $\vec{\boldsymbol{P}}^{disloc}$ of the dislocation. The relationships in figure 6.7 are perfectly identical to the dynamic relationships obtained in special relativity. We can also verify that the classical relation $E^2 = m^2c^4 + p^2c^2$ which is very known in special relativity also has its analog under the form $\left(E_{\boldsymbol{v}}^{disloc}\right)^2 = \left(M_0^{disloc}\right)^2 c_t^4 + \left(\vec{\boldsymbol{P}}^{disloc}\right)^2 c_t^2$.

A very interesting remark stands out here: the total relativistic energy $E_{\boldsymbol{v}}^{disloc}$ associated with the movement of the dislocation is the sum of the potential energy $E_{\boldsymbol{v}}^{dist}$ of elastic deformation of the lattice and the Newtonian kinetic energy $E_{\boldsymbol{v}}^{cin}$ of movement of the lattice.

But by associating the total relativistic energy $E_{\boldsymbol{v}}^{disloc}$ with this moving string, and knowing that the energy at rest of this string is given by E_{dist}^{disloc}, we could also consider that the energy of the moving string is equal to the sum of its rest energy E_{dist}^{disloc} and an energy of movement E_{mvt}^{disloc} which corresponds to the additional energy generated by its displacement within the medium, namely $E_{mvt}^{disloc} = E_{\boldsymbol{v}}^{disloc} - E_{dist}^{disloc} = \left(M_{\boldsymbol{v}}^{disloc} - M_0^{disloc}\right)c_t^2 = M_0^{disloc}\left(1/\gamma_t - 1\right)c_t^2$.

In special relativity, this motion energy E_{mvt}^{disloc} is often called *the kinetic energy* T *of the particle*. But in the case of the dislocation considered here, we know that it is not really a kinetic energy since $E_{mvt}^{disloc} = E_{\boldsymbol{v}}^{dist} + E_{\boldsymbol{v}}^{cin} - E_{dist}^{disloc} = E_{\boldsymbol{v}}^{cin} + \left(1/\gamma_t - \boldsymbol{v}^2/2\gamma_t c_t^2 - 1\right)E_{dist}^{disloc}$ is in fact a combination of real kinetic energy $E_{\boldsymbol{v}}^{cin}$ and potential energy $\left(1/\gamma_t - \boldsymbol{v}^2/2\gamma_t c_t^2 - 1\right)E_{dist}^{disloc}$ of the dislocation.

Finally, if we calculate the total energy for low speeds ($\boldsymbol{v} << c_t$), we obtain the relation $E_{\boldsymbol{v}}^{disloc} \cong E_{dist}^{disloc} + M_0^{disloc}\boldsymbol{v}^2/2 + \ldots$ and we find the classical kinetic energy linked to the mass of inertia at rest M_0^{disloc} of the dislocation.

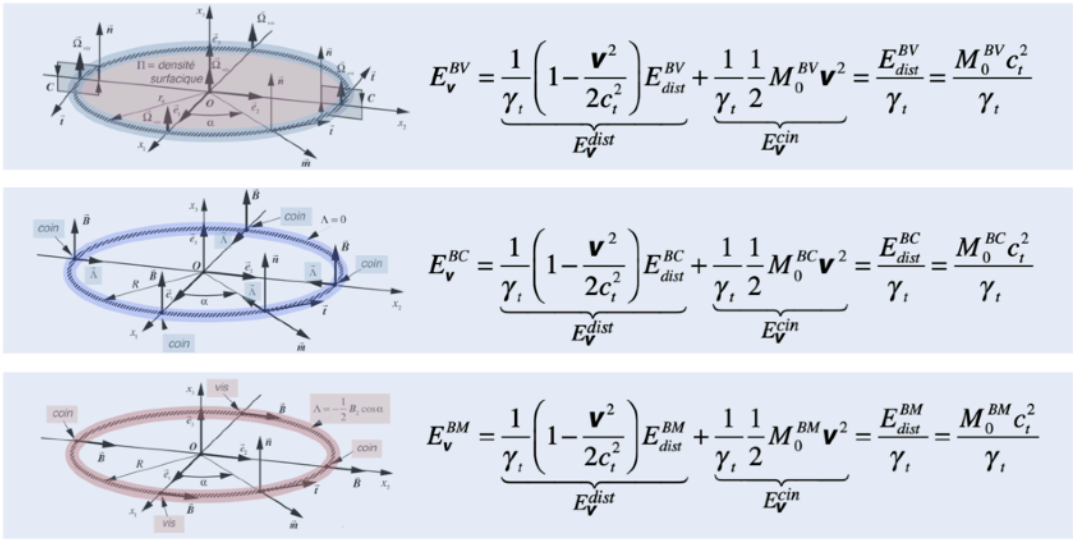
Relativistic energies of loop singularities and spherical charges of rotation

We saw in the previous chapter that the topological singularities in loops in *a perfect cosmological lattice* also all satisfy Einstein's relation $E_{dist}^{loop} = M_0^{loop}c_t^2$ which was obtained from a classical calculation of their elastic energy of distortion and their kinetic energy. This implies that the relativistic energy of the singularities in loops is deduced in an identical way that we deduced the relativistic energy of an edge dislocation above. Consequently, one deduces the relativistic energies indicated in figure 6.8 for the singularities in loops in a perfect cosmological lattice, namely *the twist disclination loop*, *the prismatic edge dislocation loop* and *the slip mixed dislocation loop*.

We also deduce that, in a perfect cosmological lattice, the relativistic dynamic equation of a loop singularity is perfectly identical to that of a screw or edge dislocation, as shown in figure 6.7, namely $d\vec{\boldsymbol{P}}^{loop} / dt = \vec{\boldsymbol{F}}^{loop}$ in which $\vec{\boldsymbol{F}}^{loop}$ is the force acting globally on the loop and $\vec{\boldsymbol{P}}^{loop}$ is the amount of relativistic momentum of the loop, given by $\vec{\boldsymbol{P}}^{loop} = M_0^{loop}\vec{\boldsymbol{v}} / \gamma_t$.

Let us now consider a localized spherical charge of rotation, like that described in figure 5.4, which moves along the axis $\boldsymbol{O}x_1$ at velocity $\vec{\boldsymbol{v}}$. In the mobile frame of reference $\boldsymbol{O}'x_1'x_2'x_3'$ with the charge, we can use the relativistic transformation relationships of momentum $n\vec{p}$ and torque $\vec{m}$ of figure 6.4, as well as the Lorentz transformation relationships of figure 6.1 to deduce the potential energy density $F_{dist}^{\boldsymbol{Q}_\lambda}$ and the kinetic energy density $F_{cin}^{\boldsymbol{Q}_\lambda}$ in $\boldsymbol{O}x_1x_2x_3$. The total relativistic energy $E_{\boldsymbol{v}}^{\boldsymbol{Q}_\lambda}$ is then calculated by integration over the entire lattice volume, and we obtain the energy reported in figure 6.8, which again consists of a relativistic potential energy $E_{\boldsymbol{pot}}^{\boldsymbol{Q}_\lambda}$ and a relativistic kinetic energy $E_{\boldsymbol{cin}}^{\boldsymbol{Q}_\lambda}$.

Relativistic energies of loop singularities

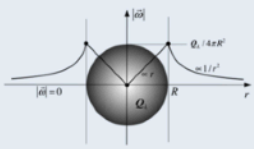


$$E_{\boldsymbol{v}}^{BV} = \underbrace{\frac{1}{\gamma_t}\left(1-\frac{\boldsymbol{v}^2}{2c_t^2}\right)E_{dist}^{BV}}_{E_{\boldsymbol{v}}^{dist}} + \underbrace{\frac{1}{\gamma_t}\frac{1}{2}M_0^{BV}\boldsymbol{v}^2}_{E_{\boldsymbol{v}}^{cin}} = \frac{E_{dist}^{BV}}{\gamma_t} = \frac{M_0^{BV}c_t^2}{\gamma_t}$$

$$E_{\boldsymbol{v}}^{BC} = \underbrace{\frac{1}{\gamma_t}\left(1-\frac{\boldsymbol{v}^2}{2c_t^2}\right)E_{dist}^{BC}}_{E_{\boldsymbol{v}}^{dist}} + \underbrace{\frac{1}{\gamma_t}\frac{1}{2}M_0^{BC}\boldsymbol{v}^2}_{E_{\boldsymbol{v}}^{cin}} = \frac{E_{dist}^{BC}}{\gamma_t} = \frac{M_0^{BC}c_t^2}{\gamma_t}$$

$$E_{\boldsymbol{v}}^{BM} = \underbrace{\frac{1}{\gamma_t}\left(1-\frac{\boldsymbol{v}^2}{2c_t^2}\right)E_{dist}^{BM}}_{E_{\boldsymbol{v}}^{dist}} + \underbrace{\frac{1}{\gamma_t}\frac{1}{2}M_0^{BM}\boldsymbol{v}^2}_{E_{\boldsymbol{v}}^{cin}} = \frac{E_{dist}^{BM}}{\gamma_t} = \frac{M_0^{BM}c_t^2}{\gamma_t}$$

Relativistic energy of a localized rotation charge



$$E_{\boldsymbol{v}}^{\boldsymbol{Q}_\lambda} = \underbrace{\frac{1}{\gamma_t}\left(1-\frac{\boldsymbol{v}^2}{3c_t^2}\right)E_{dist}^{\boldsymbol{Q}_\lambda}}_{E_{pot}^{\boldsymbol{Q}_\lambda}} + \underbrace{\frac{1}{\gamma_t}\frac{2\boldsymbol{v}^2}{3c_t^2}E_{dist}^{\boldsymbol{Q}_\lambda}}_{E_{cin}^{\boldsymbol{Q}_\lambda}} = \frac{1}{\gamma_t}\left(1+\frac{\boldsymbol{v}^2}{3c_t^2}\right)\underbrace{\frac{3(K_2+K_3)\boldsymbol{Q}_\lambda^2}{5\pi R}}_{E_{dist}^{\boldsymbol{Q}_\lambda}}$$

Figure 6.8 *- relativistic energies of loop singularities and of localized rotation charges*

By the term γ_t in the denominator, we find here a behavior of the total energy $E_{\boldsymbol{v}}^{\boldsymbol{Q}_\lambda}$ of the charge similar to that of a relativistic behavior since it tends towards an infinite value when the speed $\boldsymbol{v}$ tends towards the celerity c_t of the transverse waves as shown well by figure 6.5 in which one carried over $E_{\boldsymbol{v}}^{\boldsymbol{Q}_\lambda} / E_{dist}^{\boldsymbol{Q}_\lambda}$ according to $\boldsymbol{v} / c_t$.

As in the case of a screw or edge dislocation, the total energy is found in the form of relativistic elastic potential energy $E_{\boldsymbol{pot}}^{\boldsymbol{Q}_\lambda}$ of rotation of the lattice and in the form of relativistic kinetic energy $E_{\boldsymbol{cin}}^{\boldsymbol{Q}_\lambda}$ of the cells of the lattice, and the fractions of each of these energies depend on the value of the ratio $\boldsymbol{v} / c_t$ as shown in figure 6.6. It can be seen that these

fractions of energy in potential form and in kinetic form here also become perfectly equal when the speed $\boldsymbol{v}$ of the localized charge tends towards the celerity c_t of the transverse waves.

However, the expression of total energy $E_{\boldsymbol{v}}^{\boldsymbol{Q}_\lambda}$ is not this time in perfect agreement with classic relativistic behavior because $E_{\boldsymbol{v}}^{\boldsymbol{Q}_\lambda} \neq E_{dist}^{\boldsymbol{Q}_\lambda} / \gamma_t$. This disagreement is to be associated with the fact that the additional negative term in potential energy no longer exactly compensates for the kinetic energy term, since the kinetic energy term is twice greater than the absolute value of the additional term in potential energy. If we calculate the total energy $E_{\boldsymbol{v}}^{\boldsymbol{Q}_\lambda}$ for low speeds ($\boldsymbol{v} << c_t$) by developing the term γ_t in the denominator, we obtain the following relation $E_{\boldsymbol{v}}^{\boldsymbol{Q}_\lambda} \cong E_{dist}^{\boldsymbol{Q}_\lambda}\left(1+\boldsymbol{v}^2 / 2c_t^2 + ...\right)\left(1+\boldsymbol{v}^2 / 3c_t^2\right) \cong E_{dist}^{\boldsymbol{Q}_\lambda} + 5E_{dist}^{\boldsymbol{Q}_\lambda}\boldsymbol{v}^2 / 6c_t^2 + ...$ In this case, the energy of the moving charge is therefore equal to its rest energy and to a second energy term proportional to the speed of the charge squared, and which can be assimilated to *a kinetic energy term of the charge*. One can consequently allot *a mass of inertia at rest* M_0 to the spherical charge of rotation, and the relation of Einstein is written $E_{dist}^{\boldsymbol{Q}_\lambda} \cong 3M_0 c_t^2 / 5$. It can therefore be seen that the relationship between energy at rest and mass of inertia for a spherical rotation charge $\boldsymbol{Q}_\lambda$ deviates somewhat from Einstein's famous relation of special relativity, which states that $E_0 = M_0 c^2$.

About the probable explanation of the paradox of the electron energy

We find with the relation $E_{dist}^{\boldsymbol{Q}_\lambda} \cong 3M_0 c_t^2 / 5$ for a localized singularity of rotation a famous paradox of classical electromagnetism. Indeed, the same type of calculation carried out in classical electromagnetism to find the energy stored by the electric field of a moving electron gives a result quite similar to this one, namely that $E_{electromagnetic}^{relativistic} \neq E_{electrical\ field}^{at\ rest} / \gamma$, and therefore that the mass associated with *the electromagnetic fields of the electron does not satisfy the principles of special relativity*. This famous result in electromagnetism has caused a lot of ink to flow and has been the subject of much discussion. Several models have been proposed to explain it, without much success elsewhere. We can consider in fact that it was never really understood within the framework of the classical theory of electromagnetism and special relativity. A detailed discussion of this subject can be found in the famous physics lesson of R. P. Feynman [1].

This famous *paradox of the electrical energy of the electron* could find here a simple explanation, if we suppose that the electron also has an annular structure[2] similar to a loop of twist disclination, or to a loop of screw pseudo-dislocation and that the electric field of the electron is the analog of the field of rotation. In fact, the expression of the relativistic energy of a twist disclination loop perfectly satisfies Einstein's expression $E_{\boldsymbol{v}} \cong E_0 / \gamma_t$, so that if the electron presented the topological structure of the twist disclination loop in a cosmological lattice, we would have a localized charge $\boldsymbol{q}_\lambda$ of rotation which would present a divergent field $\vec{\omega}^{\acute{e}l}$ of rotation at a great distance just as the electron presents a divergent electric field $\vec{E}^{el}$,

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[1] *Richard P. Feynman, The Feynman Lectures on Physics, Addison-Wesly Publ. Company, 1970, chap. 28*

[2] *The idea of a ring-shaped electron was first proposed in 1915 by Parson (Smithsonian miscellaneous collections, nov. 1915) and then developed by Webster (Amer. Acad., janv. 1915) and Allen (Phil. Mag., 4, 1921, p. 113), and the proposal that an electron could be similar to a twist disclination loop was proposed in 1996 by Unziker (arXiv:gr-qc/9612061v2).*

and which would satisfy at low speed ($\boldsymbol{v} << c_t$) the relation of the special relativity since for a screw loop one has well the relation $E_{dist}^{BV} = M_0^{BV} c_t^2$.

Peach and Koehler force and relativistic force of Lorentz

In Chapter 2, we introduced *the Peach and Koehler force* $\vec{f}_{PK} = \lambda\vec{m} + \vec{\boldsymbol{v}} \wedge \vec{\boldsymbol{A}}$ which acts through the field $\vec{m}$ on the unit of volume of rotation charges with charge density λ. In this relation, the term $\lambda\vec{m}$ is the analog of the electric force $\vec{f} = \rho\vec{E}$ acting per unit of volume on a density ρ of electric charge in the Maxwell equations of electromagnetism, whereas the term $\vec{\boldsymbol{v}} \wedge \vec{\boldsymbol{A}}$ had been introduced to take account of the forces which do not produce work. For a density λ of charges moving at velocity $\vec{\boldsymbol{v}}$ along the axis $\boldsymbol{O}x_1$, the force density acting in the frame $\boldsymbol{O}'x_1'x_2'x_3'$ linked to the charge is therefore written, since the charge is immobile in this frame and that, consequently, $\vec{\boldsymbol{v}} = 0$ in this frame, under the form $\vec{f}'_{PK} = \lambda\vec{m}'$. We can therefore find the force per unit of volume acting on the same charge density which moves at velocity $\vec{\boldsymbol{v}}$ in the stationary frame of reference $\boldsymbol{O}x_1x_2x_3$, using the relativistic transformation relations of momentum $n\vec{p}$ and torque $\vec{m}$, and we obtain quite easily the next expression $\vec{f}_{PK} = \lambda m_1\vec{e}_1 + \lambda\left(m_2\vec{e}_2 + m_3\vec{e}_3\right)/\gamma_t + 2\lambda\left(\vec{\boldsymbol{v}} \wedge n\vec{p}\right)/\gamma_t$ for this force. In the case where $\left|\vec{\boldsymbol{v}}\right| << c_t$, γ_t becomes close to unity and the force per unit of volume in the stationary frame $\boldsymbol{O}x_1x_2x_3$ simply becomes equal to $\vec{f}_{PK} \cong \lambda\vec{m} + 2\lambda\left(\vec{\boldsymbol{v}} \wedge n\vec{p}\right)$, which is *the perfect analog of the electromagnetic force of Lorentz* $\vec{f}_L = \rho\vec{E} + \vec{j} \wedge \vec{B} = \rho\left(\vec{E} + \vec{\boldsymbol{v}} \wedge \vec{B}\right)$. The term $2\lambda\left(\vec{\boldsymbol{v}} \wedge n\vec{p}\right)$ in force $\vec{f}_{PK}$ is nothing other than the term $\vec{\boldsymbol{v}} \wedge \vec{\boldsymbol{A}}$ we introduced in figure 2.38 to account for non-working forces, so that the vector $\vec{\boldsymbol{A}}$ now has a known value, which is worth $\vec{\boldsymbol{A}} = 2\lambda n\vec{p}$.

We can then apply the relation giving $\vec{f}_{PK}$ to the various topological singularities of the cosmological lattice:

- *in the case of a rectilinear screw dislocation*, the integration of the relation on the unit of length of the dislocation gives the force $\vec{F}_{PK} = \Lambda\vec{m} + 2\Lambda\left(\vec{\boldsymbol{v}} \wedge n\vec{p}\right)$ acting on the unit of length of dislocation. However, if a rectilinear screw dislocation moves in a solid, its velocity $\vec{\boldsymbol{v}}$ is necessarily perpendicular to the line of dislocation, and the force $\vec{F}_{PK}$ will have action only if it is also perpendicular to the line, so that only the component $n\vec{p}$ in the direction of the string can give a force $\vec{F}_{PK}$ capable of acting on the dislocation.
- *in the case of a spherical rotation charge* $\boldsymbol{Q}_\lambda$, the relationship giving $\vec{f}_{PK}$ can be integrated on the volume of the charge, and we obtain the total force acting on the rotation charge which is worth $\vec{F}_{PK} = \boldsymbol{Q}_\lambda\vec{m} + 2\boldsymbol{Q}_\lambda\left(\vec{\boldsymbol{v}} \wedge n\vec{p}\right)$.
- *in the case of a twist disclination loop of charge* $\boldsymbol{q}_{\lambda BV} = 2\pi R\Lambda_{BV} = -\pi R\vec{\boldsymbol{B}}_{BV}\vec{t}$, we can apply the relation giving $\vec{f}_{PK}$, which allows us to write $\vec{F}_{PK} = \boldsymbol{q}_{\lambda BV}\vec{m} + 2\boldsymbol{q}_{\lambda BV}\left(\vec{\boldsymbol{v}} \wedge n\vec{p}\right)$ for the force acting on the loop.

The last two relationships correspond directly to the expression of the electromagnetic force $\vec{F} = q\left(\vec{E} + \vec{\boldsymbol{v}} \wedge \vec{B}\right)$ acting on a moving electric charge q.

About the role of «ether» played by the cosmological lattice

We have seen that the displacement of a topological singularity in the frame of reference $\boldsymbol{O}x_1x_2x_3$ of a perfect cosmological lattcie, at velocity $\vec{\boldsymbol{v}}$ in the direction of the axis $\boldsymbol{O}x_1$, can be described in a frame $\boldsymbol{O}'x_1'x_2'x_3'$ mobile with the singularity thanks to the Lorentz

transformation. At constant volume expansion, a cluster of mobile singularities within the lattice, formed for example by a set of localized singularities like dislocation and disclination loops interacting with each other via their fields of rotation, is subjected to exactly *the same Lorentz transformation, with all the properties which are allotted to it like the dilation of time and the contraction of the lengths*, since the field of rotation which provides the interactions between the singularities satisfies this transformation.

There is obviously a strong mathematical analogy between the Lorentz transformation applied here for the transmission of information and interactions via transverse waves within the cosmological lattice and the Lorentz transformation of the special relativity applied to describe the relativistic dynamics of moving objects in the Universe in relation to the speed of light. But there is also a very serious physical difference between these two theories, linked above all to the existence of an *"ether"* for topological singularities, which is in fact the lattice and which gives a privileged status to fixed singularities in the lattice comparatively to mobile singularities inside the network, whereas in theory of special relativity, all mobile objects have the same status, hence the famous name of *"relativity"*. This essential difference makes it possible to shed entirely new and original light on the phenomena of relativity. This is what we will discuss later.

The dynamics of singularities within a cosmological lattice differs from special relativity by the very existence of the lattice which acts as an *absolute reference* for the movement of singularities and as *an ether* for the propagation of transverse and longitudinal waves. Unlike special relativity, the lattice can be described from the outside by a ***GO*** observer *(Imaginary Great Observer)* which has a universal clock and universal rulers in the absolute frame of reference $Q\xi_1\xi_2\xi_3$. This observer outside the lattice is not subject to any speed of information propagation constraint, so that he is the only one able to observe qualitatively, quantitatively and exactly t*he notion of instantaneous events occurring within the lattice.*

We can also imagine a completely different type of observer. These are the local observers ***HS*** *(Homo Sapiens)*, which are *an integral part of the lattice* and which would themselves consist of topological singularities of the lattice. These particular observers then have a very different status from the ***GO*** observer since they are *an integral part of the lattice* and that they can move around there. But these observers are required to transmit information from one point to another on the lattice at the finite speed of transverse waves or longitudinal waves. A ***HS*** observer therefore has no access to an absolute definition of the simultaneity of events such as that of the ***GO***, but only has a relativistic definition of simultaneity, which depends in particular on its velocity $\vec{\boldsymbol{v}}$ of movement relative to the lattice and the local value of the volume expansion of the lattice.

For reasons of convenience, the external observer ***GO*** can obviously choose, as universal rulers and universal clock, the rulers and the clock of an ***HS*** observer stationary with respect to the lattice, and which would be located at a place on the lattice which would be stationary and of zero volume expansion ($\tau = 0$).

All ***HS*** observers are provided with a local reference frame which has rulers and its own clock, which seem immutable for this ***HS***, while the length of its rulers and the speed of counting the time of its clock actually vary in the absolute reference frame of the ***GO*** as a function of the volume expansion of the lattice at the location where it is located (we will come back to this

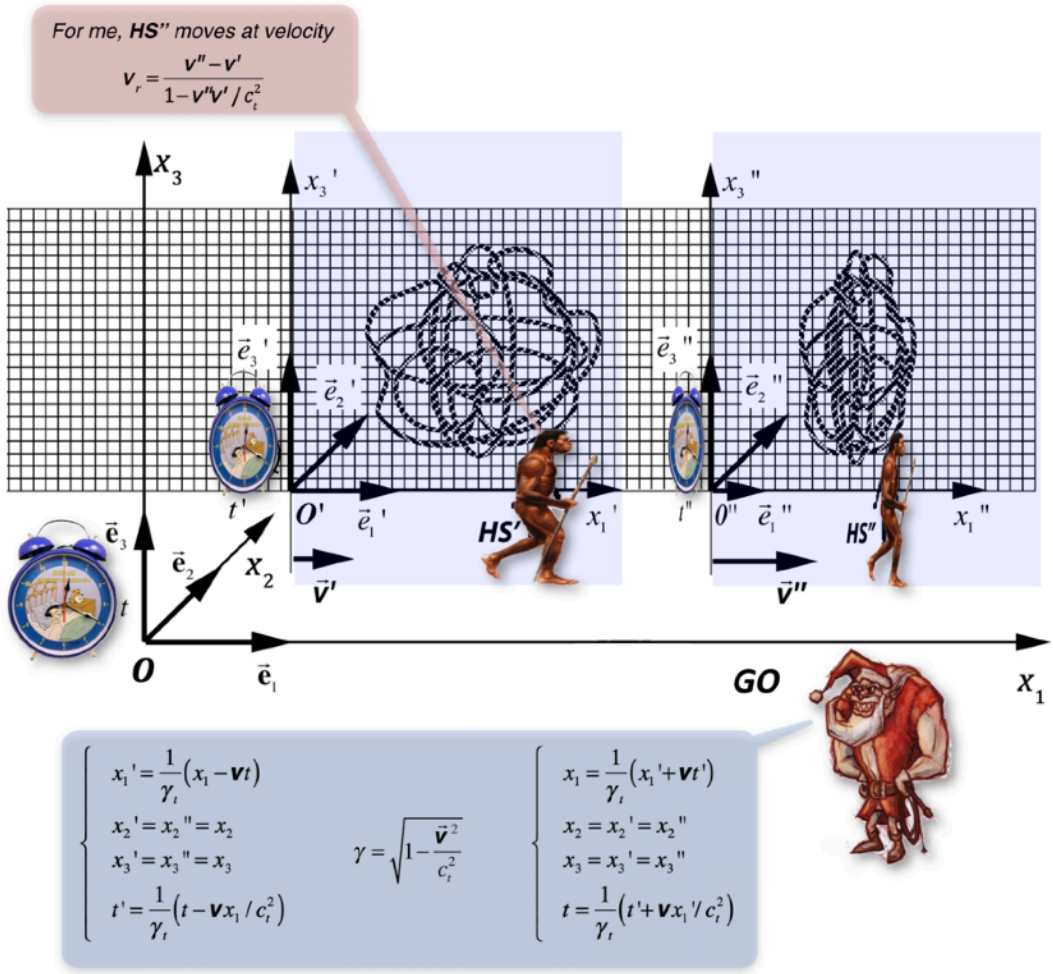


Figure 6.9 *- The mobile Lorentz frames of the moving observers* ***HS'*** *and* ***HS"***

point in detail later) and its velocity $\vec{v}$ relative to the lattice. Consequently, the ***HS*** does not have direct access to the value of the local volume expansion of the lattice or to its own velocity $\vec{v}$ of displacement relative to the lattice. Only the ***GO*** has direct access to this type of information.

The Lorentz transformations that we have defined are therefore in reality tools of the ***GO***, which can be used without problem to determine the rulers and local clocks of all the ***HS***s attached to the lattice, or simply to calculate the various fields associated with topological singularities in motion within the lattice. And it can apply these transformations to any place on the lattice where it is possible to find a state of homogeneous and constant expansion, which may very well be different from zero expansion since the Lorentz transformations are based on the transmission speed of transverse waves, which is perfectly determined whatever the state of expansion of the lattice ($c_t(\tau) = c_{t0}\, e^{\tau/2}$). From this point of view, our interpretation of Lorentz transformations is quite far from the interpretation of sepcial relativity, for which these transformations are tools that any ***HS*** observer can use to move from one referential to another referential in motion by compared to the first, and for which the speed of light is an absolute constant. The main consequences of these essential differences will be analyzed in detail later

in this chapter.

The Lorentz transformations imply that, for singularities moving at velocity $\vec{\boldsymbol{v}}$ in the direction $\boldsymbol{O}x_1$, the ruler according to the direction $\boldsymbol{O}x_1$ is shortened by a factor γ_t, so that $\vec{e}_1' = \gamma_t \vec{e}_1$. To interpret this shortening of the ruler in the direction of movement, we have to imagine the architecture of the cluster as a set of topological singularities linked together by their interactions via their respective fields of rotation (figure 6.9). These singularities of the lattice move relative to the lattice at velocity $\vec{\boldsymbol{v}}$ in the direction $\boldsymbol{O}x_1$, and the finiteness of the speed c_t of their interactions via the rotation field requires that the complete architecture of the cluster of singularity contracts in the direction $\boldsymbol{O}x_1$.

But this contraction does not affect the lattice, which retains its original volume expansion state, which is shown in figure 6.9 for the case of two clusters of identical singularities which move at two different velocities, $\vec{\boldsymbol{v}}'$ and $\vec{\boldsymbol{v}}''$, measured compared to the lattice by the ***GO*** observer. Thus, the relativistic effects on the rulers of observers ***HS'*** and ***HS''***, associated with the collective movement of singularities with respect to the lattice, have nothing to do with effects of volume expansion of the lattice, for which the modifications of the lengths observer rulers ***HS'*** and ***HS''*** will be associated with real variations in the cell parameter of the cosmological lattice as we will see later.

Note also that these two effects are cumulative, namely that the rulers of an ***HS*** observer can be contracted or expanded by variations in volume expansion of the lattice and still contracted by a movement of the cluster of singularities with respect to the lattice. In this way, the contraction-expansion of the rulers and the clock of an ***HS*** observer depends on both the local expansion of the lattice and the velocity $\vec{\boldsymbol{v}}$ of ***HS*** relative to the lattice.

In addition, in the Lorentz transformation applied by the ***GO*** observer, the value of $\gamma_t = (1 - \boldsymbol{v}^2 / c_t^2)^{1/2}$ is not only related to the velocity $\vec{\boldsymbol{v}}$ of ***HS*** with respect to the lattice, but also to the local celerity c_t of the transverse waves, which depends on the volume expansion of the cosmological lattice, since $c_t\big|_{\tau \neq 0} = c_{t0}\big|_{\tau=0} \mathrm{e}^{\tau/2}$.

The phenomenon of slowing down of the clock of the observer ***HS*** which moves relative to the lattice has already been explained, with figures 6.3 (a) and (b). Imagine that there is an observer ***HS'*** who builds his own clocks in his reference frame $\boldsymbol{O}'x'_1x'_2x'_3$, by fixing two mirrors facing each other at a distance d_0 from each other, mirrors which have the property of reflecting transverse waves. By sending a transverse wave between the two mirrors, ***HS'*** can perfectly use, as a time base, the period of time $T_0 = 2d_0 / c_t$ that elapses between a round trip of the wave between the two mirrors, because the distance d_0 and the celerity c_t of transverse waves are for him constants. If the ***HS'*** observer is initially at rest relative to the lattice, the ***GO*** can consider the time lapse $T_0 = 2d_0 / c_t$ as its own time base in $\boldsymbol{O}x_1x_2x_3$.

Now imagine that the observer ***HS'*** moves relative to the lattice with velocity $\vec{\boldsymbol{v}}$ in the direction $\boldsymbol{O}x_1$, and that he places two clocks in quadrature, that is to say a clock having its two mirrors in the direction $\boldsymbol{O}x_1'$ and a second clock having its two mirrors along the axis $\boldsymbol{O}x_3'$ (or $\boldsymbol{O}x_2'$). In principle, in its frame $\boldsymbol{O}'x'_1x'_2x'_3$, the time span $T_0 = 2d_0 / c_t$ measured by ***HS'*** with its two clocks is exactly the same.

Now let's take the ***GO*** point of view. We have shown that the base time of the mobile clock of the observer ***HS'*** in $\boldsymbol{O}'x_1'x_2'x_3'$, measured by the observer ***GO*** in its absolute frame of reference $\boldsymbol{O}x_1x_2x_3$, appears dilated as a function of the velocity $\vec{\boldsymbol{v}}$ of a factor $1/\gamma_t$, in an

identical manner for the two clocks in quadrature, so that $T = T_0 / \gamma_t$. This means that a local time t' actually exists for the observer ***HS'***, that this local time elapses more slowly for an observer ***HS'*** in movement relative to the lattice, and that this local time t' remains isotropic in $O'x_1'x_2'x_3'$, regardless of the direction of movement of the observer ***HS'*** within the lattice.

Concerning the dilation or contraction of time, there can also be coupling between the relativistic effects and the effects of volume expansion. We will see for example later that, in the case of a cosmological lattice, an observer ***HS'*** which would be placed in a zone of strong volume contraction ($\tau << 0$) would present a proper time very strongly slowed compared to the proper time of the ***GO.*** In addition, if it were still moving at a speed ***v*** close to c_t with regard to the lattice, its proper time would be even more significantly slowed down compared to the ***GO's*** proper time.

Experiment of Michelson-Morley in the cosmological lattice

The network plays the same role vis-à-vis the singularities and the propagation of transverse waves as the famous *"ether"* supposedly propagating light waves and so much discussed at the beginning of the XXth century. The Michelson-Morley experiment, which consisted in trying to measure, using an interferometer, a difference in the speed of propagation of light waves in the direction of a displacement of the interferometer at velocity $\vec{v}$ and transversely to the direction of this displacement, has gave negative results, and it was concluded at the time that there was no ether. But in the two examples above, the calculation proposed in the solid lattice with two local clocks in quadrature shows that the result is identical to that obtained by Michelson-Morley, namely that there is no time difference from travel in the two perpendicular directions, which the ***HS*** obviously interprets as the fact that the speed of propagation does not depend on the direction in which it is measured. But in the case that we have treated here, there is indeed an ether constituted by the lattice within which the singularities move, and which is perfectly known by the ***GO***.

We deduce that, in the case of the solid lattice acting as an ether, the singularities which move at velocity $\vec{v}$ have effectively their own clock which slows down since the ***GO*** measures a clock time T_0 with the ***HS*** clock stationary compared to the network, but a time $T = T_0 / \gamma_t$ with the clock of an ***HS*** which moves at velocity $\vec{v}$ compared to the lattice.

On the other hand, if an ***HS'*** measures the speed c_t' of a transverse wave in its moving frame of reference $O'x'_1x'_2x'_3$, with its own rulers and clock, it finds exactly the same value as that measured by the ***GO*** in the lattice, since we have in the direction Ox_1' that $c_t' = 2d_0 / T = \left(2d / \gamma_t\right) / \left(T / \gamma_t\right) = 2d / T = c_t$.

The relativistic composition of velocities and the absence of an absolute notion of simultaneity for the local observers HS

In figure 6.9, two frames have been shown in translation along the axis Ox_1 at velocities $\vec{v}'$ and $\vec{v}''$ measured by the ***GO*** observer. One may wonder how translates the relativity of the velocities measured by the ***HS***, and in particular what is *the relative velocity* $\vec{v}_r$ that the observer ***HS'*** measures in his reference frame $O'x'_1x'_2x'_3$ for the displacement of the reference frame $O''x''_1x''_2x''_3$ of the observer ***HS''***. For ***GO***, the point O'' of the frame of ***HS''***

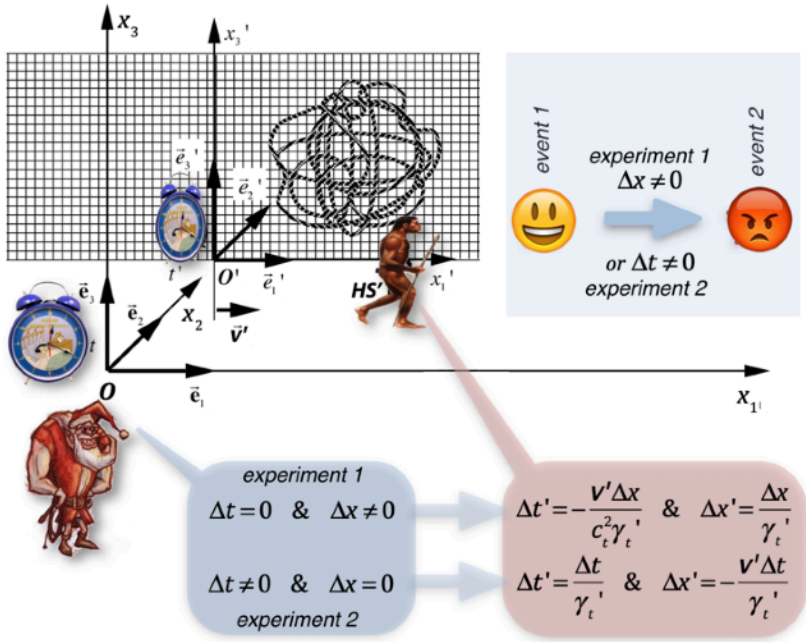


Figure 6.10 *- The non-simultaneity of the events of* ***GO*** *for the moving observers* ***HS'***

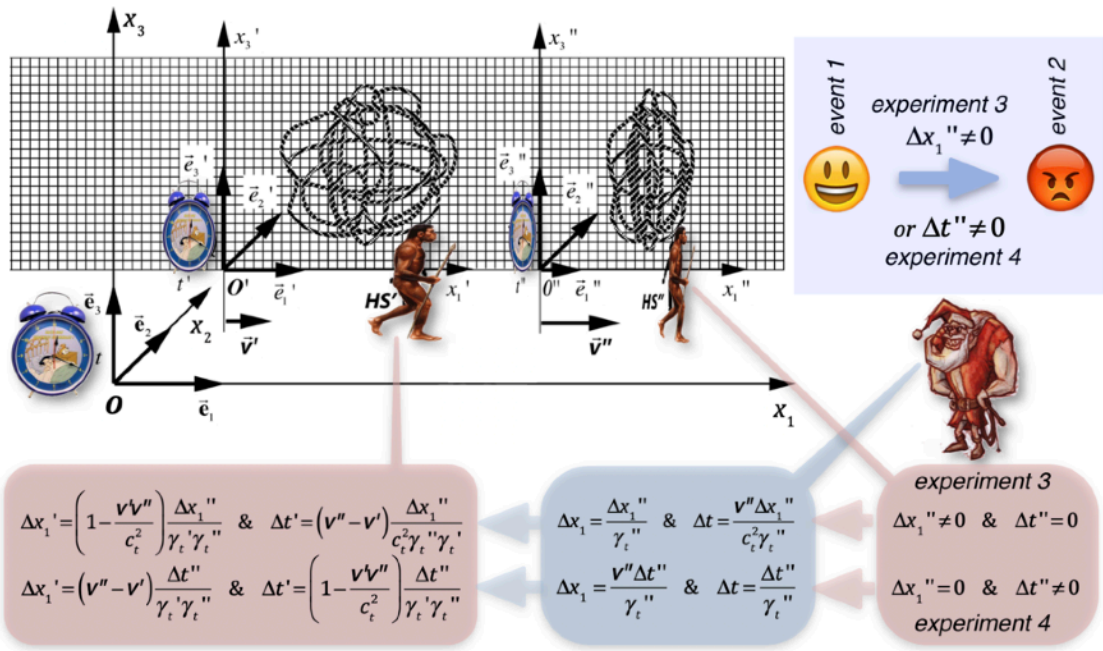


Figure 6.11 *- The non-simultaneity of the events for the moving observers* ***HS'*** *and* ***HS''***

moves in $Ox_1x_2x_3$ from $x_1^{(1)}$ to $x_1^{(2)}$ in a time lapse that goes from t_1 to t_2, so the norm of velocity $\vec{V}''$ is worth $V''=(x_1^{(2)}-x_1^{(1)})/(t_2-t_1)$.

If ***HS'*** observes this same displacement, it finds a relative velocity $\vec{V}_r$ whose norm is worth $V_r=(x_1^{(2)}{}'-x_1^{(1)}{}')/(t_2'-t_1')$. This expression can then be transformed using the Lorentz relations of figure 6.9, and there comes the expression of the relative velocity $\vec{V}_r$ of movement of the observer ***HS''*** as measured by the observer ***HS'*** and expressed under the form $V_r=(V''-V')/(1-V''V'/c_t^2)$ according exclusively to the velocities $\vec{V}'$ and $\vec{V}''$ measured by the ***GO***. The relative velocity of the frame $O''x''_1x''_2x''_3$ measured by ***HS'*** corresponds to what is called *the classical relativistic composition of velocities*. By symmetry, the relative velocity of the frame $O'x'_1x'_2x'_3$ measured by ***HS''*** will be given by exactly the same expression with a change of sign.

The observers linked to the lattice do not in fact have access to the absolute notion of simultaneity that the ***GO*** can have. To illustrate this point, we can imagine four very simple experiments:

1st experiment: let us consider *two simultaneous events observed by **GO** in the frame of reference $Ox_1x_2x_3$ at the time $t=0$ at the coordinates $x_1^{(1)}=0$ and $x_1^{(2)}=\Delta x_1$, therefore distant from Δx_1* (figure 6.10). These two simultaneous events are then observed by an ***HS'*** in its reference frame $O'x'_1x'_2x'_3$ moving at velocity $\vec{V}$ in the direction Ox_1 at the coordinates $\left(x_1^{(1)}{}'=0\ ,\ t_1'=0\right)$ and $\left(x_1^{(2)}{}'=\Delta x_1/\gamma_t\ ,\ t_2'=-V\Delta x_1/(c_t^2\gamma_t)\right)$, obtained by the Lorentz transformations reported in figure 6.9. We therefore observe that the two events are not observed as simultaneous by the ***HS'***, but separated by a non-zero time interval $\Delta t'=t_2'$, and the distance measured by the ***HS'*** between the two events is equal to $\Delta x_1'=x_1^{(2)}{}'=\Delta x_1/\gamma_t$ which is greater than the distance measured by the ***GO***, and which is the consequence of the contraction of the ruler $\vec{e}_1'$ of ***HS'*** in the direction Ox_1.

2nd experiment: consider *an event occurring at the origin of the **GO** reference frame $Ox_1x_2x_3$ and which extends from $t_1=0$ to $t_2=\Delta t$, therefore over an absolute period of time Δt* (figure 6.10). This event is then observed by an ***HS'*** in its coordinate system moving at velocity $\vec{V}$ in the direction Ox_1 at the coordinates $\left(x_1^{(1)}{}'=0\ ,\ t_1'=0\right)$ and $\left(x_1^{(2)}{}'=-V\Delta t/\gamma_t\ ,\ t_2'=\Delta t/\gamma_t\right)$, obtained using the Lorentz relations of figure 6.9. We note that the event seems to move in the frame of ***HS'*** over a distance $\Delta x_1'=\left|x_1^{(2)}{}'\right|=V\Delta t/\gamma_t$, longer than the absolute course $V\Delta t$ of the frame $O'x'_1x'_2x'_3$ in the lattice, due to the contraction of the ruler $\vec{e}_1'$ used by HS', and that the lapse of time that the event lasts for HS 'is worth, and therefore seems longer for ***HS'*** than for ***GO***, which is at first sight rather strange since the clock of ***HS'*** rotates more slowly than that of ***GO***. This phenomenon is due to the flight times taken by the transverse waves to reach the ***HS'*** in movement relative to the lattice. This last experiment clearly shows that the time intervals measured by ***HS'*** are relative intervals since they depend on the finite speed of propagation of information within the lattice.

3rd experiment: let us now consider *two simultaneous events in the mobile coordinate system $O''x''_1x''_2x''_3$ of **HS''**, at the coordinates $x_1^{(1)}{}''=0$ and $x_1^{(2)}{}''=\Delta x_1''$, and occurring at the moment $t''=0$* (figure 6.11). In the stationary frame of reference $Ox_1x_2x_3$ with respect to the lattice, the coordinates of these two events become two distinct events in time, the intervals between them being written $\Delta x_1=\Delta x_1''/\gamma_t''$ and $\Delta t=V''\Delta x_1''/(c_t^2\gamma_t'')$. These relations can be used now to obtain the coordinates of the two events in the reference

frame of ***HS'***, which can then be clarified in the form of a spatial distance $\Delta x_1'$ and a time interval $\Delta t'$ between the two events, represented in the figure 6.11. The two simultaneous events distant from $\Delta x_1''$ in the frame $O''x''_1x''_2x''_3$ of ***HS"*** become two non-simultaneous events in the frame $O'x'_1x'_2x'_3$ of ***HS'***.

4th experiment: let us now consider *two successive events in the mobile coordinate system* $O''x''_1x''_2x''_3$*, occurring at the same place at the coordinate* $x_1^{(1)}''=0$ *and occurring at times* $t_1''=0$ *and* $t_2''=\Delta t''$ (figure 6.11). In the motionless frame of reference $Ox_1x_2x_3$, the coordinates of these two events become two distinct events in space which can be used to obtain the coordinates of the two events in the reference frame $O'x_1'x_2'x_3'$ of ***HS'***, which can be clarified in the form of a spatial distance $\Delta x_1'$ and a time interval $\Delta t'$ between the two events as shown in Figure 6.11. The two events occurring at the origin of the ***HS"*** frame $O''x''_1x''_2x''_3$ therefore become two separate events in the space of the ***HS'*** frame $O'x'_1x'_2x'_3$.

Doppler-Fizeau effects between moving singularities in the cosmological lattice

In figures 6.12 and 6.13, we have reported several experiments of exchanging signals at a given frequency between singularities in motion within the lattice via transverse waves. By taking the ***GO*** point of view, it is possible to easily describe these experiments which reveal the Doppler-Fizeau phenomenon. It is obviously assumed that all these experiments take place in a lattice with a homogeneous and constant value of the volume expansion, without which the description of these experiments would become much more complex.

1st experiment: an observer ***HS'*** in the reference frame $O'x'_1x'_2x'_3$ moving at velocity $\vec{\boldsymbol{v}}'$ relative to the lattice in the direction Ox_1 emits a wave at the frequency f_e', measured with his own clock, towards an observer ***HS*** in a stationary frame of reference $Ox_1x_2x_3$ relative to the lattice (figure 6.12a). The transverse wave emitted in $O'x'_1x'_2x'_3$ is written simply $\vec{\omega}=\vec{\omega}_0\sin\left(\omega' t'-k'x_1'\right)$ with $f_e'=\omega'/2\pi$ and $k'=\omega'/c_t$. In the reference frame $Ox_1x_2x_3$, the same wave is obtained by replacing the coordinates t' and x_1' of ***HS'*** by the coordinates t and x_1 of ***HS***, using the Lorentz transformations of figure 6.9, and identifying the wave vector and the pulsation obtained with those of the expression of the wave $\vec{\omega}=\vec{\omega}_0\sin\left(\omega t-kx_1\right)$ in the frame of reference $Ox_1x_2x_3$, and we find the relations giving ω and k from the values of ω' and k' in the frame of reference $O'x'_1x'_2x'_3$, in the form $\omega=\left(\omega'+k'\boldsymbol{v}'\right)/\gamma_t'$ and $k=\left(k'+\omega'\boldsymbol{v}'/c_t^2\right)/\gamma_t'$. As $k'=\omega'/c_t$ and $f_e'=\omega'/2\pi$, we deduce the relationship between the frequency f_e' of the signal sent by ***HS'*** and the frequency f_r of the received signal measured by ***HS*** with its own clock, as shown in figure 6.12a.

For $\boldsymbol{v}'>0$, that is to say when ***HS'*** approaches ***HS***, the frequency f_r of the signal received by ***HS*** is higher than the frequency f_e' of the signal transmitted by ***HS'***. This is *the Doppler-Fizeau effect*, and in the usual jargon of physicists, we speak of a *"signal shifted towards blue"*. Otherwise, if ***HS'*** moves away from ***HS*** ($\boldsymbol{v}'<0$), the received signal is of frequency f_r lower than the frequency f_e' of the transmitted signal, and one speaks about a *"signal shifted towards red"*. In the form shown in figure 6.12a, the relation shows the term $(1-\boldsymbol{v}'/c_t)^{-1}$ of *the purely classical Doppler effect*, but which applies to a transmitted frequency $\gamma_t' f_e'$, which is nothing other than the frequency of the signal transmitted by ***HS'***, but measured by ***HS*** with its

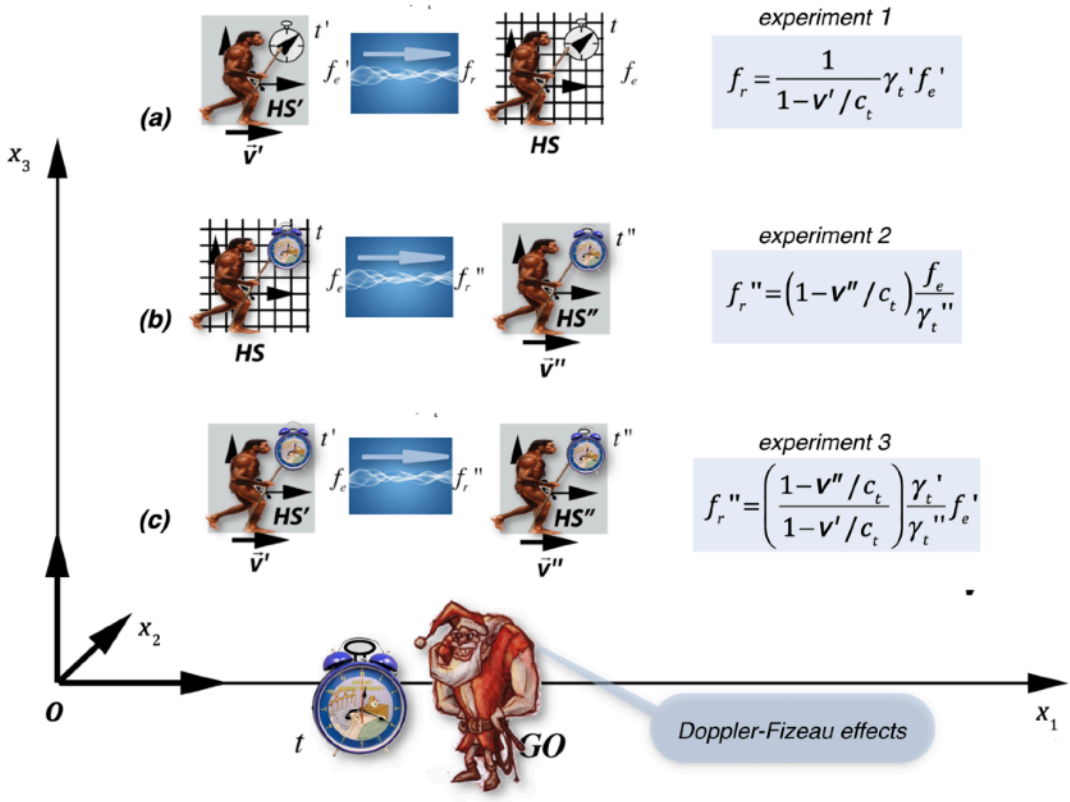


Figure 6.12 - *Different measuring configurations of the Doppler-Fizeau effect*

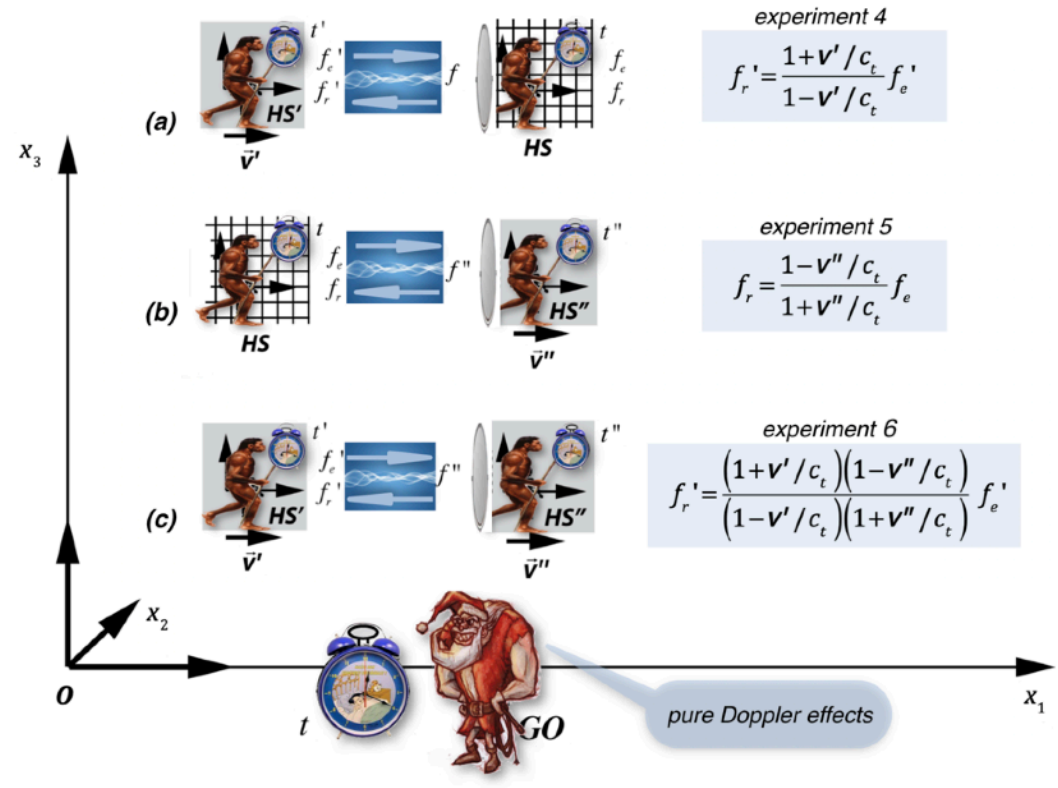


Figure 6.13 - *Different measuring configurations of the pure Doppler effect*

own clock, or by ***GO*** with the universal clock.

2nd experiment: an ***HS*** observer in the reference frame $Ox_1x_2x_3$ at rest with respect to the lattice transmits a signal with a frequency f_e, measured with his own clock, to an ***HS"*** observer which moves at velocity $\vec{v}''$ in the direction Ox_1 relative to the lattice (figure 6.12b) . With the same type of calculation as in the case of the 1st experiment, it is possible to verify that the frequency f_r'' of the signal received by ***HS"*** and measured with its own clock takes the value shown in figure 6.12b.

For $v'' > 0$, that is to say when ***HS"*** moves away from ***HS***, the frequency f_r'' of the signal received by ***HS"*** is lower than the frequency f_e of the signal transmitted by ***HS***. Again, this is *the Doppler-Fizeau effect*. In this form, the expression of f_r'' makes appear the term $(1 - v''/c_t)$ of *the classic Doppler effect*, but which applies to a frequency f_e/γ_t'', which is nothing other than the frequency of the signal emitted by ***HS***, but as measured with the ***HS"*** clock.

3rd experiment: an observer ***HS'*** in the reference frame $O'x'_1x'_2x'_3$ moving at velocity $\vec{v}'$ in the direction Ox_1 relative to the lattice emits a wave at the frequency f_e', measured with its own clock, towards an observer ***HS"*** which moves at velocity $\vec{v}''$ in the direction Ox_1 relative to the lattice (figure 6.12c). The frequency f_r'' of the signal received by ***HS"*** and measured by him with his own clock is easily obtained by combining the two relations (6.12 a) and (6.12b) obtained previously. In this form, the expression of f_r'' shows in fact in parentheses *the classic Doppler effect* due to the movements of the two observers relative to the lattice, as well as the frequency $\gamma_t' f_e'/\gamma_t''$ which is nothing other than the frequency of the signal emitted by ***HS'***, but measured with the ***HS"*** clock.

4th experiment: an observer ***HS'*** in the reference frame $O'x'_1x'_2x'_3$ moving at velocity $\vec{v}'$ in the direction Ox_1 relative to the lattice emits a wave at the frequency f_e', measured with its own clock, which is reflected on a mirror associated with a fixed reference frame with respect to the lattice, and receives the echo of this wave whose he measures the frequency f_r', always with its own clock (figure 6.13a). It is easy to find the value of f_r' using the relations (6.12a) and (6.12b) previously obtained in which we introduce the frequency f received and re-emitted by the mirror in the ***HS*** reference frame. The combination of these two relationships then shows us that, in this case, the effect measured by ***HS'*** is *a pure classic Doppler effect*, which is perfectly logical since ***HS'*** uses its own clock to measure f_e' and f_r'.

5th experiment: an observer ***HS*** in the fixed reference $Ox_1x_2x_3$ with respect to the lattice emits a wave at the frequency f_e, measured with his own clock, which is reflected on a mirror associated with a reference frame $O''x''_1x''_2x''_3$ in movement in the direction Ox_1 at velocity $\vec{v}''$ compared to the fixed lattice, and receives the echo of this wave whose he measures the frequency f_r, always with its own clock (figure 6.13b). It is easy to find the value of f_r by again using the relations previously obtained in which the frequency f'' received and re-emitted by the mirror is introduced into the reference frame of ***HS"***. The combination of the two relations (6.12a) and (6.12b) again shows us that, in this case, the effect measured by ***HS*** is *a pure classic Doppler effect*, since ***HS*** uses its own clock to measure f_e and f_r.

6th experiment: an observer ***HS'*** in the reference frame $O'x'_1x'_2x'_3$ in movement relative to the lattice at velocity $\vec{v}'$ in the directionn Ox_1 emits a wave at the frequency f_e', measured

with its own clock, which is reflected on a mirror associated with a reference frame $O''x''_1x''_2x''_3$ in movement relative to the lattice at velocity $\vec{v}''$ in the direction Ox_1, and receives the echo of this wave whose he measures the frequency f_r', always with its own clock (figure 6.13c). Again, it is easy to find the value of f_r' by using twice the relationship (6.12c). We find again that, in this case, the effect measured by ***HS'*** is *a pure classic Doppler effect*, since ***HS'*** uses its own clock to measure f_e' and f_r'.

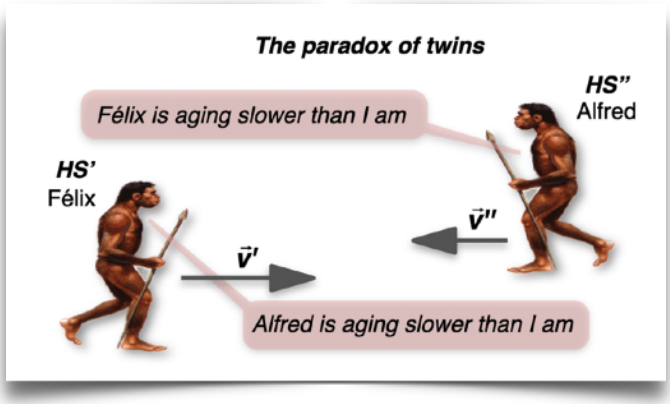
About the famous paradox of the Twins of Special Relativity…

... which is only one in the minds of the HS observers

The existence of the lattice, therefore of an *"ether",* makes it possible to give a very simple and very elegant explanation to the famous *paradox of the Twins of Special Relativity*. We have already seen that a local observer ***HS''*** in its mobile reference frame $O''x''_1x''_2x''_3$ at velocity $\vec{v}''$ relative to the lattice in the direction Ox_1 is in principle not able to measure this velocity since its clock and its own rulers do not change for him, which results also in the fact that Michelson-Morley type experiments do not provide useful informations to him. However, one may wonder whether Doppler-Fizeau type experiments with another ***HS'*** observer moving at velocity $\vec{v}'$ relative to the lattice in the direction Ox_1 could provide him with more information. In relation to the ***HS'*** observer, the observer ***HS''*** can perform three types of measurement:

- he can measure the relative speed v_r of ***HS'*** with respect to it, given by the formula in figure 6.9, with a changed sign,
- he can measure the frequency ratio f_r''/f_e' of a certain known event occurring in his reference frame and in the reference frame of ***HS'***, given in figure 6.12c,
- he can measure the frequency ratio f_r''/f_e'' of a signal which he has sent itself and which is reflected on a mirror in the frame of reference of ***HS'***, given in figure 6.13c.

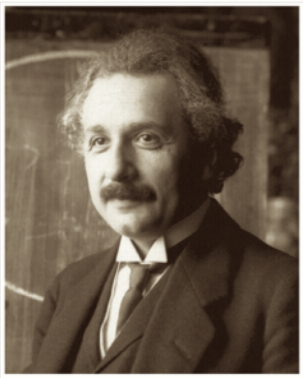
We can then show that these three experimental measurements do not allow ***HS''*** to determine unequivocally $\vec{v}'$ and $\vec{v}''$. Indeed, the last two relationships are absolutely equivalent and therefore do not solve the problem. As for the first two relations, it is easy to show that this system is also indeterminate, because it provides the relation $f_r''/f_e' = \left[(1-(v_r/c_t)^2\right]^{1/2}$, so that ***HS''*** ultimately has no way of finding his velocity $\vec{v}''$ relative to the lattice using experiments of Doppler-Fizeau type.



This last relation is extremely interesting, because it shows that ***HS''*** can deduce the relative speed v_r of ***HS'*** compared to him by measuring the frequency ratio f_r''/f_e' of a certain known event occurring in his reference frame and in the reference frame of ***HS'*** and that for him, in his reference frame $O''x''_1x''_2x''_3$, this frequency ratio is of the relativistic type.

But the observer ***HS'***, in his reference frame $O'x'_1x'_2x'_3$, could make the same measurement, and he would then obtain exactly the same result. Thus, for ***HS*** observers who do not have

access to their absolute velocities relative to the lattice *(therefore relative to «ether»)*, their principle of relativity is exactly *the same principle as that of Special Relativity*. In particular, by applying the Lorentz transformation, ***HS"*** will have the impression that ***HS'*** ages slower than him, while ***HS'*** will also have the impression that it is ***HS"*** who ages slower than him. This strange situation at first sight is called *the paradox of twins in Special Relativity*.



Albert Einstein (1879-1955)

But this paradox of twins is only one in the minds of the observers ***HS'*** and ***HS"*** . Indeed, for the ***GO*** which has access to the relative speeds of the ***HS*** observers compared to the lattice, it is perfectly clear that it is the observer ***HS*** which moves compared to the lattice which ages less quickly than the observer ***HS*** which remains fixed compared to the lattice. Thus, if a pair of ***HS*** twins carry out the famous *Langevin twin experiment*, namely that one of the twins sets off in a rocket at subluminous speeds and then returns to his twin which has remained at the starting point, the ***GO*** will be able to say unequivocally that the ***HS*** who has traveled at very high speed compared to the lattice will be the youngest when they meet after the trip. And the ***GO*** knows perfectly well that this effect took place throughout the journey, *even during periods when the speed of the traveling twin has been constant in relation to the lattice.*

This interpretation of the paradox of twins based on the existence of the cosmological lattice, *therefore of an ether*, is entirely new and gives a very simple, logical and elegant answer to many questions and interpretations of the paradox of twins suggested by Special Relativity and by Einstein's General Relativity[3].

[3] *See for example:*
http://fr.wikipedia.org/wiki/Paradoxe_des_jumeaux
http://en.wikipedia.org/wiki/Twin_paradox