

Universe and Matter conjectured
as a 3-dimensional Lattice
with Topological Singularities

Gérard Gremaud
2016

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I A - Eulerian theory of newtonian deformable media

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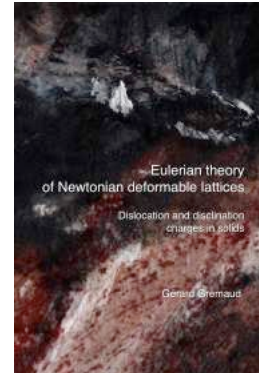
I C - Dislocation and disclination charges

I D - Application: elements of dislocation theory in usual solids

Conclusion of the first part



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2016, 312 pages
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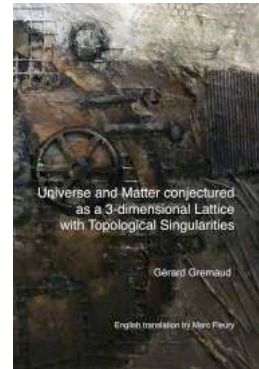
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Conclusion of the second part



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Part I – Eulerian theory of deformable media

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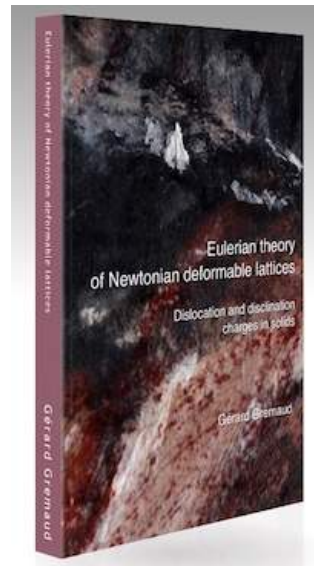
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I A - Eulerian theory of newtonian deformable medias

Coordinates systems

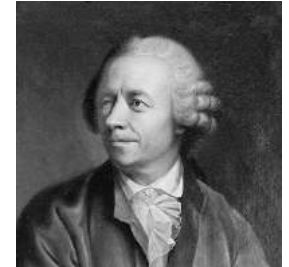
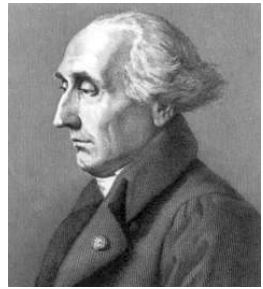
Differential geometries
(Riemann-Cartan, Finsler, Kawaguchi, ...)



Lagrange coordinates

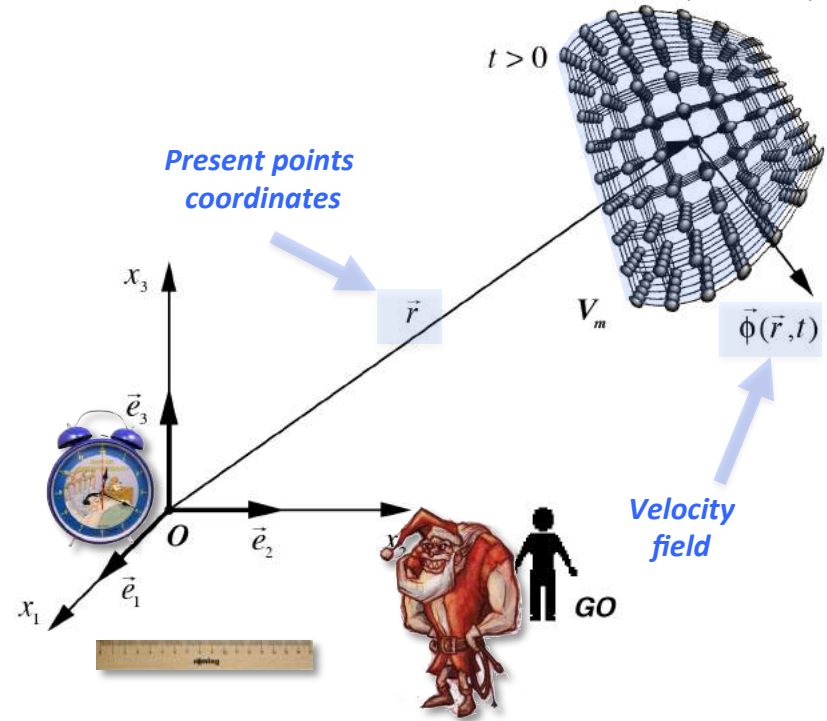
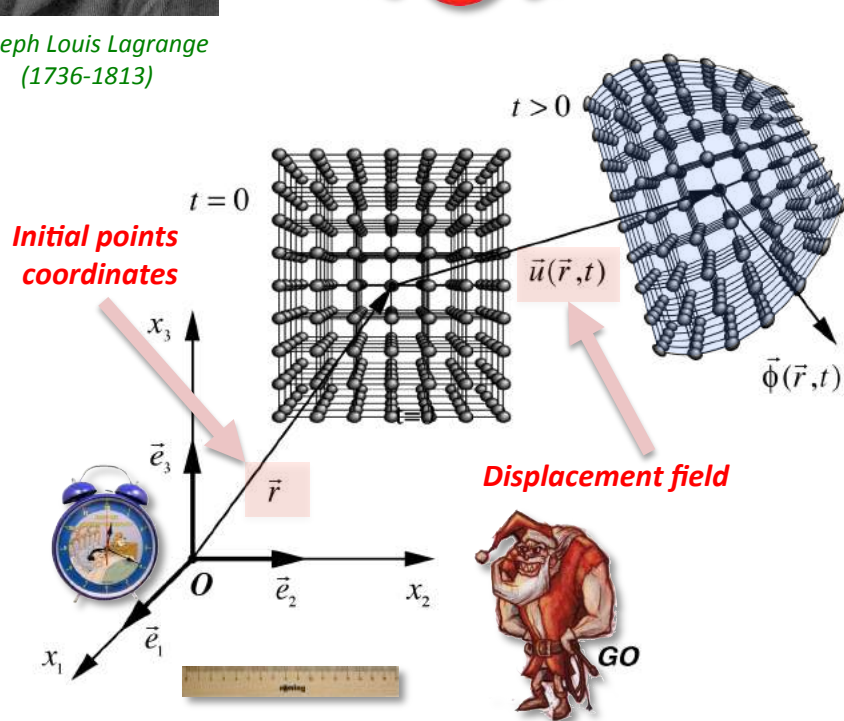


Euler coordinates



Leonhard Euler (1707-1783)

Joseph Louis Lagrange
(1736-1813)

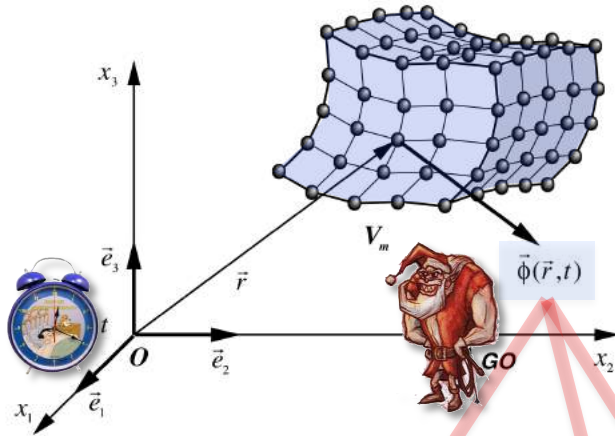


Geometrokinetic equations and distortion tensors in Euler coordinates

Temporal variations of the lattice « distortions » are linked to the spatial variations of the velocity field



Vectorial representation of the distortion tensors



Material derivative

$$\frac{d}{dt} = \frac{\partial}{\partial t} + (\vec{\phi} \cdot \nabla)$$

Tensor of distortion

$$\frac{d\vec{\beta}_i}{dt} = -\frac{S_n}{3n} \vec{e}_i + \overline{\text{grad}} \phi_i$$

trace

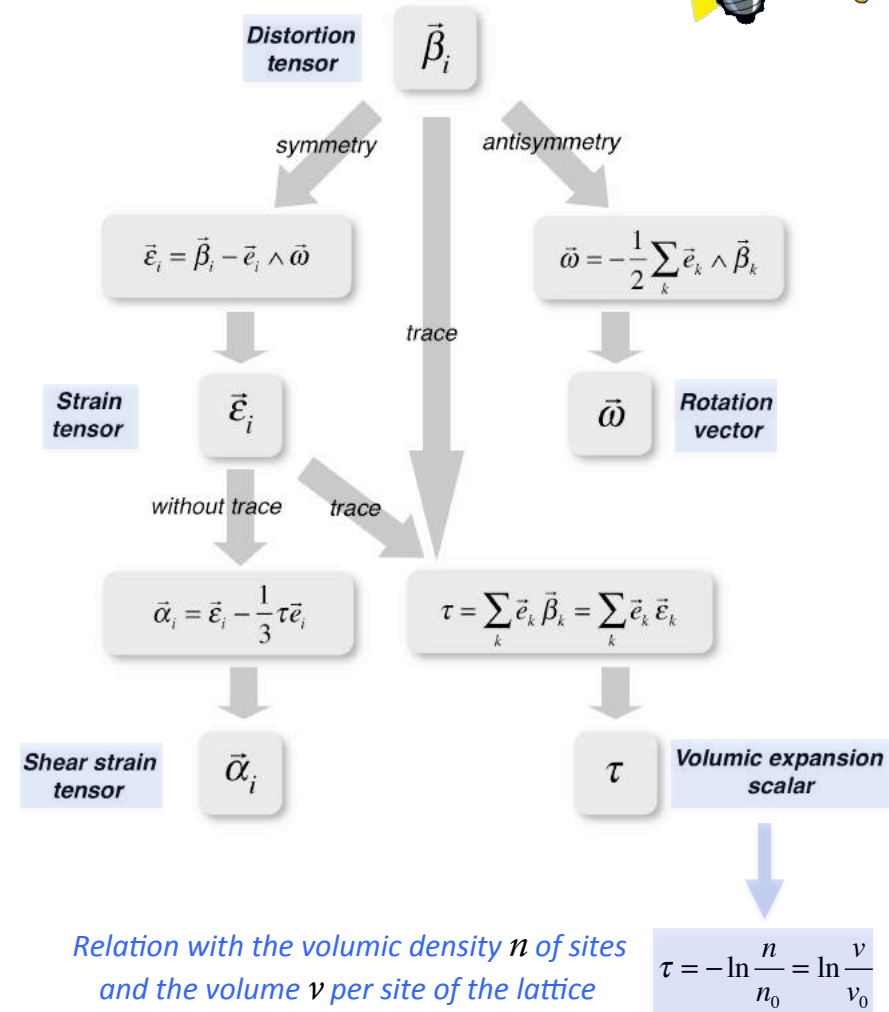
Scalar of expansion

$$\frac{d\tau}{dt} = -\frac{S_n}{n} + \text{div} \vec{\phi}$$

Antisymmetric part

Vector of rotation

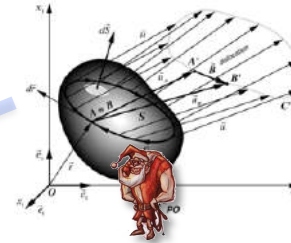
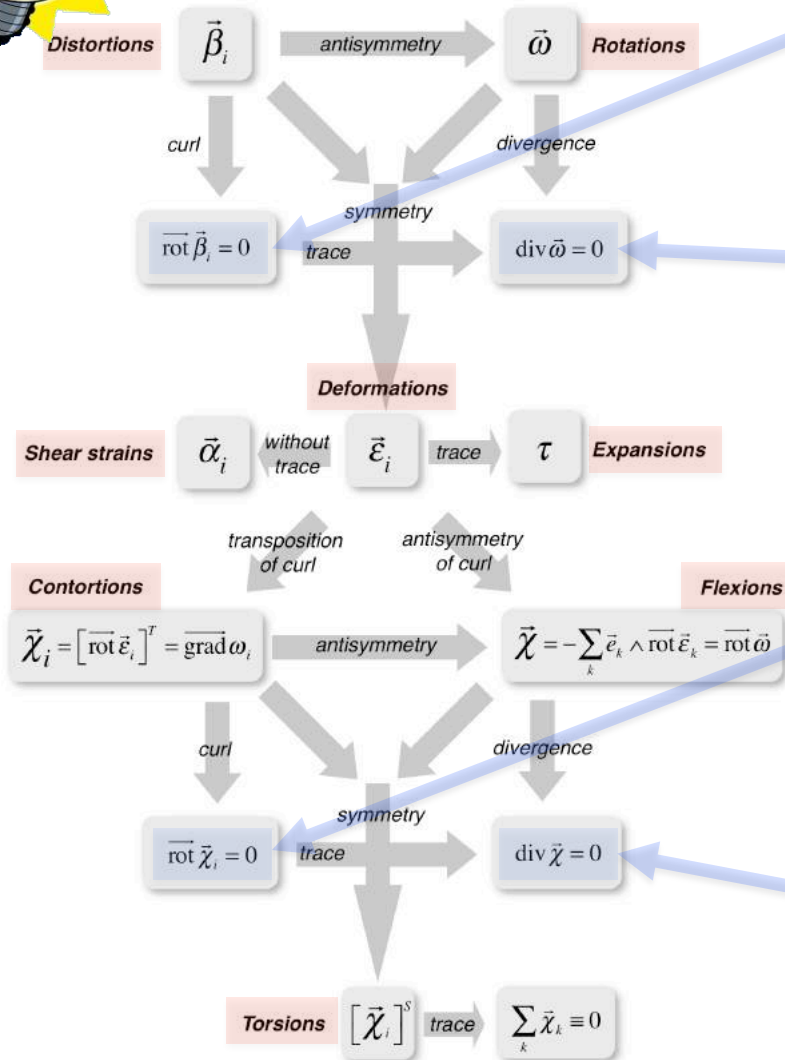
$$\frac{d\vec{\omega}}{dt} = \frac{1}{2} \overline{\text{rot}} \vec{\phi}$$



Geometrocompatibility equations and contortion tensors in Euler coordinates

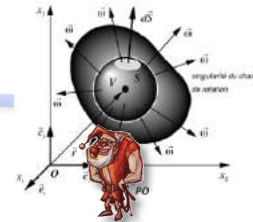


Distortion and contortion tensors and geometrocompatibility equations



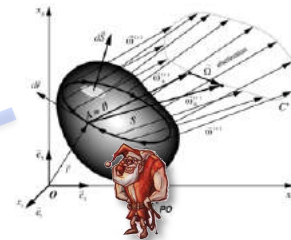
Continuity of the displacement field

$$\oint_C d\vec{u} = -\sum_k \vec{e}_k \iint_S \text{rot } \vec{\beta}_k d\vec{S} = 0 \quad ; \quad \forall C$$



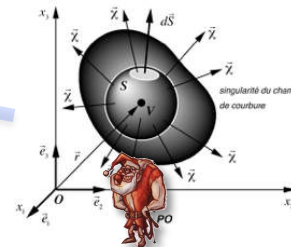
No singularity by divergence of the rotation field

$$\iint_S \omega_{\perp} dS = \iint_S \vec{\omega} d\vec{S} = \iiint_V \text{div } \vec{\omega} dV = 0 \quad ; \quad \forall S$$



Continuity of the rotation field associated to the deformations

$$\oint_C d\vec{\omega}^{(\epsilon)} = \sum_k \vec{e}_k \iint_S \text{rot } \vec{\chi}_k d\vec{S} = \sum_k \vec{e}_k \iint_S \text{rot } [\text{rot } \vec{\epsilon}_k]^T d\vec{S} = 0$$



No singularity by divergence of the flexion field

$$\iint_S \chi_{\perp} dS = \iint_S \vec{\chi} d\vec{S} = \iiint_V \text{div } \vec{\chi} dV = \sum_k \vec{e}_k \iint_S \text{rot } \text{rot } \vec{\epsilon}_k dV = 0$$

The only three necessary physical principles in Euler coordinates



Isaac Newton
(1643-1727)

**Axiom of
newtonian
dynamics**

$$e_{cin} = \frac{1}{2} m \vec{\phi}^2$$



**Continuity principle
for the newtonian inertial mass**

$$\frac{\partial \rho}{\partial t} = S_m - \text{div}(\rho \vec{\phi} + \vec{J}_m) = S_m - \text{div}(n \vec{p}) \quad (1)$$

**Axiom of
the first principle + kinetic energy
of thermodynamics**

$$dU = \delta W + \delta Q$$

$$e_{cin} = \frac{1}{2} m \vec{\phi}^2$$



Continuity principle for the total energy

$$n \frac{du}{dt} + n \frac{de_{cin}}{dt} = S_w^{ext} - \text{div} \vec{J}_w - \text{div} \vec{J}_q - u S_n - e_{cin} S_n \quad (2)$$



Sadi Carnot
(1837-1894)

**Axiom of
the second principle
of thermodynamics**

$$dS \geq \frac{\delta Q}{T}$$



Continuity principle for the entropy

$$n \frac{ds}{dt} = S_e - \text{div} \left(\frac{\vec{J}_q}{T} \right) - s S_n \quad (3)$$

Mix all these ingredients

Geometrocompatibility

Elasticity

Selfdiffusion

Anelasticity

Geometrokinetic

Continuity principles

Plasticity

Newtonian dynamics

Viscoelasticity



Complete set of equations of spatio-temporal evolution

The complete set of equations of spatio-temporal evolution in Euler coordinates

Topological equations

Fundamental equations

Heat equation



Topology

Thermic

Dynamics

Newton equation

Diffusion

Selfdiffusion equations

Equations topologiques

$$\begin{cases} \frac{d\vec{\beta}_i}{dt} = \overline{\text{grad}} \phi_i & (1) \\ \frac{d\vec{\omega}}{dt} = \frac{1}{2} \overline{\text{rot}} \vec{\phi} & (2) \\ \frac{d\vec{\tau}}{dt} = \text{div} \vec{\phi} & (3) \end{cases} \quad \begin{cases} \overline{\text{rot}} \vec{\beta}_i = 0 & (4) \\ \text{div} \vec{\omega} = 0 & (5) \\ d/dt = \partial/\partial t + (\vec{\phi} \nabla) & (6) \\ \vec{\phi} = \vec{\phi} - \vec{\phi}_o(t) - \vec{\omega}_o(t) \wedge \vec{r} & (7) \end{cases}$$

$$\begin{cases} \vec{\beta}_i = \vec{\beta}_i^{(s)} + \vec{e}_i \wedge \vec{\omega}_o(t) = \vec{\beta}_i^{(s)} + \vec{\beta}_i^{(m)} + \vec{\beta}_i^{(p)} + \vec{e}_i \wedge \vec{\omega}_o(t) & (8) \\ \vec{\omega} = -\frac{1}{2} \sum_k \vec{e}_k \wedge \vec{\beta}_k = \vec{\omega}^{(s)} + \vec{\omega}_o(t) = \vec{\omega}^{(s)} + \vec{\omega}^{(m)} + \vec{\omega}^{(p)} + \vec{\omega}_o(t) & (9) \\ \vec{\tau} = \sum_k \vec{\beta}_k \vec{e}_k = \sum_k \vec{\beta}_k^{(s)} \vec{e}_k = \vec{\tau}^{(s)} + \vec{\tau}^{(m)} \quad (\vec{\tau}^{(m)} = 0 \text{ par hypothèse}) & (10) \\ \vec{e}_i = \vec{\beta}_i - \vec{e}_i \wedge \vec{\omega} = \vec{\beta}_i^{(s)} - \vec{e}_i \wedge \vec{\omega}^{(s)} = \vec{e}_i^{(s)} + \vec{e}_i^{(m)} & (11) \\ \vec{\alpha}_i = \vec{e}_i - \frac{1}{3} \vec{r} \vec{e}_i = \vec{\alpha}_i^{(s)} + \vec{\alpha}_i^{(m)} + \vec{\alpha}_i^{(p)} & (12) \end{cases}$$

Equations dynamique

$$n \frac{d\vec{p}}{dt} = \rho \vec{g} + \sum_k \vec{e}_k \text{div} \vec{s}_k - \frac{1}{2} \overline{\text{rot}} \vec{m} - \overline{\text{grad}} p + nm \vec{\phi}_i \frac{dC_L}{dt} - nm \vec{\phi}_L \frac{dC_L}{dt} \quad (13)$$

$$\begin{cases} n = 1/v = n_0 \exp(-\tau^a) & (14) \\ \vec{p} = m(\vec{\phi} + C_i \vec{\phi}_i - C_L \vec{\phi}_L) = m\vec{\phi} + m(C_i - C_L)\vec{\phi} + \frac{m}{n}(\vec{J}_i - \vec{J}_L) & (15) \\ \quad = [\rho \vec{\phi} + m(\vec{J}_i - \vec{J}_L)]/n & (16) \end{cases}$$

Equations de diffusion

$$\begin{cases} n \frac{dC_L}{dt} = (S_{i-L} + S_L^{(s)}) - C_L(S_L^{(s)} - S_i^{(s)}) - \text{div} \vec{J}_L & (17) \\ n \frac{dC_i}{dt} = (S_{i-L} + S_i^{(s)}) - C_i(S_L^{(s)} - S_i^{(s)}) - \text{div} \vec{J}_i & (18) \\ \vec{J}_L = nC_L \Delta \vec{\phi}_L = nC_L(\vec{\phi}_L - \vec{\phi}) = nC_L(\vec{\phi}_L - \vec{\phi}) & (19) \\ \vec{J}_i = nC_i \Delta \vec{\phi}_i = nC_i(\vec{\phi}_i - \vec{\phi}) = nC_i(\vec{\phi}_i - \vec{\phi}) & (20) \end{cases}$$

Equations thermiques

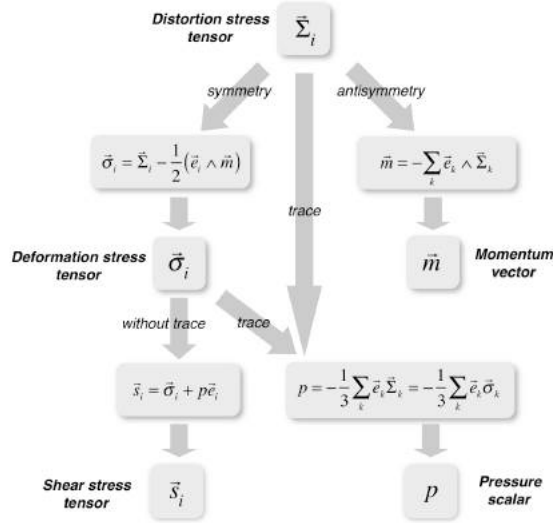
$$nT \frac{ds}{dt} = -(\mu_L^* + \mu_i^*) S_{i-L} - (\mu_L^* + h^*) S_L^{(s)} - (\mu_i^* - h^*) S_i^{(s)} + T \vec{J}_L \vec{X}_L \quad (21)$$

$$+ T \vec{J}_i \vec{X}_i + \vec{s}_k \text{div} \frac{d\vec{\beta}_k^{(m)}}{dt} + \vec{m}^{(s)} \frac{d\vec{\omega}^{(m)}}{dt} + \vec{s}_k \frac{d\vec{\beta}_k^{(s)}}{dt} + \vec{m} \frac{d\vec{\omega}^{(s)}}{dt} - \text{div} \vec{J}_q$$

$$\begin{cases} \mu_L^* = \mu_L - \frac{1}{2} m(\vec{\phi}_L^2 - 2\Delta \vec{\phi}_L^2) & (22) \\ \mu_i^* = \mu_i + \frac{1}{2} m \vec{\phi}_i^2 & (23) \\ \vec{X}_q = \overline{\text{grad}} \frac{1}{T} & (24) \\ \vec{X}_L = \frac{1}{T} \left(-\overline{\text{grad}} \mu_L^* + m \frac{d}{dt} (\vec{\phi}_L - 2\Delta \vec{\phi}_L) - m \vec{g} \right) & (25) \\ \vec{X}_i = \frac{1}{T} \left(-\overline{\text{grad}} \mu_i^* - m \frac{d}{dt} (\vec{\phi}_i) + m \vec{g} \right) & (26) \\ h^* = f + Ts + pv + \frac{1}{2} m \vec{\phi}^2 - \mu_L C_L - \mu_i C_i & (27) \end{cases}$$


The complete set of equations of spatio-temporal evolution in Euler coordinates

Phenomenological equations : state equations and dissipative equations



Distortion stress tensors



State function and equations

Fonctions et équations d'état

$$f = f(\alpha_{ij}^{el}, \alpha_{ij}^{an}, \omega_k^{el}, \omega_k^{an}, \tau^{el}, C_L, C_I, T) \quad (28)$$

$$s_{ij} = \frac{n}{2} \left(\frac{\partial f}{\partial \alpha_{ij}^{el}} + \frac{\partial f}{\partial \alpha_{ij}^{an}} \right) - \frac{n}{3} \delta_{ij} \sum_k \frac{\partial f}{\partial \alpha_{kk}^{el}} = s_{ij}(\alpha_{mn}^{el}, \omega_n^{el}, \tau^{el}, \alpha_{mn}^{an}, \omega_n^{an}, C_L, C_I, T) \quad (29)$$

$$m_k = n \frac{\partial f}{\partial \omega_k^{an}} = m_k(\alpha_{mn}^{el}, \omega_n^{el}, \tau^{el}, \alpha_{mn}^{an}, \omega_n^{an}, C_L, C_I, T) \quad (30)$$

$$p = -n \frac{\partial f}{\partial \tau^{el}} = p(\alpha_{mn}^{el}, \omega_n^{el}, \tau^{el}, \alpha_{mn}^{an}, \omega_n^{an}, C_L, C_I, T) \quad (31)$$

$$s_{ij}^{dis} = \frac{n}{2} \left(\frac{\partial f}{\partial \alpha_{ij}^{el}} + \frac{\partial f}{\partial \alpha_{ij}^{an}} \right) - \frac{n}{3} \delta_{ij} \sum_k \frac{\partial f}{\partial \alpha_{kk}^{el}} = s_{ij}^{dis}(\alpha_{mn}^{el}, \omega_n^{el}, \tau^{el}, \alpha_{mn}^{an}, \omega_n^{an}, C_L, C_I, T) \quad (32)$$

$$m_k^{dis} = n \frac{\partial f}{\partial \omega_k^{an}} = m_k^{dis}(\alpha_{mn}^{el}, \omega_n^{el}, \tau^{el}, \alpha_{mn}^{an}, \omega_n^{an}, C_L, C_I, T) \quad (33)$$

Elasticity

Anelasticity

State equations

Selfdiffusion

Anelasticity

Plasticity

$$s = -\frac{\partial f}{\partial T} = s(\alpha_{mn}^{el}, \omega_n^{el}, \tau^{el}, \alpha_{mn}^{an}, \omega_n^{an}, C_L, C_I, T) \quad (34)$$

$$\mu_L = \frac{\partial f}{\partial C_L} = \mu_L(\alpha_{mn}^{el}, \omega_n^{el}, \tau^{el}, \alpha_{mn}^{an}, \omega_n^{an}, C_L, C_I, T) \quad (35)$$

$$\mu_I = \frac{\partial f}{\partial C_I} = \mu_I(\alpha_{mn}^{el}, \omega_n^{el}, \tau^{el}, \alpha_{mn}^{an}, \omega_n^{an}, C_L, C_I, T) \quad (36)$$

Thermicity

Selfdiffusivity

Equations de dissipation: auto-diffusion et création-annihilation de paires

$$\bar{J}_q = \bar{J}_q(\bar{X}_q, \bar{X}_L, \bar{X}_I, n, T, C_L, C_I, \dots) \quad (37)$$

$$\bar{J}_L = \bar{J}_L(\bar{X}_q, \bar{X}_L, \bar{X}_I, n, T, C_L, C_I, \dots) \quad (38)$$

$$\bar{J}_I = \bar{J}_I(\bar{X}_q, \bar{X}_L, \bar{X}_I, n, T, C_L, C_I, \dots) \quad (39)$$

$$S_{I-L} = S_{I-L}(\mu_L^*, \mu_I^*, n, T, C_L, C_I, \dots) \quad (40)$$

+ Creation-annihilation of point defect pairs

Equations de dissipation: anélasticité

$$\bar{s}_i = \bar{s}_i^{cons}(\bar{\alpha}_m^{an}, v, T, \dots) + \bar{s}_i^{dis} \left(\frac{d\bar{\alpha}_m^{an}}{dt}, v, T, \dots \right) \quad (41)$$

$$\bar{m} = \bar{m}^{cons}(\bar{\omega}^{an}, v, T, \dots) + \bar{m}^{dis} \left(\frac{d\bar{\omega}^{an}}{dt}, v, T, \dots \right) \quad (42)$$

Equations de dissipation: plasticité

$$\frac{d\tau^{pl}}{dt} = \frac{S_n}{n} = \frac{1}{n} (S_L^{pl} - S_I^{pl}) \quad (43)$$

$$S_L^{pl} = S_L^{pl}[(\mu_L^* + g^*), v, T, C_L, C_I, \dots] \quad (44)$$

$$S_I^{pl} = S_I^{pl}[(\mu_I^* - g^*), v, T, C_L, C_I, \dots] \quad (45)$$

$$g^* = f + pv + m\bar{\phi}^2 / 2 - \mu_L C_L - \mu_I C_I \quad (46)$$

$$\frac{d\bar{\alpha}_i^{pl}}{dt} = \frac{d\bar{\alpha}_i^{pl}}{dt}(\bar{s}_m, v, T, \dots) \quad (47)$$

$$\frac{d\bar{\omega}^{pl}}{dt} = \frac{d\bar{\omega}^{pl}}{dt}(\bar{m}, v, T, \dots) \quad (48)$$

+ Creation-annihilation of point defects

The complete set of equations of spatio-temporal evolution in Euler coordinates

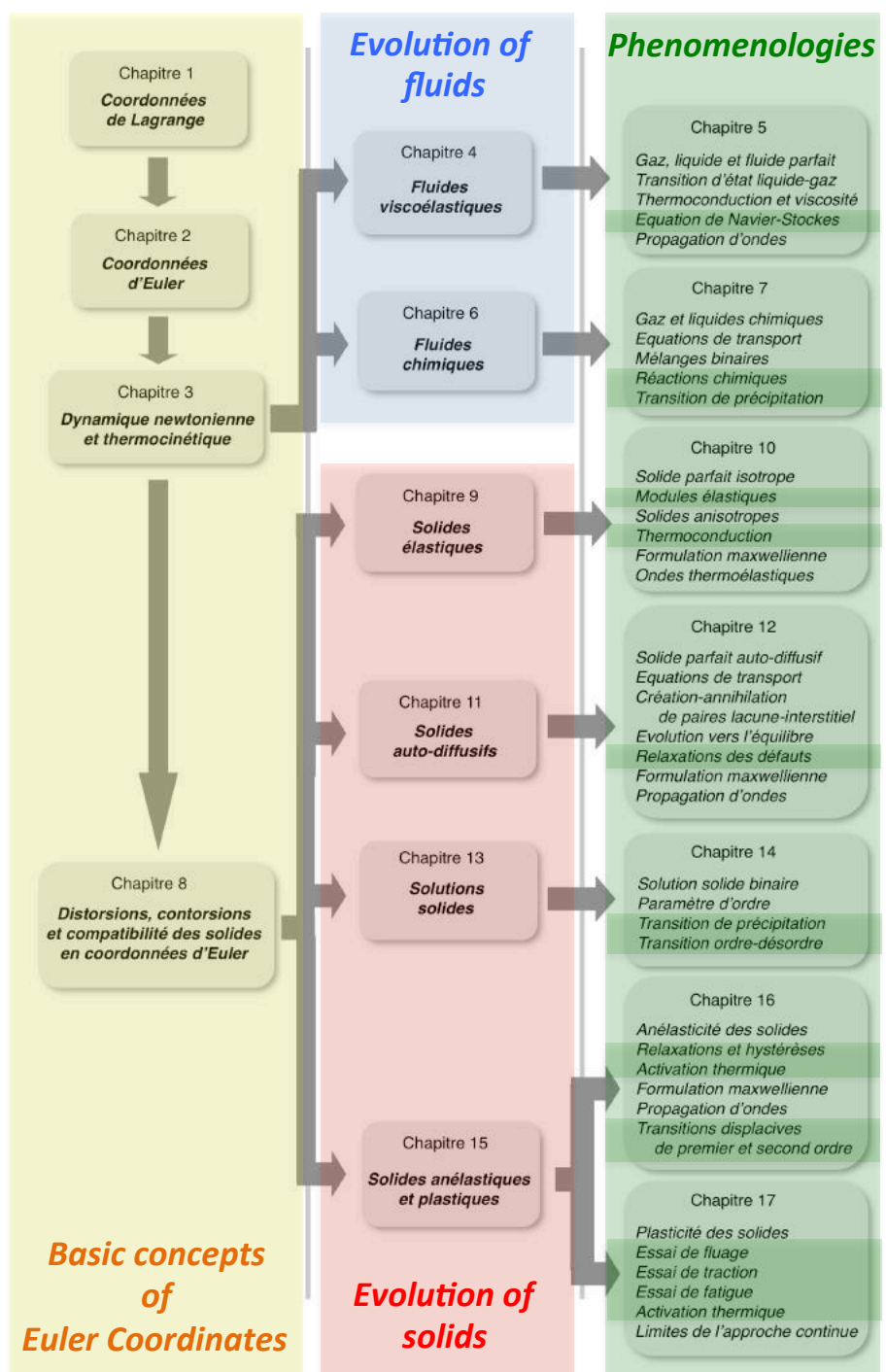
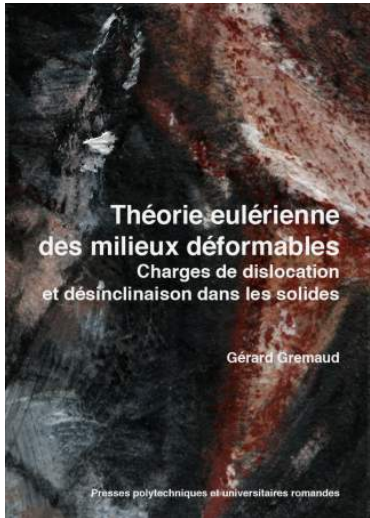
Additional equations

<p style="text-align: center;"><i>Continuité de la masse</i></p> $\frac{\partial \rho}{\partial t} = -\text{div}[\rho \vec{\phi} + m(\vec{J}_I - \vec{J}_L)] = -\text{div}(n\vec{p}) \quad \text{dans } Q_{\xi_1 \xi_2 \xi_3} \quad (49)$	<p style="color: blue; font-weight: bold; transform: rotate(-45deg);">Inertial mass continuity</p> <p style="color: blue; font-weight: bold; transform: rotate(-45deg);">Work flux Surface forces</p> <p style="color: blue; font-weight: bold; transform: rotate(-45deg);">Entropy source</p> <p style="color: blue; font-weight: bold; transform: rotate(-45deg);">Energy balance</p>
<p style="text-align: center;"><i>Flux de travail et force de surface</i></p> $\left\{ \begin{array}{l} \vec{J}_w = \mu_L^* \vec{J}_L + \mu_I^* \vec{J}_I - \phi_k \bar{s}_k - \frac{1}{2}(\vec{\phi} \wedge \vec{m}) + p \vec{\phi} \quad (50) \\ \vec{F}_s = \sum_k \bar{e}_k (\bar{s}_k \vec{n}) + \frac{1}{2}(\vec{m} \wedge \vec{n}) - \vec{n} p \quad (51) \end{array} \right.$	
<p style="text-align: center;"><i>Source d'entropie</i></p> $S_e = -\frac{1}{T}(\mu_L^* + \mu_I^*)S_{I-L} - \frac{1}{T}(\mu_L^* + g^*)S_L^{pl} - \frac{1}{T}(\mu_I^* - g^*)S_I^{pl} \\ + \vec{J}_L \bar{X}_L + \vec{J}_I \bar{X}_I + \frac{1}{T} \left(\bar{s}_k^{dis} \frac{d\bar{\beta}_k^{an}}{dt} + \bar{m}^{dis} \frac{d\bar{\omega}^{an}}{dt} + \bar{s}_k \frac{d\bar{\beta}_k^{pl}}{dt} + \bar{m} \frac{d\bar{\omega}^{pl}}{dt} \right) \\ + \vec{J}_q \overline{\text{grad}} \left(\frac{1}{T} \right) \quad (52)$	
<p style="text-align: center;"><i>Bilan énergétique</i></p> $n\vec{\phi} \left(\frac{d\bar{p}}{dt} - m\vec{\phi}_I \frac{dC_I}{dt} + m\vec{\phi}_L \frac{dC_L}{dt} \right) + \bar{s}_k \frac{d\bar{\beta}_k}{dt} + \bar{m} \frac{d\bar{\omega}}{dt} - p \frac{d\tau}{dt} \\ = \rho \vec{g} \vec{\phi} - \text{div} \left[-\phi_k \bar{s}_k - \frac{1}{2}(\vec{\phi} \wedge \vec{m}) + p \vec{\phi} \right] \quad (53)$	



Poynting
vector

IB - Application: phenomenologies of usual fluids and solids



IC – Dislocation and disclination charges

What's a line of topological singularity?

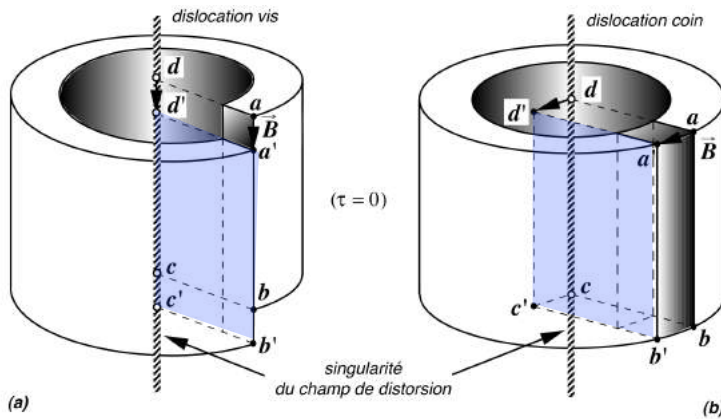


Vito Volterra
(1860-1940)

Singularity line
by translation

Screw dislocation

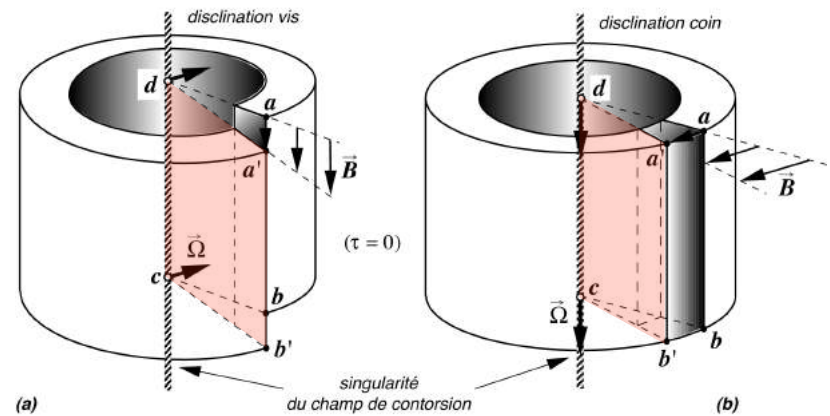
Edge dislocation



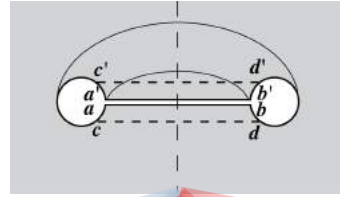
Singularity line
by rotation

Twist disclination

Wedge disclination



What's a loop of topological singularity?

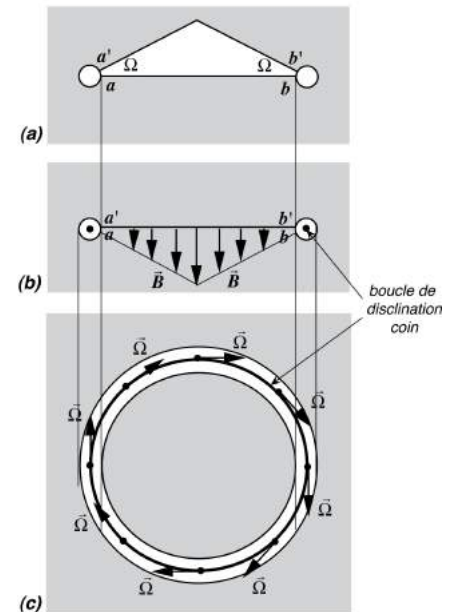
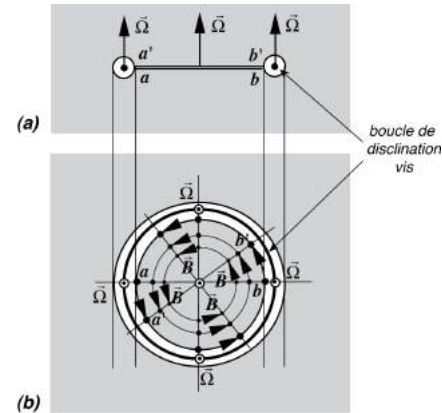
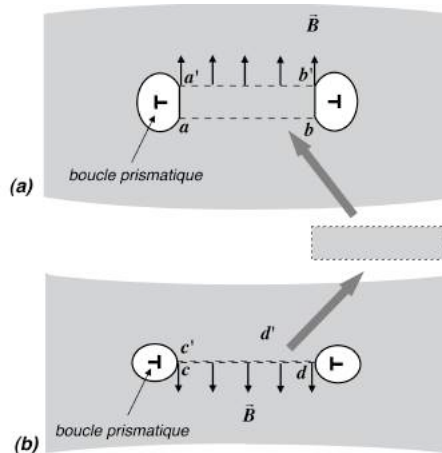
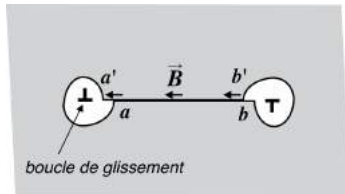


**Mixed dislocation loop
by translation**

**Edge dislocation loop
by material
addition or subtraction**

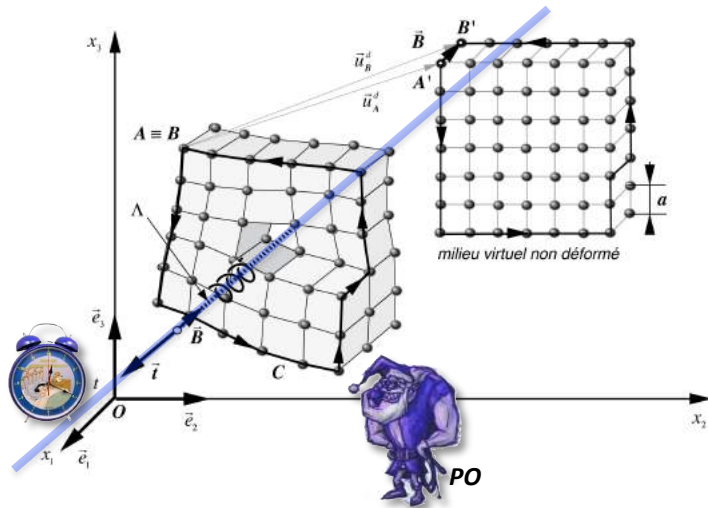
**Twist disclination loop
by rotation**

**Wedge disclination loop
by material
addition or subtraction**

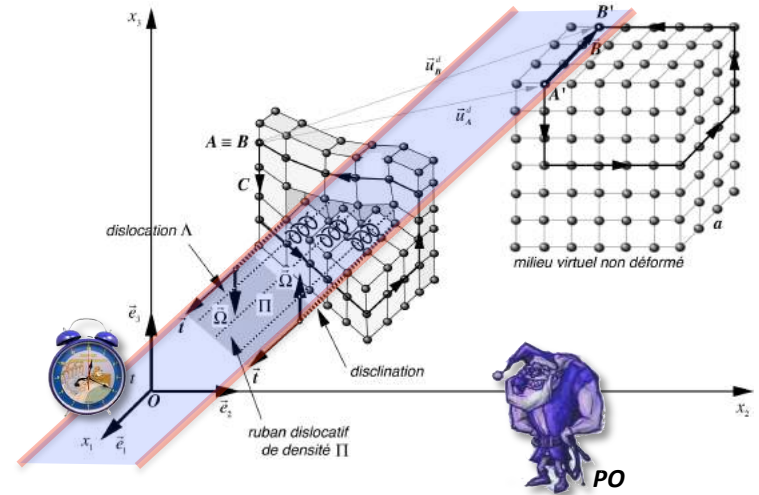


Quantification of the topological singularities as strings or membranes in solid lattices

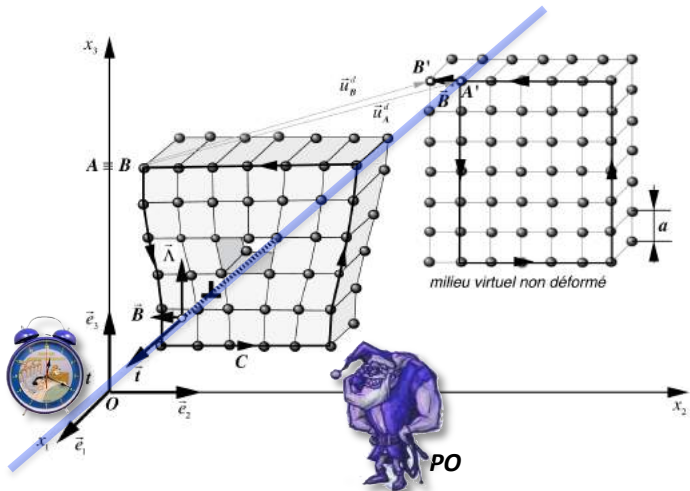
Screw dislocation string



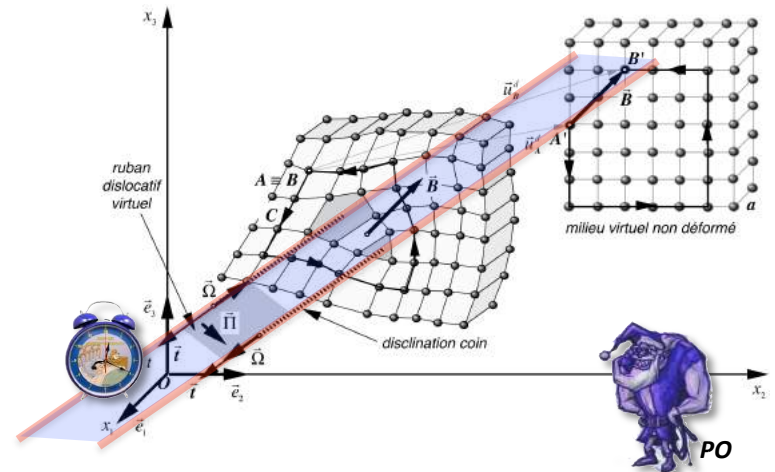
Srew dislocation membrane limited by two twist disclination strings



Edge dislocation string

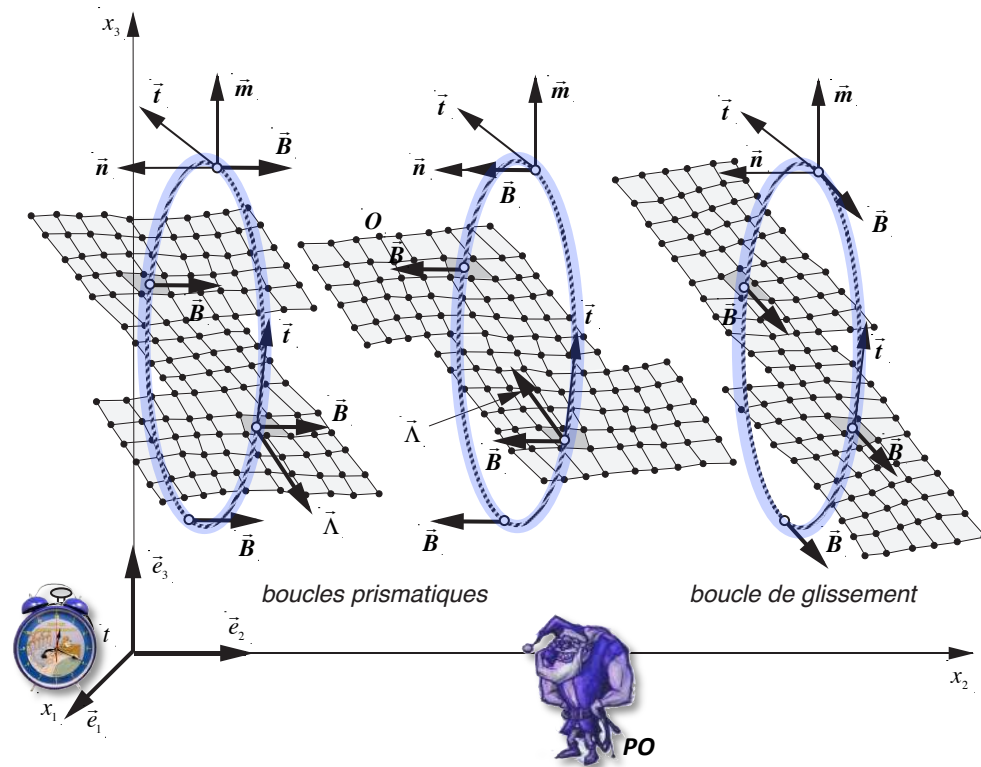


Edge dislocation membrane limited by two wedge disclination strings

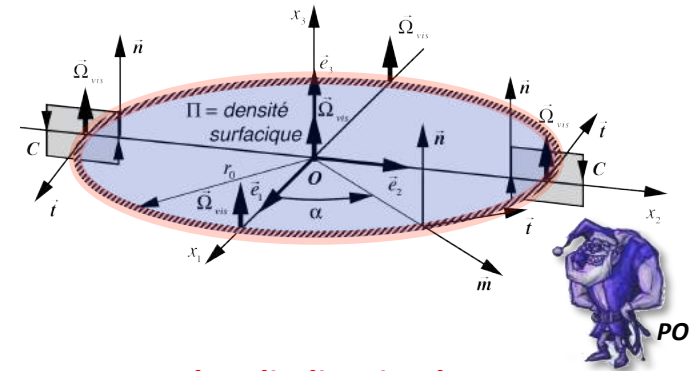


Quantification of the topological singularities as loops and membranes in solid lattices

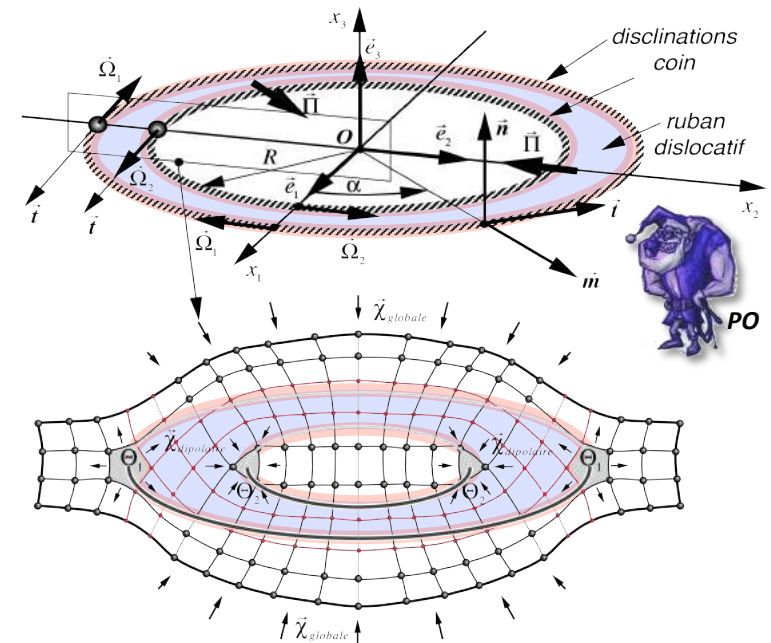
Edge and mixed dislocation loops



Twist disclination loop with screw dislocation membrane



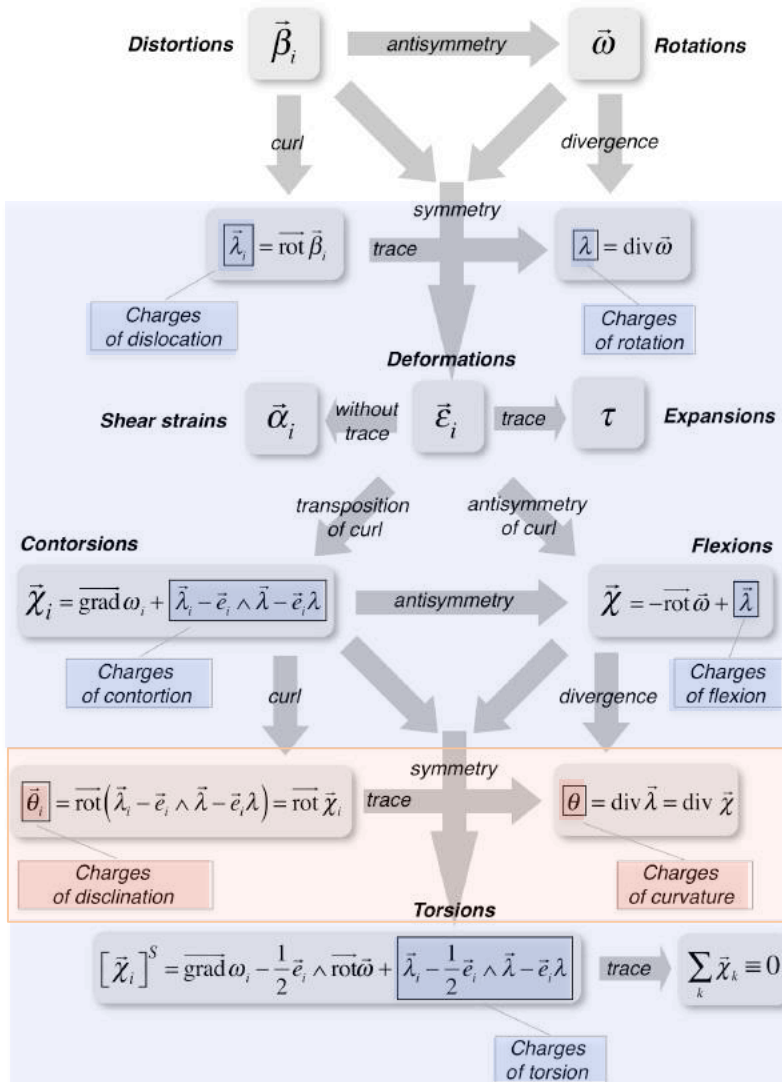
Wedge disclination loop with edge dislocation membrane



Incompatibility charges

associated to the topological singularities (strings, membranes and loops) of a solid lattice

Incompatibility equations and charge tensors



Charges of first order

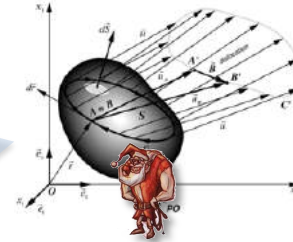
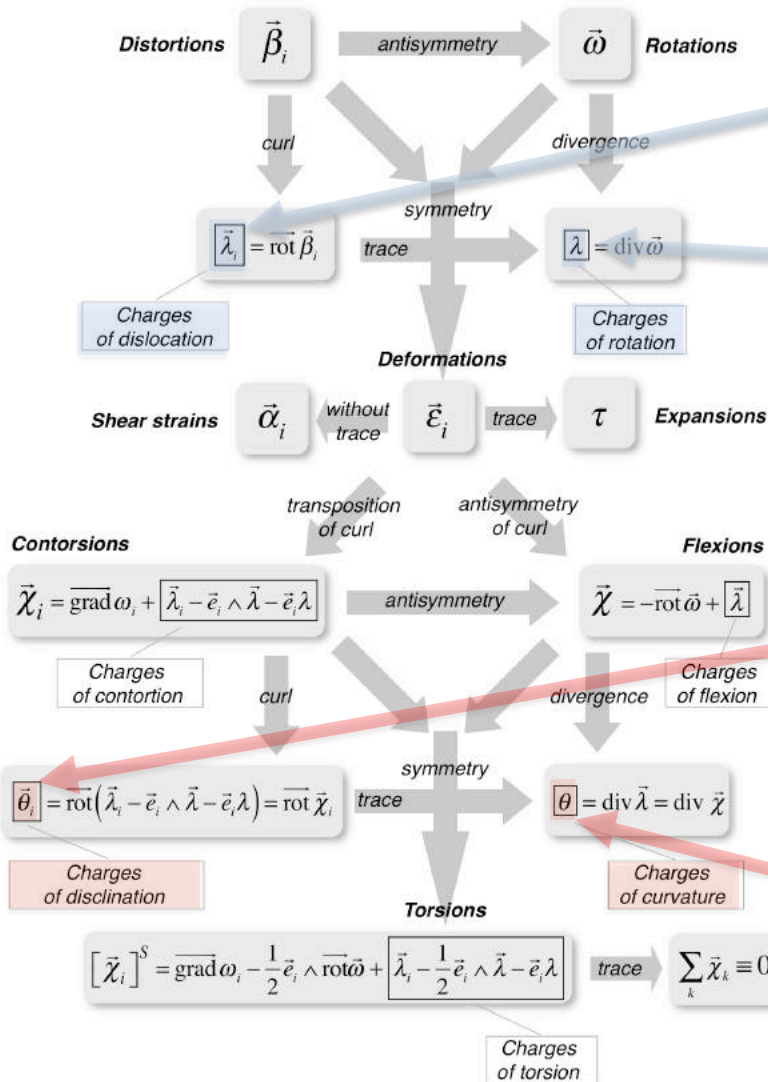


Charges of second order

Incompatibility charges

associated to the topological singularities (strings, membranes and loops) of a solid lattice

Incompatibility equations and charge tensors

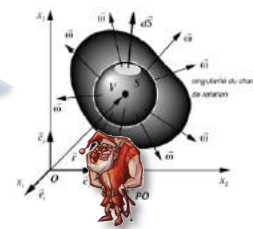


Discontinuity of the displacement field

Dislocation Burgers vector

$$\vec{B} = \vec{u}_B - \vec{u}_A = \oint_C \delta \vec{u} = - \sum_k \vec{e}_k \iint_S \text{rot } \vec{\beta}_k d\vec{S}$$

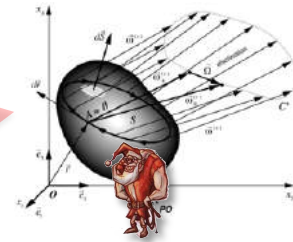
$$= - \sum_k \vec{e}_k \iint_S \vec{\lambda}_k d\vec{S} \neq 0$$



Singularity of the divergence of the rotation field

$$Q_\lambda = \oint_S \vec{\omega} d\vec{S} = \iiint_V \text{div } \vec{\omega} dV = \iiint_V \vec{\lambda} dV \neq 0$$

Macroscopic scalar charge of rotation

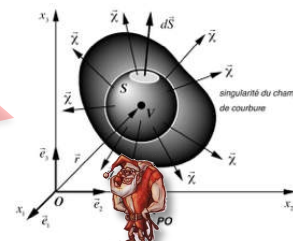


Discontinuity of the rotation field associated to the deformations

Disclination Franck vector

$$\vec{\Omega} = \oint_C \delta \vec{\omega}^\epsilon = \sum_k \vec{e}_k \iint_S \text{rot } \vec{\chi}_k d\vec{S} = \sum_k \vec{e}_k \iint_S \vec{\theta}_i d\vec{S}$$

$$= \sum_k \vec{e}_k \oint_C (\vec{\lambda}_k - \vec{e}_k \wedge \vec{\lambda} - \vec{e}_k \lambda) d\vec{r} \neq 0$$



Singularity of the divergence of the flexion field

$$Q_\theta = \oint_S \vec{\chi} d\vec{S} = \iiint_V \text{div } \vec{\chi} dV = \iiint_V \vec{\theta} dV \neq 0$$

Macroscopic scalar charge of flexion

The complete set of equations of spatio-temporal evolution of a charged lattice

Geometrokinetic

Geometrocompatibility

Continuity principles

Newtonian dynamics

Elasticity

Anelasticity

Selfdiffusion



Charges associated with the topological singularities



Fundamental equations

Phenomenological equations

Tableau 20.2 - Equations fondamentales d'évolution des solides auto-diffusifs, élastiques et anélastiques, avec charges plastiques dislocaives

Equations topologiques

$$\begin{cases} \dot{J}_i = -\frac{d\beta_i}{dt} + \text{grad} \phi_i & (1) \\ J = -\frac{1}{2} \sum_i \dot{\epsilon}_i \wedge \dot{\lambda}_i = -\frac{d\hat{\omega}}{dt} + \frac{1}{2} \text{rot} \hat{\phi} & (2) \\ \frac{S_i}{n} = \sum_i \dot{\epsilon}_i \dot{\lambda}_i = -\frac{d\tau}{dt} + \text{div} \hat{\phi} & (3) \end{cases} \quad \begin{cases} \bar{\lambda} = \text{rot} \bar{\beta} \quad \text{avec} \quad \text{div} \bar{\lambda} = 0 & (4) \\ \bar{\lambda} = -\sum_i \dot{\epsilon}_i \wedge \dot{\lambda}_i = -\sum_i \dot{\epsilon}_i \wedge \text{rot} \bar{\beta}_i & (5) \\ \bar{\lambda} = \frac{1}{2} \sum_i \dot{\epsilon}_i \dot{\lambda}_i = \text{div} \hat{\omega} & (6) \end{cases}$$

Equations dynamiques

$$\begin{cases} \dot{\beta}_i = \dot{\beta}_i^{(e)} + \dot{\epsilon}_i \wedge \dot{\omega}_0(t) = \dot{\beta}_i^{(e)} + \dot{\epsilon}_i \wedge \dot{\omega}_0(t) & (7) \\ \dot{\omega} = -\frac{1}{2} \sum_i \dot{\epsilon}_i \wedge \dot{\beta}_i = \dot{\omega}^d + \dot{\omega}^m + \dot{\omega}_0(t) & (8) \\ \dot{\tau} = \sum_i \dot{\beta}_i \dot{\epsilon}_i = \sum_i \dot{\beta}_i^{(e)} \dot{\epsilon}_i = \tau^e \quad (\tau^m = 0 \text{ par hypothèse}) & (9) \\ \dot{\epsilon}_i = \dot{\beta}_i - \dot{\epsilon}_i \wedge \dot{\omega} = \dot{\beta}_i^{(e)} - \dot{\epsilon}_i \wedge \dot{\omega}^{(d)} = \dot{\epsilon}_i^e + \dot{\epsilon}_i^m & (10) \\ \dot{\alpha}_i = \dot{\epsilon}_i - \frac{1}{2} \tau \dot{\epsilon}_i = \dot{\alpha}_i^e + \dot{\alpha}_i^m & (11) \end{cases}$$

Equations de diffusion

$$\begin{cases} n \frac{dC_i}{dt} = (S_{i-1} + S_{i+1}) - C_i (S_i + S_{i+1}) - \text{div} \dot{J}_i & (18) \\ n \frac{dC_i}{dt} = (S_{i-1} + S_{i+1}) - C_i (S_i + S_{i+1}) - \text{div} \dot{J}_i & (19) \\ \dot{J}_i = n \dot{\phi}_i = n C_i (\dot{\phi}_i - \dot{\phi}) = n C_i (\dot{\phi}_i - \dot{\phi}) & (20) \\ \dot{J}_i = n C_i \dot{\phi}_i = n C_i (\dot{\phi}_i - \dot{\phi}) = n C_i (\dot{\phi}_i - \dot{\phi}) & (21) \end{cases}$$

Equations thermiques

$$nT \frac{d\alpha}{dt} = -(\mu_i^e + \mu_i^m) S_{i-1} - (\mu_i^e + \mu_i^m) S_i^e - (\mu_i^e - \mu_i^m) S_i^m + T \dot{J}_i \dot{\lambda}_i + T \dot{J}_i \dot{\lambda}_i + \dot{S}_i^e \frac{d\hat{\omega}^e}{dt} + \dot{m}_i^m \frac{d\hat{\omega}^m}{dt} + \dot{S}_i^m \dot{J}_i + \dot{m}_i \dot{J}_i - \text{div} \dot{J}_i \quad (22)$$

Equations liées aux charges

$$\begin{cases} \frac{d\bar{\lambda}}{dt} = \dot{S}_i^{(e)} - (\nabla \cdot \bar{\lambda}) \dot{S}_i^{(e)} - \text{rot}(\nabla \wedge \bar{\lambda}) = \dot{S}_i^{(e)} - \text{rot} \dot{J}_i & (23) \\ \frac{d\bar{\lambda}}{dt} = \dot{S}_i^{(d)} - (\nabla \cdot \bar{\lambda}) \dot{S}_i^{(d)} + \text{rot}(\nabla \wedge \bar{\lambda}) - \nabla \text{div} \bar{\lambda} = \dot{S}_i^{(d)} - 2 \text{rot} \dot{J}_i - \nabla \hat{\rho} & (24) \\ \frac{d\bar{\lambda}}{dt} = \dot{S}_i^{(m)} - (\nabla \cdot \bar{\lambda}) \dot{S}_i^{(m)} - \text{div}(\lambda \bar{V}) = \dot{S}_i^{(m)} - \hat{\rho} & (25) \end{cases}$$

Equations de diffusion

$$\begin{cases} \dot{J}_i = \dot{\lambda}_i \wedge \dot{\lambda}_i & (30) \\ \dot{J}_i = \dot{\lambda}_i \wedge \dot{\lambda}_i + \lambda \dot{\omega} + \frac{1}{2} (\dot{\lambda}_i \wedge \dot{\lambda}_i) & (31) \\ \dot{J}_i = \dot{\lambda}_i \wedge \dot{\lambda}_i + \lambda \dot{\omega} + \frac{1}{2} (\dot{\lambda}_i \wedge \dot{\lambda}_i) & (32) \\ \dot{S}_i^{(e)} = -\sum_i \dot{\epsilon}_i \wedge \dot{S}_i^{(e)} & (33) \\ \dot{S}_i^{(d)} = \frac{1}{2} \sum_i \dot{\epsilon}_i \dot{S}_i^{(d)} & (34) \end{cases}$$

$$\dot{J}_{OK} = \sum_i (\dot{S}_i \wedge \dot{\lambda}_i) + \lambda \dot{\omega} + \frac{1}{2} (\dot{\lambda}_i \wedge \dot{\lambda}_i) + \dot{\lambda}_i p + \nabla \wedge \bar{A} \quad (37)$$

Equations phénoménologiques d'évolution des solides auto-diffusifs, élastiques et anélastiques, avec charges plastiques dislocaives

Fonctions et équations d'état

$$f = f(\alpha_i^e, \alpha_i^m, \omega_i^e, \omega_i^m, \tau^e, C_i, C_i, T) \quad (38)$$

$$S_i = \frac{n}{2} \left(\frac{\partial f}{\partial \alpha_i^e} + \frac{\partial f}{\partial \alpha_i^m} \right) - \frac{n}{3} \delta_i \sum_j \frac{\partial f}{\partial \alpha_j^e} = S_i(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T) \quad (39)$$

$$m_i = n \frac{\partial f}{\partial \omega_i^e} = m_i(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T) \quad (40)$$

$$p = -n \frac{\partial f}{\partial \tau} = p(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T, \tau) \quad (41)$$

$$S_i^e = \frac{n}{2} \left(\frac{\partial f}{\partial \alpha_i^e} + \frac{\partial f}{\partial \alpha_i^m} \right) - \frac{n}{3} \delta_i \sum_j \frac{\partial f}{\partial \alpha_j^e} = S_i^e(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T) \quad (42)$$

$$m_i^m = n \frac{\partial f}{\partial \omega_i^m} = m_i^m(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T) \quad (43)$$

$$s = \frac{\partial f}{\partial T} = s(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T) \quad (44)$$

$$\mu_i = \frac{\partial f}{\partial C_i} = \mu_i(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T) \quad (45)$$

$$\mu_i = \frac{\partial f}{\partial C_i} = \mu_i(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T) \quad (46)$$

Equations de dissipation: auto-diffusion et ordination, répartition de paires

$$\begin{cases} \dot{J}_i = \dot{\lambda}_i \wedge \dot{\lambda}_i + \lambda \dot{\omega} + \frac{1}{2} (\dot{\lambda}_i \wedge \dot{\lambda}_i) & (47) \\ \dot{J}_i = \dot{\lambda}_i \wedge \dot{\lambda}_i + \lambda \dot{\omega} + \frac{1}{2} (\dot{\lambda}_i \wedge \dot{\lambda}_i) & (48) \\ \dot{J}_i = \dot{\lambda}_i \wedge \dot{\lambda}_i + \lambda \dot{\omega} + \frac{1}{2} (\dot{\lambda}_i \wedge \dot{\lambda}_i) & (49) \\ \dot{J}_i = \dot{\lambda}_i \wedge \dot{\lambda}_i + \lambda \dot{\omega} + \frac{1}{2} (\dot{\lambda}_i \wedge \dot{\lambda}_i) & (50) \end{cases}$$

Equations de dissipation: anélasticité

$$\begin{cases} S_i = \dot{S}_i^e + \frac{1}{2} (\dot{\omega}_i^e + \dot{\omega}_i^m) + S_i^e(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T) & (51) \\ \dot{m} = \dot{m}^e + \frac{1}{2} (\dot{\omega}_i^e + \dot{\omega}_i^m) + \dot{m}^m(\alpha_i^e, \omega_i^e, \tau^e, \alpha_i^m, \omega_i^m, C_i, C_i, T) & (52) \end{cases}$$

Equations de dissipation: flux de charges plastiques dissipatives

$$\begin{cases} \dot{J}_i = \dot{\lambda}_i \wedge \dot{\lambda}_i + \lambda \dot{\omega} + \frac{1}{2} (\dot{\lambda}_i \wedge \dot{\lambda}_i) & (53) \\ \dot{J} = -\frac{1}{2} \sum_i \dot{\epsilon}_i \wedge \dot{\lambda}_i = \dot{\lambda} \dot{\omega} + \frac{1}{2} (\dot{\lambda}_i \wedge \dot{\lambda}_i) = \dot{J}(\dot{\omega}, \dot{\lambda}_i, \nu, T, \dots) & (54) \\ \frac{S_i}{n} = \sum_i \dot{\epsilon}_i \dot{\lambda}_i = -\dot{\lambda} \dot{\omega} = \frac{1}{n} (S_i^e - S_i^m) & (55) \\ S_i^e = S_i^e[(\mu_i^e + g^e), p, \dot{\lambda}_i, \nu, C_i, C_i, \dots] & (56) \\ S_i^m = S_i^m[(\mu_i^m + g^m), p, \dot{\lambda}_i, \nu, C_i, C_i, \dots] & (57) \\ g^e = f + p\nu + \dot{\omega} - \mu_i C_i & (58) \end{cases}$$

Equations de dissipation: sources de charges plastiques dissipatives

$$\begin{cases} \dot{S}_i^{(e)} = \dot{S}_i^{(e)}(\dots) & (59) \\ \dot{S}_i^{(d)} = \dot{S}_i^{(d)}(\dots) & (60) \\ \dot{S}_i^{(m)} = \dot{S}_i^{(m)}(\dots) & (61) \end{cases}$$

Equations additionnelles d'évolution

Continuité de la masse

$$\frac{\partial \rho}{\partial t} = -\text{div}[\rho \dot{\omega} + m(\dot{J}_i - \dot{J}_i)] = -\text{div}(\dot{\omega} p) \quad \text{dans } Q \cap \partial \Omega_i \quad (62)$$

Flux de travail et force de surface

$$\begin{cases} \dot{J}_i = \mu_i \dot{J}_i + \mu_i \dot{J}_i - \dot{\omega}_i \dot{\lambda}_i - \frac{1}{2} (\dot{\phi}_i \wedge \dot{m}) + \dot{\rho} \dot{\phi} & (63) \\ \dot{F}_i = \sum_i \dot{\epsilon}_i (\dot{S}_i \dot{\lambda}_i) + \frac{1}{2} (\dot{m} \wedge \dot{h}) - \dot{h} p & (64) \end{cases}$$

Source d'entropie

$$S_i = -\frac{1}{T} (\mu_i^e + \mu_i^m) S_{i-1} - \frac{1}{T} (\mu_i^e + \mu_i^m) S_i - \frac{1}{T} (\mu_i^e - \mu_i^m) S_i^e + \dot{J}_i \dot{\lambda}_i + \dot{J}_i \dot{\lambda}_i + \frac{1}{T} \left(\frac{d\hat{\omega}^e}{dt} + \dot{S}_i \dot{J}_i + \dot{m} \dot{J}_i \right) + \dot{S}_i \text{grad} \left(\frac{1}{T} \right) \quad (65)$$

Bilan énergétique

$$\begin{cases} \dot{m} \left(\frac{d\hat{\omega}}{dt} - m \dot{\omega} \right) \frac{dC_i}{dt} + m \dot{\omega}_2 \frac{dC_i}{dt} + \left(\dot{S}_i \frac{d\hat{\omega}}{dt} + \dot{m} \frac{d\hat{\omega}}{dt} - p \frac{d\tau}{dt} \right) + \left(\dot{S}_i \dot{J}_i + \dot{m} \dot{J}_i - p \frac{S_i}{n} \right) = \rho \dot{\omega} - \text{div} \left[-\dot{\phi}_i \dot{S}_i - \frac{1}{2} (\dot{\phi}_i \wedge \dot{m}) + \dot{\rho} \dot{\phi} \right] & (66) \end{cases}$$

Topology

Dynamics

Selfdiffusion

Thermics

Charges due to the topological singularities

State equations

Selfdiffusion

Anelasticity

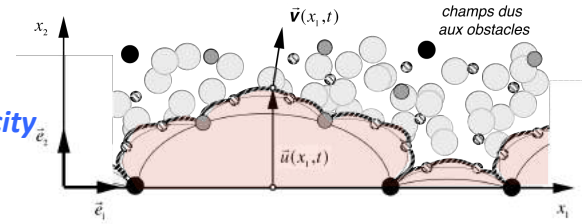
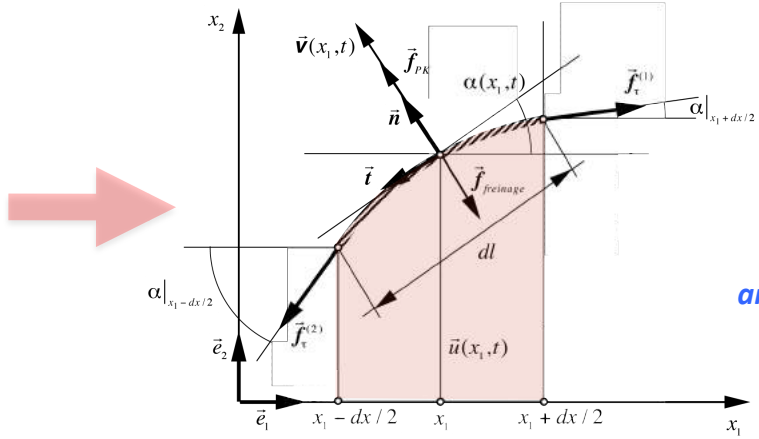
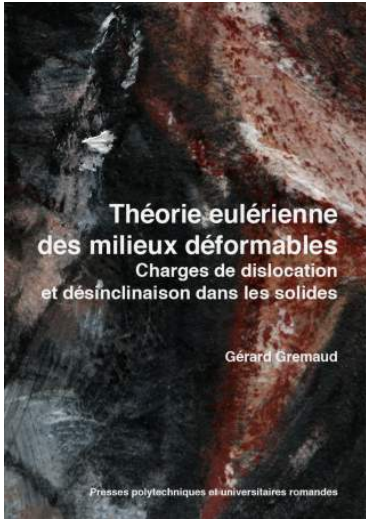
Flux and sources of charges

Additional equations

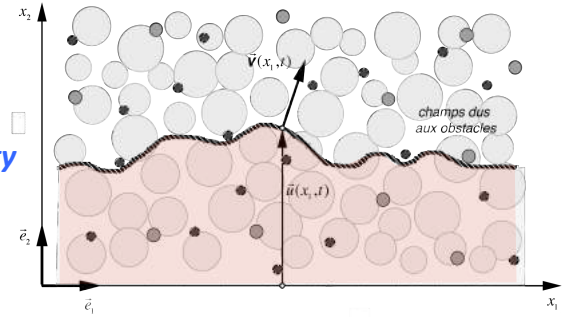
Additional equations

I D - Application: elements of dislocation theory in usual solids

String model of a dislocation line



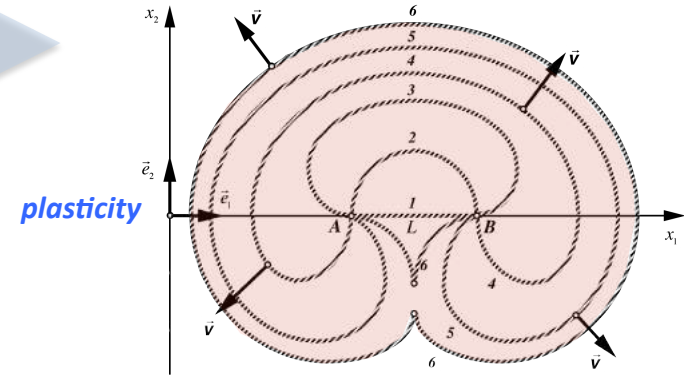
anelasticity



plasticity

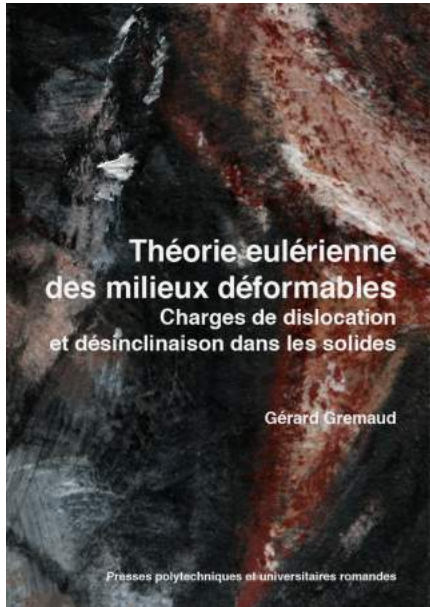
$$\left(M_0 \frac{\partial^2 u}{\partial t^2} + B_f \frac{\partial u}{\partial t} \right) \sqrt{1 + (\partial u / \partial x_1)^2} - \frac{\partial}{\partial x_1} \left[\tau \frac{\partial u}{\partial x_1} / \sqrt{1 + (\partial u / \partial x_1)^2} \right]$$

$$= B s_{23} + \sum_{n=1}^N f_n(x_1, u(x_1, t)) + F_{fluctuation}(x_1, u(x_1, t), t)$$



plasticity

Other consequences



Relativistic dynamics
of the charges

Maxwell equations
and
Lorentz force
at constant volumic expansion

Interactions
of electrical type
and
of gravitational type
between charges

String model
of the dislocation line

+

Absence of particles
analogue to magnetic monopoles

Possible solution of the famous paradox
of the electron field energy

Existence of a small asymmetry
between curvature charges of vacancy or interstitial type

$$\begin{cases} -\frac{d(2\vec{\omega})}{dt} + \text{rot} \vec{\phi} = 2\vec{J}, \\ \text{div} (2\vec{\omega}) = (2\lambda), \end{cases} \Leftrightarrow \begin{cases} -\frac{\partial \vec{D}}{\partial t} + \text{rot} \vec{H} = \vec{j} \\ \text{div} \vec{D} = \rho \end{cases}$$

$$\begin{cases} \frac{d(n\vec{p})}{dt} = -\text{rot} \left(\frac{\vec{m}}{2} \right), \\ \text{div} (n\vec{p}) = 0 \end{cases} \Leftrightarrow \begin{cases} \frac{\partial \vec{B}}{\partial t} = -\text{rot} \vec{E} \\ \text{div} \vec{B} = 0 \end{cases}$$

$$\begin{cases} (2\vec{\omega}) = \left(\frac{1}{nk_2} \right) \left(\frac{\vec{m}}{2} \right) + 2\vec{\omega}^{an} + 2\vec{\omega}_0(t), \\ n\vec{p} = (nm) \left[\vec{\phi} + (C_I - C_L) \vec{\phi} + \left(\frac{1}{n} (\vec{J}_I - \vec{J}_L) \right) \right] \end{cases} \Leftrightarrow \begin{cases} \vec{D} = \epsilon_0 \vec{E} + \vec{P} + \vec{P}_0(t) \\ \vec{B} = \mu_0 \left[\vec{H} + (\chi^{para} + \chi^{dia}) \vec{H} + \vec{M} \right] \end{cases}$$

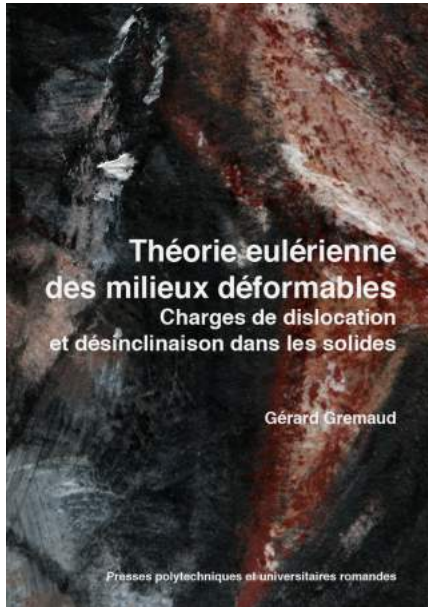
$$\begin{cases} \frac{d(2\lambda)}{dt} = -\text{div} (2\vec{J}), \end{cases} \Leftrightarrow \begin{cases} \frac{\partial \rho}{\partial t} = -\text{div} \vec{j} \end{cases}$$

$$\begin{cases} -\left(\frac{\vec{m}}{2} \right) (2\vec{J}) = \\ \vec{\phi} \frac{d(n\vec{p})}{dt} + \left(\frac{\vec{m}}{2} \right) \frac{d(2\vec{\omega})}{dt} - \text{div} \left(\vec{\phi} \wedge \left(\frac{\vec{m}}{2} \right) \right) \end{cases} \Leftrightarrow \begin{cases} -\vec{E} \cdot \vec{j} = \\ \vec{H} \frac{\partial \vec{B}}{\partial t} + \vec{E} \frac{\partial \vec{D}}{\partial t} - \text{div} (\vec{H} \wedge \vec{E}) \end{cases}$$

$$\begin{cases} c_i = \sqrt{\frac{nk_2}{nm}} = \sqrt{\frac{k_2}{m}} \end{cases} \Leftrightarrow \begin{cases} c = \sqrt{\frac{1}{\epsilon_0 \mu_0}} \end{cases}$$

$$\begin{cases} \vec{F}_{PK} = 2Q_\lambda \left(\frac{\vec{m}}{2} + \vec{v} \wedge n\vec{p} \right) \end{cases} \Leftrightarrow \begin{cases} \vec{F} = q(\vec{E} + \vec{v} \wedge \vec{B}) \end{cases}$$

Conclusion of the first part



*Relativistic dynamics
of the charges*

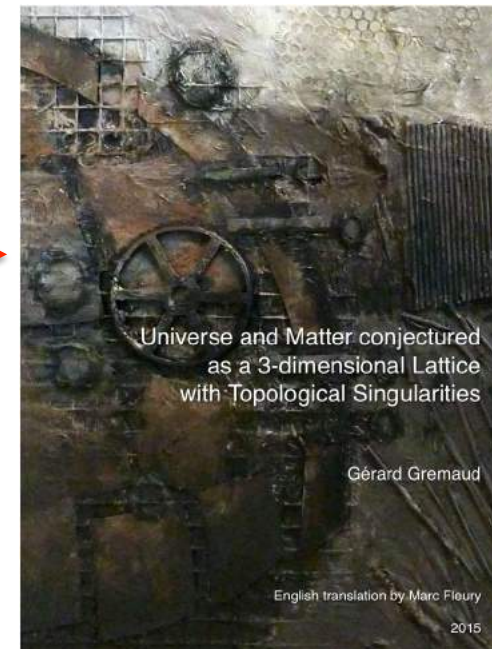
*Maxwell equations
and
Lorentz force
at constant volumic expansion*

*Interactions
of electrical type
and
of gravitational type
between charges*

*String model
of the dislocation line*

The numerous analogies which appear between the eulerian theory of deformable media and the theories of electromagnetism, gravitation, special relativity, general relativity and even standard model of elementary particles, reinforced by the absence of particles analogue to magnetic monopoles, by a possible solution of the famous paradox of electron field energy and by the existence of a small asymmetry between curvature charges of vacancy or interstitial type, are sufficiently surprising and remarkable to alert any open and curious scientific spirit!

But it is also clear that these analogies are, by far, not perfect. It is then tantalizing to analyze much more carefully these analogies and to try to find how to perfect them.



Part II – Could the universe be a 3D-lattice?

II A - The « cosmic lattice »

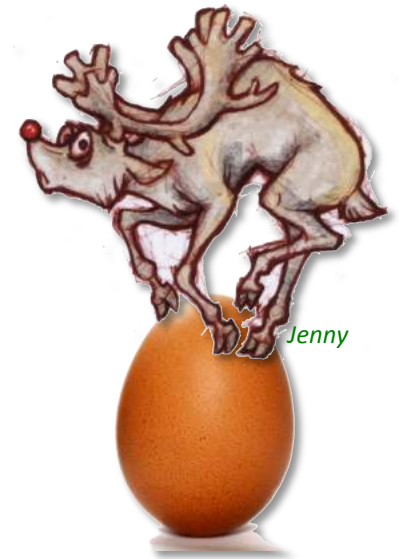
II B - Maxwell equations and special relativity

II C - Gravitation and cosmology

II D - Quantum physics and standard model of particles

II E - Some other hypothetical consequences of the cosmic lattice

Conclusion of the second part



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Amazon Press,
Charleston (USA),
2016, 664 pages
(ISBN 978-2-8399-1940-1)

II A - The « cosmic lattice »

Newton equation of usual isotropic solids

Elastic state function given per lattice site

$$f^{def} = -k_0\tau + k_1\tau^2 + k_2 \sum_i (\bar{\alpha}_i^{el})^2$$



Newton equation

$$\frac{d\vec{p}}{dt} = -2k_2 \overline{\text{rot}} \bar{\omega}^{el} - 2k_2 \sum_k (\bar{e}_k \overline{\text{grad}} \tau) \bar{\alpha}_k^{el} + \overline{\text{grad}} \left[\left(\frac{4}{3}k_2 + 2k_1(1-\tau) + k_0 \right) \tau \right] + 2k_2 \bar{\lambda}$$

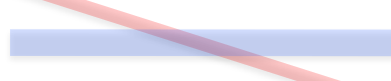
Newton equation of a very special isotropic lattice: the « cosmic lattice »

Conjecture: elastic state function given per unit volume of lattice and depending also on the elastic rotation



Analogy with general relativity:
expansion depends on
the energy stored in the lattice

$$F^{def} = -K_0\tau + K_1\tau^2 + K_2 \sum_i (\bar{\alpha}_i^{el})^2 + 2K_3(\bar{\omega}^{el})^2$$



Newton equation

$$n \frac{d\vec{p}}{dt} = -2(K_2 + K_3) \overline{\text{rot}} \bar{\omega}^{el} + \left(\frac{4}{3}K_2 + 2K_1 \right) \overline{\text{grad}} \tau + \overline{\text{grad}} \left(\underbrace{K_2 \sum_i (\bar{\alpha}_i^{el})^2 + 2K_3(\bar{\omega}^{el})^2 + K_1\tau^2 - K_0\tau}_{F^{def}} \right) + 2K_2 \bar{\lambda}$$

Circularly polarized transversal waves and longitudinal « local fluctuations »

Newton equation of the cosmic lattice

$$n \frac{d\vec{p}}{dt} = -2(K_2 + K_3) \overrightarrow{\text{rot}} \vec{\omega}^{el} + \left(\frac{4}{3} K_2 + 2K_1 \right) \overrightarrow{\text{grad}} \tau + \overrightarrow{\text{grad}} \left(\underbrace{K_2 \sum_i (\vec{\alpha}_i^{el})^2 + 2K_3 (\vec{\omega}^{el})^2 + K_1 \tau^2 - K_0 \tau}_{F^{def}} \right) + 2K_2 \vec{\lambda}$$



Analogy with
the circular polarization
of the photons in quantum physics



Conjectures:

$$\begin{cases} K_2 + K_3 > 0 \\ \tau_0 < \tau_{0cr} = \frac{K_0}{2K_1} - \frac{2K_2}{3K_1} - 1 \end{cases}$$



1/ Analogy with the absence
of longitudinal waves
in general relativity

2/ Analogy with the vacuum fluctuations
in quantum physics

Purely transversal waves are necessarily
circularly polarized

$$c_i = \frac{\omega}{k_i} \equiv \sqrt{\frac{K_2 + K_3}{mn}} = e^{\tau_0/2} \sqrt{\frac{K_2 + K_3}{mn_0}}$$

(linearly polarized transversal waves
are necessarily coupled with longitudinal wavelets)

$$\text{if } \tau_0 > \tau_{0cr} = \frac{K_0}{2K_1} - \frac{2K_2}{3K_1} - 1$$

Pure longitudinal waves can exist

$$c_i \equiv \sqrt{\frac{1}{mn} \left[\frac{4}{3} K_2 + 2K_1 (1 + \tau_0) - K_0 \right]} = e^{\tau_0/2} \sqrt{\frac{1}{mn_0} \left[\frac{4}{3} K_2 + 2K_1 (1 + \tau_0) - K_0 \right]}$$

$$\text{if } \tau_0 < \tau_{0cr} = \frac{K_0}{2K_1} - \frac{2K_2}{3K_1} - 1$$

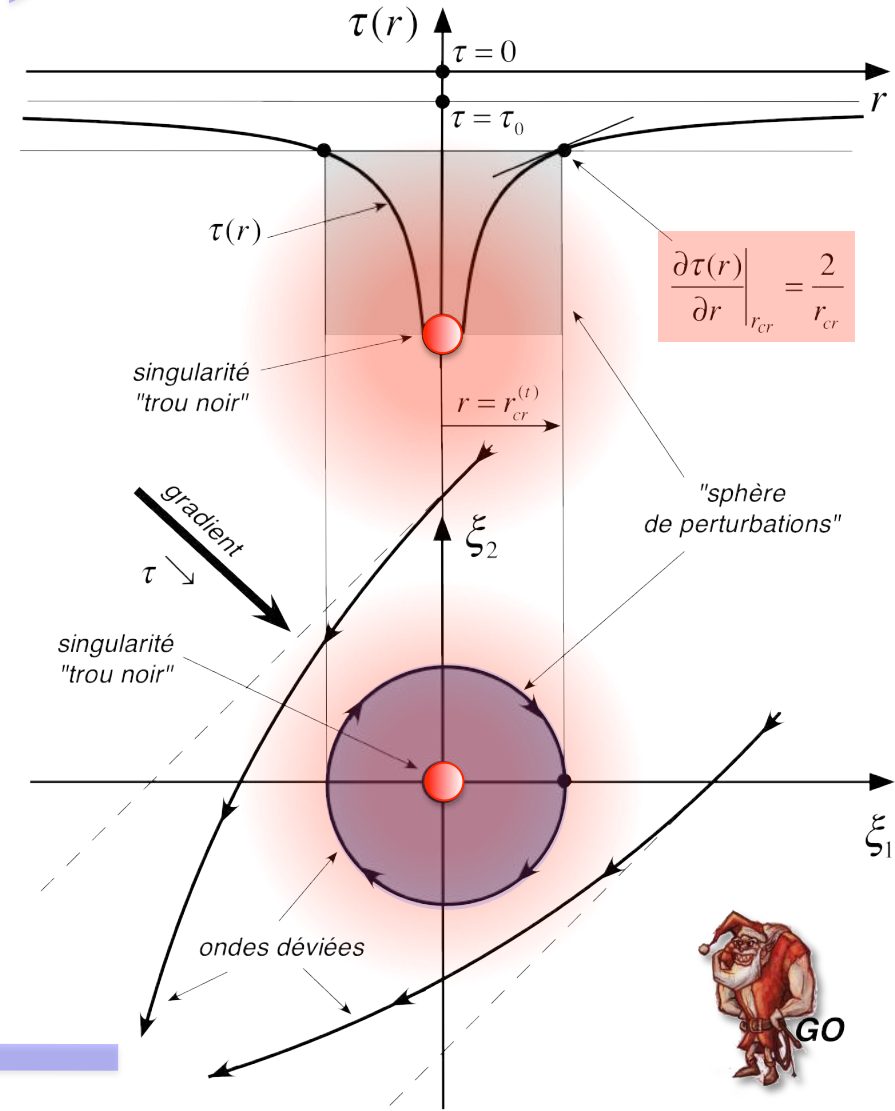
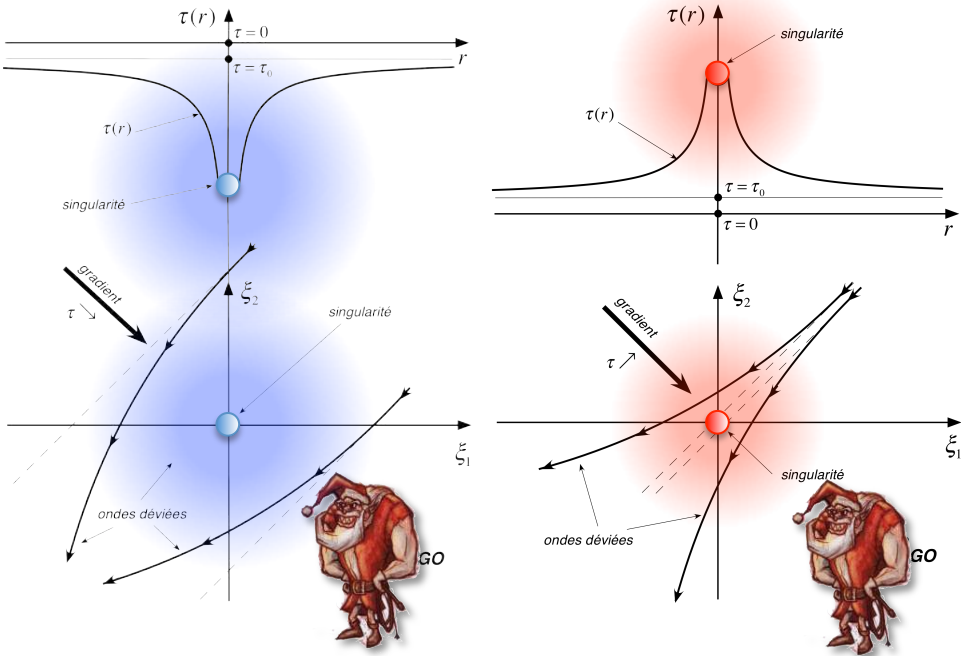
Only longitudinal «local fluctuations»
of the expansion can exist

Curvature of the wave rays and « perturbation sphere »

**Curvature of the wave rays
in the presence of an expansion singularity**

$$c_t = \frac{\omega}{k_t} \equiv \sqrt{\frac{K_2 + K_3}{mn}} = e^{\tau_0/2} \sqrt{\frac{K_2 + K_3}{mn_0}}$$

Appearance of a « perturbation sphere »

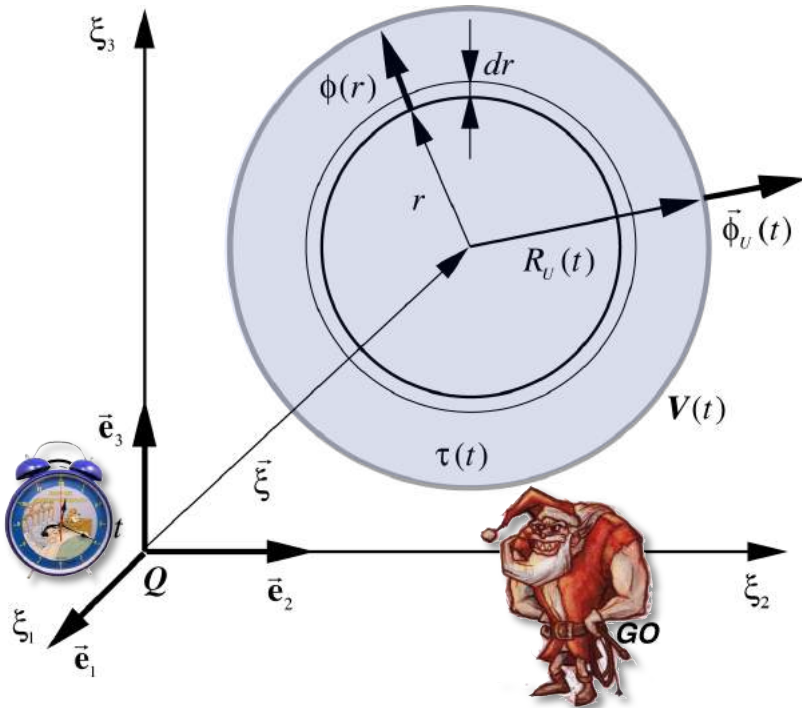


Analogy with the « photon sphere »
of a black hole in general relativity



Cosmological behaviours of a finite cosmic lattice

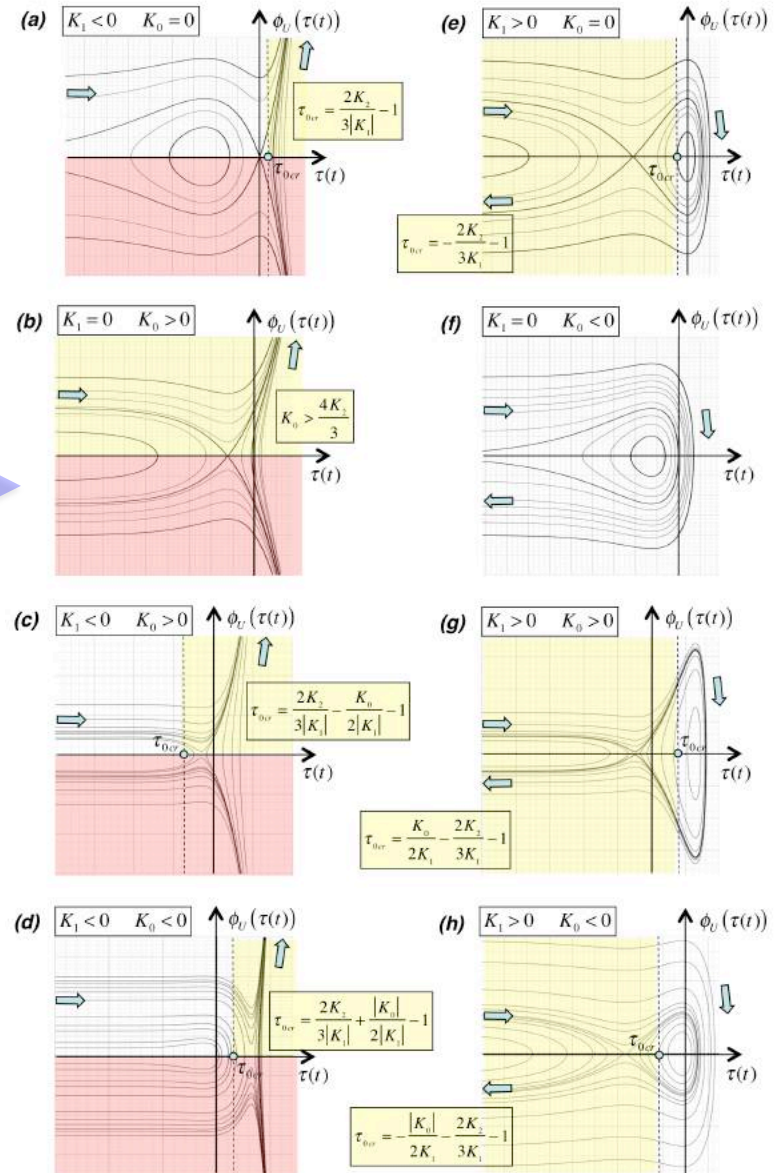
Cosmological expansion
of a spheric lattice with a given total energy



$$\phi_U(\tau) = \sqrt{\frac{10}{3Nm}} T(\tau) = \sqrt{\frac{10}{3Nm}} (E - F(\tau))$$

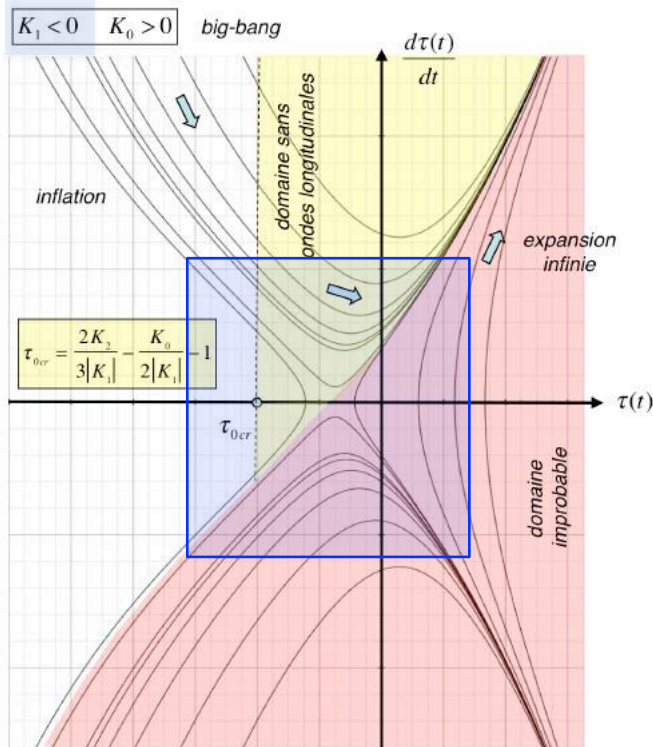
$$F = \frac{N}{n_0} (K_1 \tau - K_0) \tau e^\tau$$

8 possible cosmological models

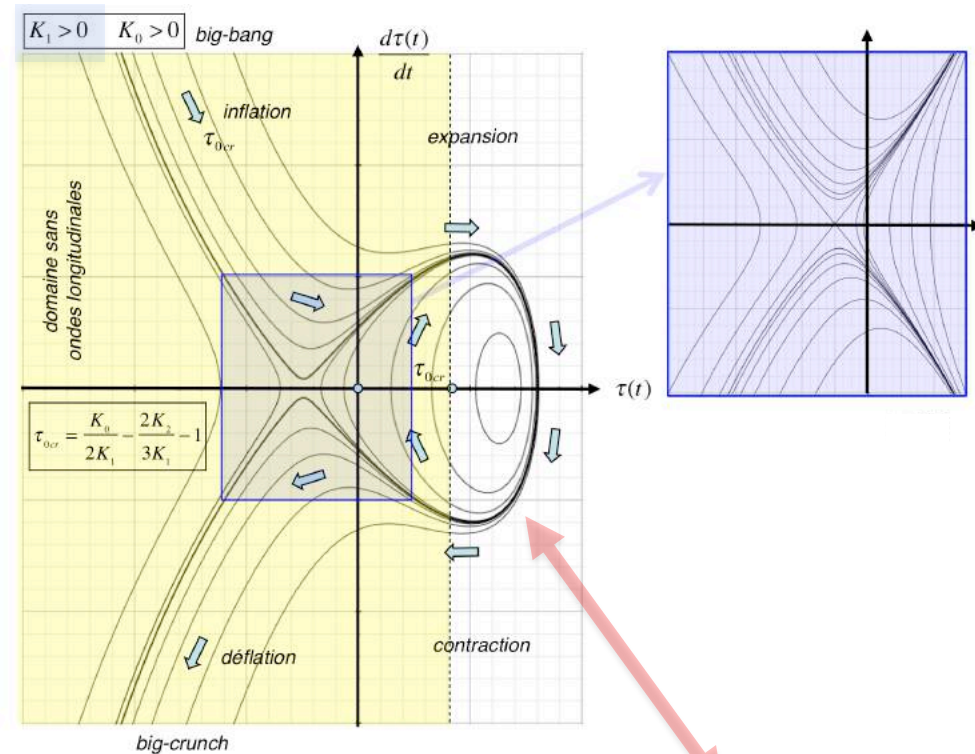


Two types of pleasant cosmological models!

Model without «big-crunch»



Model with «big-crunch»



1/ Analogy with the cosmological expansion of the universe:
 «big-bang», inflation, then slowing down
 followed by an acceleration of the expansion

2/ Possible model with «big-crunch» and «big-bounce»

3/ Origin of the «dark energy»: $F = \frac{N}{n_0} (K_1\tau - K_0)\tau e^\tau$



Conjecture: $K_1 > 0$; $K_0 > 0$

II B - Maxwell equations and special relativity

Maxwell equations

Equations of the cosmic lattice
(at constant expansion)

$$\begin{cases} -\frac{\partial(2\bar{\omega}^{el})}{\partial t} + \overline{\text{rot}} \bar{\phi}^{rot} \equiv (2\bar{J}) \\ \text{div}(2\bar{\omega}^{el}) = (2\lambda) \end{cases}$$

$$\begin{cases} \frac{\partial(n\bar{p}^{rot})}{\partial t} \equiv -\overline{\text{rot}}\left(\frac{\bar{m}}{2}\right) + 2K_2\bar{\lambda}^{rot} \\ \text{div}(n\bar{p}^{rot}) = 0 \end{cases}$$

$$\begin{cases} (2\bar{\omega}^{el}) = \frac{1}{(K_2 + K_3)}\left(\frac{\bar{m}}{2}\right) + (2\bar{\omega}^{an}) + (2\bar{\omega}_0(t)) \\ (n\bar{p}^{rot}) = (nm)\left[\bar{\phi}^{rot} + (C_I - C_L)\bar{\phi}^{rot} + \left(\frac{1}{n}(\bar{J}_I^{rot} - \bar{J}_L^{rot})\right)\right] \end{cases}$$

$$\begin{cases} \frac{\partial(2\lambda)}{\partial t} \equiv -\text{div}(2\bar{J}) \end{cases}$$

$$\begin{cases} -\left(\frac{\bar{m}}{2}\right)(2\bar{J}) \equiv \\ \bar{\phi}^{rot} \frac{\partial(n\bar{p}^{rot})}{\partial t} + \left(\frac{\bar{m}}{2}\right) \frac{\partial(2\bar{\omega}^{el})}{\partial t} - \text{div}\left(\bar{\phi}^{rot} \wedge \left(\frac{\bar{m}}{2}\right)\right) \end{cases}$$

$$\begin{cases} c_t = \sqrt{\frac{K_2 + K_3}{mn}} \end{cases}$$

$$\begin{cases} \vec{F}_{PK} = 2Q_\lambda \left(\frac{\bar{m}}{2} + \vec{v} \wedge n\bar{p}\right) \end{cases}$$

Maxwell equations
of electromagnetism

$$\begin{cases} -\frac{\partial\bar{D}}{\partial t} + \overline{\text{rot}} \bar{H} = \bar{j} \\ \text{div} \bar{D} = \rho \end{cases}$$

$$\begin{cases} \frac{\partial\bar{B}}{\partial t} = -\overline{\text{rot}} \bar{E} \\ \text{div} \bar{B} = 0 \end{cases}$$

$$\begin{cases} \bar{D} = \epsilon_0 \bar{E} + \bar{P} + \bar{P}_0(t) \\ \bar{B} = \mu_0 [\bar{H} + (\chi^{para} + \chi^{dia})\bar{H} + \bar{M}] \end{cases}$$

$$\begin{cases} \frac{\partial\rho}{\partial t} = -\text{div} \bar{j} \end{cases}$$

$$\begin{cases} -\bar{E} \bar{j} = \\ \bar{H} \frac{\partial\bar{B}}{\partial t} + \bar{E} \frac{\partial\bar{D}}{\partial t} - \text{div}(\bar{H} \wedge \bar{E}) \end{cases}$$

$$\begin{cases} c = \sqrt{\frac{1}{\epsilon_0\mu_0}} \end{cases}$$

$$\begin{cases} \vec{F} = q(\vec{E} + \vec{v} \wedge \vec{B}) \end{cases}$$



James Clerk Maxwell
(1831-1879)

$$\begin{aligned} \bar{D} &\Leftrightarrow \bar{\omega} \\ \bar{E} &\Leftrightarrow \bar{m} \\ \bar{B} &\Leftrightarrow n\bar{p} \\ \bar{H} &\Leftrightarrow \bar{\phi} \\ \bar{P} &\Leftrightarrow \bar{\omega}^{an} \\ \rho &\Leftrightarrow \lambda \\ \bar{j} &\Leftrightarrow \bar{J} \end{aligned}$$

$$\bar{M} \Leftrightarrow \frac{1}{n}(\bar{J}_I - \bar{J}_L)$$

$$(\chi^{para} + \chi^{dia})\bar{H} \Leftrightarrow (C_I - C_L)\bar{\phi}$$

$$\epsilon_0 \Leftrightarrow \frac{1}{K_2}$$

$$\mu_0 \Leftrightarrow nm$$

$$c = \sqrt{\frac{1}{\epsilon_0\mu_0}} \Leftrightarrow c_t = \sqrt{\frac{K_2}{mn}}$$



1/ Complete analogy
with the Maxwell equations
of electromagnetism
(with dielectric polarisation,
para- and dia-magnetism,
magnetisation,
electrical charges and currents,
Lorentz forces)

2/ Magnetic monopoles cannot exist!

Separability of the Newton equation in the presence of topological singularities

Newton equation of the cosmic lattice

$$n \frac{d\vec{p}}{dt} = -2(K_2 + K_3) \overline{\text{rot}} \vec{\omega}^{el} + \left(\frac{4}{3} K_2 + 2K_1 \right) \overline{\text{grad}} \tau + \overline{\text{grad}} \left(\underbrace{K_2 \sum_i (\vec{\alpha}_i^{el})^2 + 2K_3 (\vec{\omega}^{el})^2 + K_1 \tau^2 - K_0 \tau}_{F^{def}} \right) + 2K_2 \vec{\lambda}$$

First partial Newton equation
for the elastic distortions
associated with the topological singularities

Second partial Newton equation
for the perturbations of the expansion
associated with the topological singularities

$$nm \frac{d\vec{\phi}^{ch}}{dt} = -2(K_2 + K_3) \overline{\text{rot}} (\vec{\omega}^{ch}) + (4K_2/3 + 2K_1(1 + \tau_0) - K_0) \overline{\text{grad}} \tau^{ch} + 2K_2 \vec{\lambda}^{ch}$$

Static case:

$$\Delta(\tau_{statique}^{ch}) = -\frac{2K_2}{4K_2/3 + 2K_1(1 + \tau_0) - K_0} \text{div} \vec{\lambda}^{ch}$$

$$= -\frac{2K_2}{4K_2/3 + 2K_1(1 + \tau_0) - K_0} \theta^{ch}$$

Calculation of the elastic distortions
associated with the topological singularities
(dislocation and disclination loops)

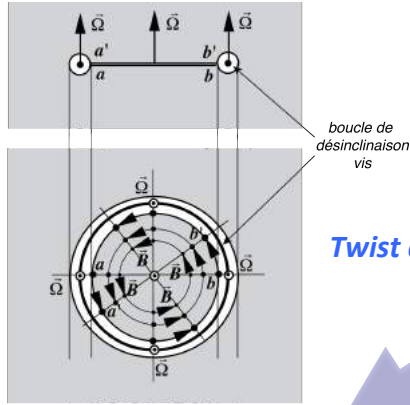
$$nm \frac{d\vec{\phi}^{(p)}}{dt} = \overline{\text{grad}} \left[\begin{aligned} & (4K_2/3 + 2K_1(1 + \tau_0 + \tau^{ext} + \tau^{ch}) - K_0) \tau^{(p)} + K_1 (\tau^{(p)})^2 \\ & + \left(K_2 \sum_i (\vec{\alpha}_i^{ch})^2 + 2K_3 (\vec{\omega}^{ch})^2 + K_1 (\tau^{ch})^2 \right) \\ & + \left(2K_2 \sum_i \vec{\alpha}_i^{ext} \vec{\alpha}_i^{ch} + 4K_3 \vec{\omega}^{ext} \vec{\omega}^{ch} + 2K_1 \tau^{ext} \tau^{ch} \right) \end{aligned} \right]$$

Static case:

$$K_1 (\tau^{(p)}(\vec{r}))^2 + [4K_2/3 + 2K_1(1 + \tau_0 + \tau^{ext}(\vec{r}) + \tau^{ch}(\vec{r})) - K_0] \tau^{(p)}(\vec{r}) + (F_{dist}^{ch}(\vec{r}) + F_{pot}^{ch}(\vec{r})) = cste = 0$$

Calculation of the perturbations of the volumic expansion
associated with the topological singularities
(dislocation and disclination loops)

Twist disclination loop and edge dislocation loop

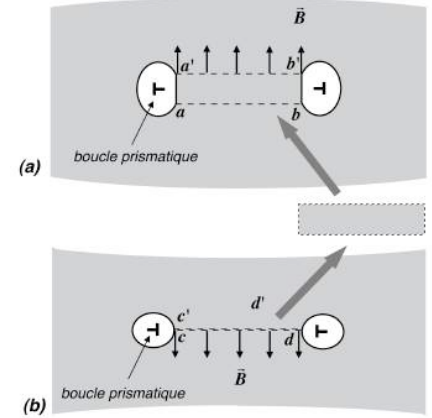


First partial Newton equation

$$nm \frac{d\vec{\phi}^{ch}}{dt} = -2(K_2 + K_3) \overline{\text{rot}}(\vec{\omega}^{ch}) + (4K_2/3 + 2K_1(1 + \tau_0) - K_0) \overline{\text{grad}} \tau^{ch} + 2K_2 \vec{\lambda}^{ch}$$

Twist disclination loop

Edge dislocation loop



Rotation charge (analogous to electrical charge)

$$\mathbf{q}_{\lambda BV} = 2\pi R_{BV} \Lambda_{BV} = -\pi R_{BV} \vec{B}_{BV} \vec{t} \quad \& \quad \mathbf{q}_{\theta BV} = 0$$

$$\vec{\omega}_{ext}^{BV} = \frac{\mathbf{q}_{\lambda BV} \vec{r}}{4\pi r^3} \quad \text{Source of a divergent rotation field (analogous to an electrical field)}$$

$$E_{dist}^{BV} \cong E_{dist\,tore}^{BV} \cong 2(K_2 + K_3) \zeta_{BV} R_{BV} \Lambda_{BV}^2 = \frac{1}{2}(K_2 + K_3) \zeta_{BV} R_{BV} \vec{B}_{BV}^2$$

$$E_{cin}^{BV} \cong E_{cin\,tore}^{BV} \cong mn \zeta_{BV} R_{BV} \Lambda_{BV}^2 \mathbf{v}^2 = \frac{1}{4} mn \zeta_{BV} R_{BV} \vec{B}_{BV}^2 \mathbf{v}^2$$

$$M_0^{BV} = \frac{E_{dist}^{BV}}{c_t^2} = \frac{2}{c_t^2} (K_2 + K_3) \zeta_{BV} R_{BV} \Lambda_{BV}^2 = \frac{1}{2c_t^2} (K_2 + K_3) \zeta_{BV} R_{BV} \vec{B}_{BV}^2$$

$$\zeta_{BV} = \ln(A_{BV} R_{BV} / a)$$

Flexion charge (analogous to spatial curvature charge)

$$\mathbf{q}_{\lambda BC} = 0 \quad \& \quad \mathbf{q}_{\theta BC} = -2\pi \vec{n} (\vec{t} \wedge \vec{\Lambda}_{BC}) = 2\pi \vec{\Lambda}_{BC} \vec{m} = -2\pi \vec{n} \vec{B}_{BC}$$

$$\vec{\chi}_{ext}^{BC} = \frac{\mathbf{q}_{\theta BC} \vec{r}}{4\pi r^3} \quad \text{Source of a divergent flexion field (analogous to a spatial curvature field)}$$

$$E_{dist}^{BC} \cong E_{dist\,tore}^{BC} \cong \left(\frac{K_2}{K_3}\right)^2 K_3 \zeta_{BC} R_{BC} \vec{\Lambda}_{BC}^2 \cong \left(\frac{K_2}{K_3}\right)^2 K_3 \zeta_{BC} R_{BC} \vec{B}_{BC}^2$$

$$E_{cin}^{BC} \cong E_{cin\,tore}^{BC} \cong \frac{1}{2} \left(\frac{K_2}{K_3}\right)^2 mn \zeta_{BC} R_{BC} \vec{\Lambda}_{BC}^2 \mathbf{v}^2 = \frac{1}{2} \left(\frac{K_2}{K_3}\right)^2 mn \zeta_{BC} R_{BC} \vec{B}_{BC}^2 \mathbf{v}^2$$

$$M_0^{BC} = \frac{E_{dist}^{BC}}{c_t^2} = \left(\frac{K_2}{K_3}\right)^2 \frac{1}{c_t^2} K_3 \zeta_{BC} R_{BC} \vec{\Lambda}_{BC}^2 = \left(\frac{K_2}{K_3}\right)^2 \frac{1}{c_t^2} K_3 \zeta_{BC} R_{BC} \vec{B}_{BC}^2$$

$$\zeta_{BC} \cong \ln(A_{BC} R_{BC} / a)$$



1/ Perfect analogy between the rotation charge and a localized electrical charge

2/ No analogy in all other theories for the localized curvature charge !!!

Relativistic dynamics of the topological singularities



Hendrik Anton Lorentz
(1853-1928)

$$\begin{cases} x_1' = \frac{x_1 - \mathbf{v}t}{\gamma_t} \\ x_2' = x_2'' = x_2 \\ x_3' = x_3'' = x_3 \\ t' = \frac{t - \mathbf{v}x_1 / c_t^2}{\gamma_t} \end{cases} \quad \gamma = \sqrt{1 - \frac{\mathbf{v}^2}{c_t^2}}$$

Conjecture: $\begin{cases} K_0 = K_3 > 0, \\ 0 < K_1 \ll K_0 = K_3 \\ 0 \leq K_2 \ll K_3 = K_0 \end{cases}$

Same Lorentz transformations for all topological singularities

Relativistic energy of the twist disclination loop

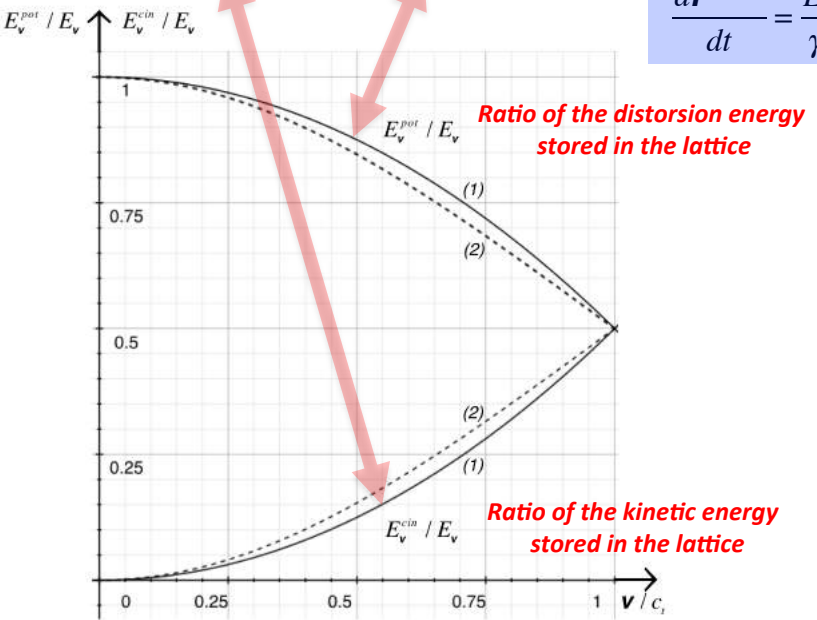
Relativistic dynamics equation for the topological singularities

Relativistic energy of the edge dislocation loop

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

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

$$\frac{d\vec{\mathbf{P}}^{disloc}}{dt} = \frac{E_{dist}^{disloc}}{\gamma_t^3 c_t^2} \vec{\mathbf{a}} = \frac{M_0^{disloc}}{\gamma_t^3} \vec{\mathbf{a}} = \vec{\mathbf{F}}_{PK}$$



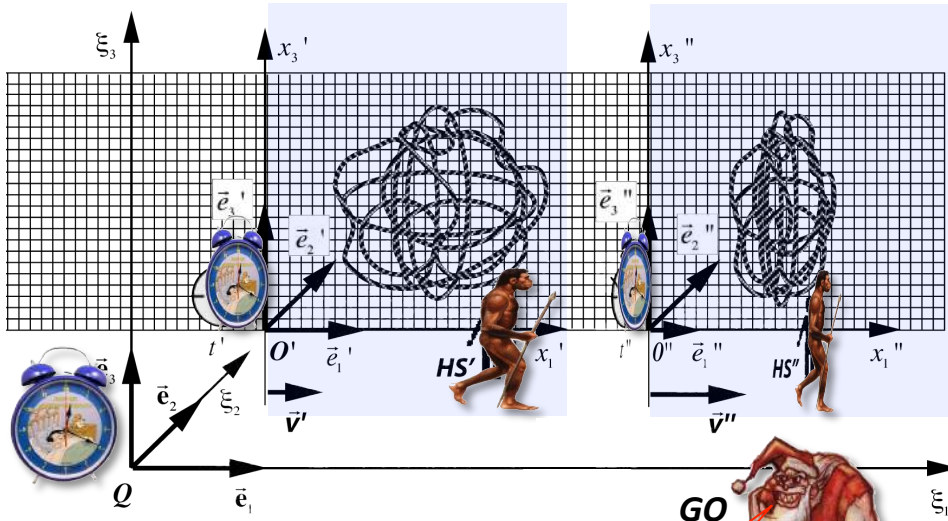
All the topological singularities (of dislocation or disclination types) follow exactly the theory of special relativity

Effects of the Lorentz transformation of the special relativity



Albert Einstein
(1879-1955)

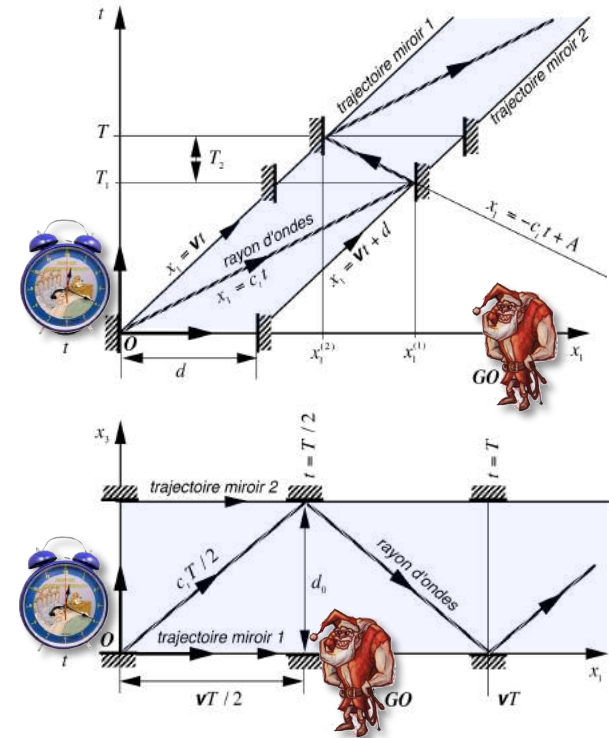
Measuring rods contraction and clock slowing down for the local observers HS



$$\begin{cases} x_1' = \frac{x_1 - vt}{\gamma_t} \\ x_2' = x_2'' = x_2 \\ x_3' = x_3'' = x_3 \\ t' = \frac{t - \mathbf{v}x_1 / c_t^2}{\gamma_t} \end{cases} \quad \gamma = \sqrt{1 - \frac{\mathbf{v}^2}{c_t^2}}$$



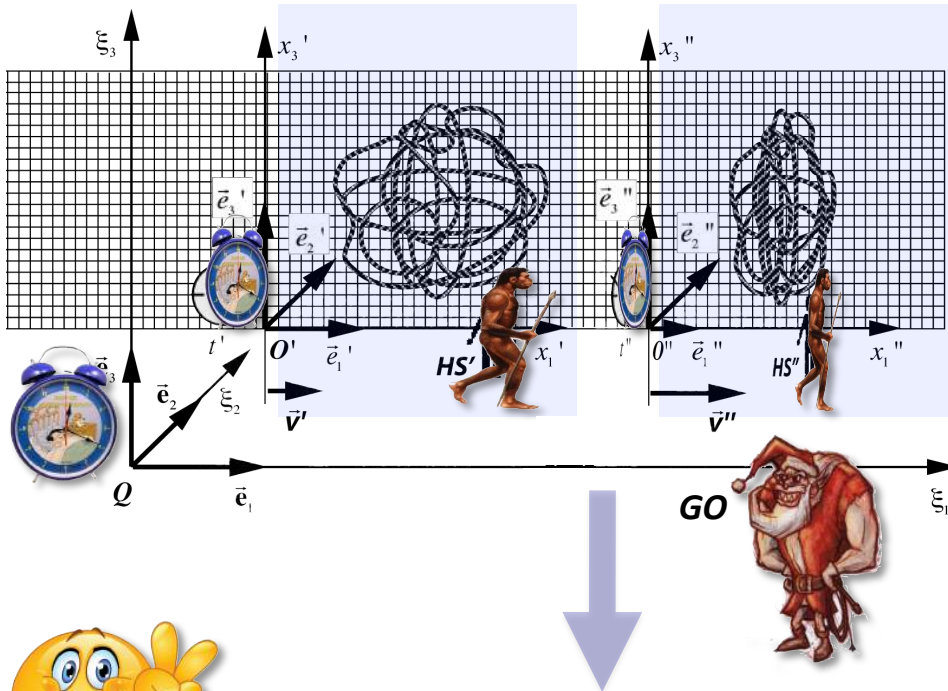
Verification of the Michelson-Morley experiments



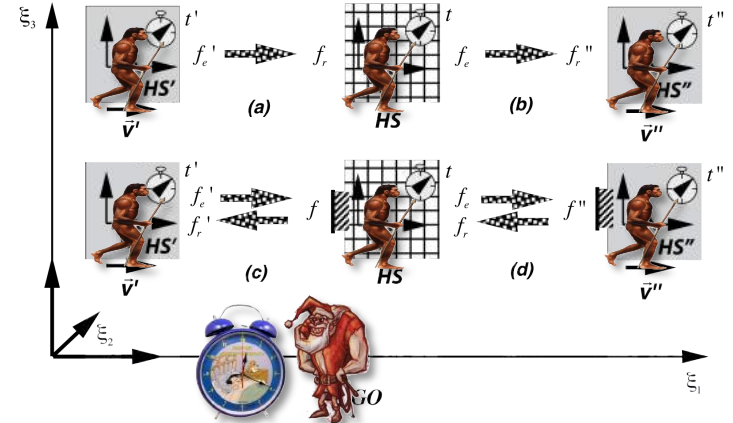
The new « aether » is arrived!

Effects of the Lorentz transformation of the special relativity

Impossibility for the local observers HS to measure their own velocity with regard to the lattice



Verification of all the Doppler-Fizeau experiments



Simple explanation of the famous twin paradox of the special relativity



1/ Complete analogy with the Lorentz transformation and the special relativity

2/ The cosmological lattice behaves as an « aether » which verifies the Michelson-Morley experiment and the Doppler-Fizeau effects, and which explains very simply the twin paradox.

3/ The local observers HS cannot measure their own velocity with regard to the lattice!

II C - Gravitation and cosmology

Perturbation of the external expansion field of a topological singularity

$$K_1(\tau^{(p)}(\vec{r}))^2 + [4K_2/3 + 2K_1(1 + \tau_0 + \tau^{ext}(\vec{r}) + \tau^{ch}(\vec{r})) - K_0]\tau^{(p)}(\vec{r}) + (F_{dist}^{ch}(\vec{r}) + F_{pot}^{ch}(\vec{r})) = cste = 0$$

Second partial Newton equation
(in the static case)

Effect of the energy of a singularity

$$E_{dist}^{amas} + V_{pot}^{amas}$$

Effect of the flexion charge of a singularity

$$Q_\theta$$

Effect of the rotation charge of a singularity

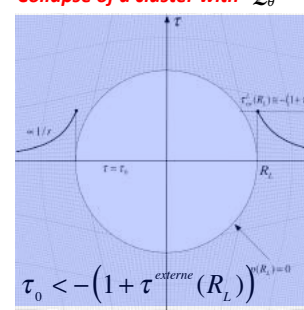
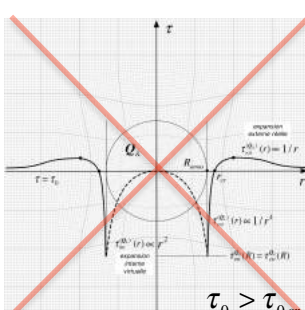
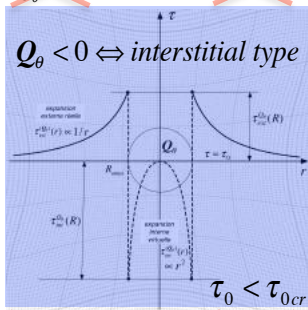
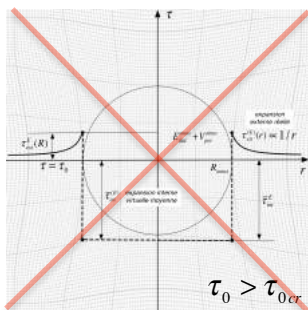
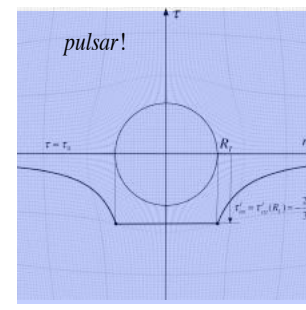
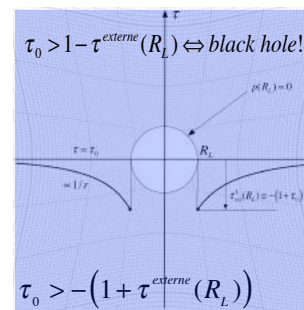
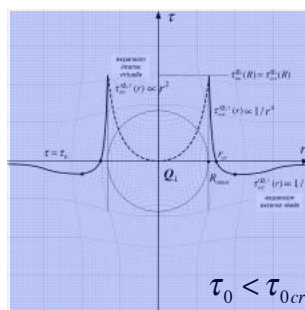
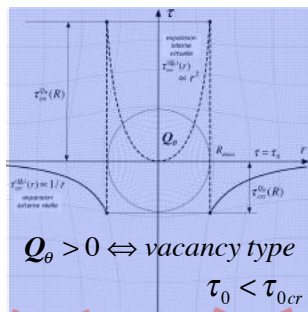
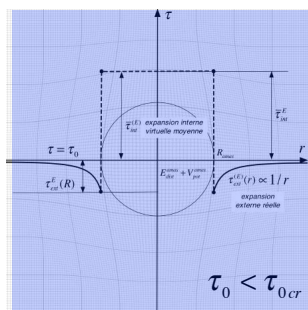
$$Q_\lambda$$

Effect of a macroscopic vacancy singularity

$$R_L \cong \sqrt[3]{\frac{3N_L}{4\pi n_0 e}}$$

Effect of a macroscopic interstitial singularity

$$R_I \cong \sqrt[3]{\frac{3N_I}{4\pi n_0 e}} e^{\frac{\tau_0 + \tau^{ext}(R_I)}{3}}$$



~~$Q_\theta < 0$~~

~~$\tau_0 > \tau_{0cr}$~~

$Q_\theta < 0 \Leftrightarrow$ interstitial type

~~$Q_\theta > 0$~~

~~$\tau_0 > \tau_{0cr}$~~

Collapse of a cluster with $Q_\theta > 0$

Collapse of a cluster with $Q_\theta < 0$

~~$\tau_0 < - (1 + \tau^{externe}(R_L))$~~

~~$\tau_{ext}^{amas}(R_L) = -(1 + \tau_0)$~~

~~$\tau_0 < - (1 + \tau^{externe}(R_L))$~~

External expansion field of a topological singularity of vacancy or interstitial type

$$K_1(\tau^{(p)}(\vec{r}))^2 + [4K_2/3 + 2K_1(1 + \tau_0 + \tau^{ext}(\vec{r}) + \tau^{ch}(\vec{r})) - K_0]\tau^{(p)}(\vec{r}) + (F_{dist}^{ch}(\vec{r}) + F_{pot}^{ch}(\vec{r})) = cste = 0$$

Second partial Newton equation
(in the static case)

Effect of the energy of the singularity

$$E_{dist}^{amas} + V_{pot}^{amas}$$

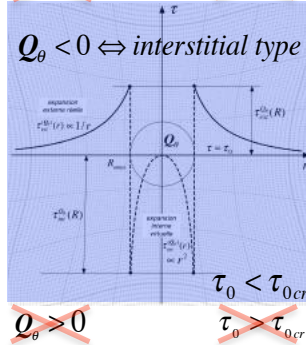
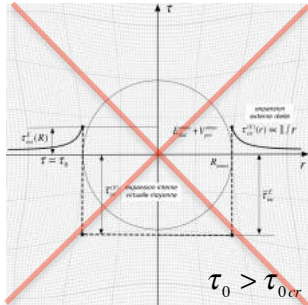
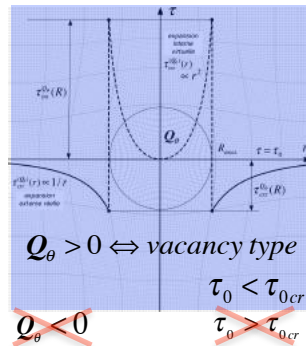
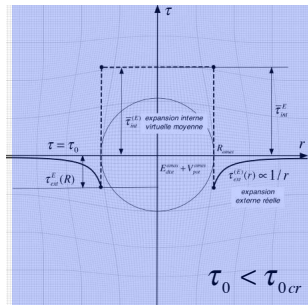
Effect of the flexion charge of the singularity

$$Q_\theta$$

Conjecture:

flexion charge :

$$\begin{cases} Q_\theta > 0 \Leftrightarrow \text{vacancy type} \Leftrightarrow \text{analogous to anti-matter} \\ Q_\theta < 0 \Leftrightarrow \text{interstitial type} \Leftrightarrow \text{analogous to matter} \end{cases}$$



$$|\tau_{ext}^{Q_\theta}| \ll |\tau_{ext}^E|$$



1/ The gravitational field of a vacancy type cluster (anti-matter) is slightly higher than that of an interstitial type cluster (matter)

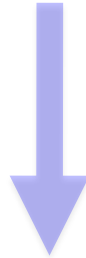
Collapse of clusters of vacancy or interstitial type: **black holes and pulsars**

$$K_1 (\tau^{(p)}(\vec{r}))^2 + [4K_2 / 3 + 2K_1 (1 + \tau_0 + \tau^{ext}(\vec{r}) + \tau^{ch}(\vec{r})) - K_0] \tau^{(p)}(\vec{r}) + (F_{dist}^{ch}(\vec{r}) + F_{pot}^{ch}(\vec{r})) = cste = 0$$

Second partial Newton equation
(in the static case)

Conjecture:

flexion charge: $\begin{cases} Q_\theta > 0 \Leftrightarrow \text{vacancy type} \Leftrightarrow \text{analogous to anti-matter} \\ Q_\theta < 0 \Leftrightarrow \text{interstitial type} \Leftrightarrow \text{analogous to matter} \end{cases}$



1/ The collapse of a cluster with $Q_\theta > 0$ (**anti-matter**) leads to a **macroscopic vacancy singularity**

2/ If $\tau_0 > 1 - \tau^{externe}(R_L)$, the macroscopic vacancy becomes a **black hole**

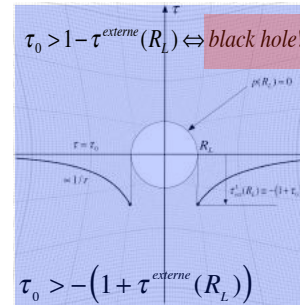
3/ The collapse of a cluster with $Q_\theta < 0$ (**matter**) leads to a **macroscopic interstitial singularity**

4/ The macroscopic interstitial has to correspond to a **pulsar !!!**

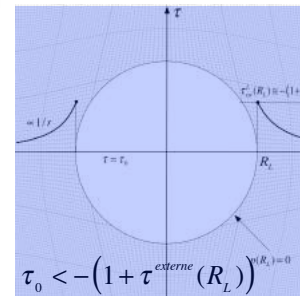


Effect of a macroscopic vacancy singularity

$$R_L \cong \sqrt[3]{\frac{3N_L}{4\pi n_0} e}$$

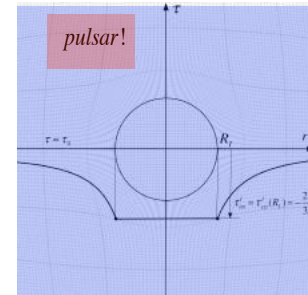


Collapse of a cluster with $Q_\theta > 0$



Effect of a macroscopic interstitial singularity

$$R_I \cong \sqrt[3]{\frac{3N_I}{4\pi n_0} e^{\frac{\tau_0 + \tau^{externe}(R_I)}{3}}}$$



Collapse of a cluster with $Q_\theta < 0$

« Gravitational » interaction between elementary topological singularities

Calculations of the interaction forces between two elementary singularities due to their expansion perturbations

$$F_{grav}^{BV-BV} \equiv G_{grav} \frac{M_{0(1)}^{BV} M_{0(2)}^{BV}}{d^2} \quad \text{Predominant interaction}$$

$$F_{grav}^{BC-BC} \equiv (\alpha_{BC} + 2\beta_{BC}) G_{grav} \frac{M_{courbure(1)}^{BC} M_{0(2)}^{BC} + M_{courbure(2)}^{BC} M_{0(1)}^{BC}}{d^2} + 2(\alpha_{BC} + 2\beta_{BC}) G_{grav} \frac{M_{0(1)}^{BC} M_{0(2)}^{BC}}{d^2}$$

$$F_{grav}^{BM-BM} \equiv 2(\alpha_{BM} + 2\beta_{BM}) G_{grav} \frac{M_{0(1)}^{BM} M_{0(2)}^{BM}}{d^2}$$

$$F_{grav}^{BV-BC} \equiv \frac{1}{2} G_{grav} \frac{M_{courbure}^{BC} M_0^{BV}}{d^2} + \left(\frac{1}{2} + 4(\alpha_{BC} + 2\beta_{BC}) \right) G_{grav} \frac{M_0^{BV} M_0^{BC}}{d^2}$$

$$F_{grav}^{BV-BM} \equiv \left(\frac{1}{2} + 4(\alpha_{BM} + 2\beta_{BM}) \right) G_{grav} \frac{M_0^{BV} M_0^{BM}}{d^2}$$

$$F_{grav}^{BC-BM} \equiv 4(\alpha_{BM} + 2\beta_{BM}) G_{grav} \frac{M_{courbure}^{BC} M_0^{BM}}{d^2} + 4(\alpha_{BC} + 2\beta_{BC} + \alpha_{BM} + 2\beta_{BM}) G_{grav} \frac{M_0^{BC} M_0^{BM}}{d^2}$$

$$F_{grav}^{BV-L} \equiv \frac{1}{2} G_{grav} \frac{9 + \tau_0}{1 + \tau_0} \frac{M_0^{BV} M_{grav}^{(L)}}{d^2} \equiv \frac{c_t^2}{8} (9 + \tau_0) \frac{M_0^{BV} R_L}{d^2}$$

$$F_{grav}^{BC-L} \equiv 4G_{grav} \frac{1}{1 + \tau_0} \frac{M_{courbure}^{BC} M_{grav}^{(L)}}{d^2} + 4G_{grav} \frac{1 + (\alpha_{BC} + 2\beta_{BC})(1 + \tau_0)}{1 + \tau_0} \frac{M_0^{BC} M_{grav}^{(L)}}{d^2}$$

$$\equiv c_t^2 \frac{M_{courbure}^{BC} R_L}{d^2} + c_t^2 [1 + (\alpha_{BC} + 2\beta_{BC})(1 + \tau_0)] \frac{M_0^{BC} R_L}{d^2}$$

$$F_{grav}^{BM-L} \equiv 4G_{grav} \frac{1 + (\alpha_{BM} + 2\beta_{BM})(1 + \tau_0)}{1 + \tau_0} \frac{M_0^{BM} M_{grav}^{(L)}}{d^2} \equiv c_t^2 [1 + (\alpha_{BM} + 2\beta_{BM})(1 + \tau_0)] \frac{M_0^{BM} R_L}{d^2}$$

$$F_{grav}^{BV-l} \equiv \frac{9}{2} G_{grav} \frac{M_0^{BV} M_{grav}^{(l)}}{d^2} \equiv \frac{3c_t^2}{4R_\infty^2} \frac{M_0^{BV} R_l^3}{d^2}$$

$$F_{grav}^{BC-l} \equiv 4G_{grav} \frac{M_{courbure}^{BC} M_{grav}^{(l)}}{d^2} + 4G_{grav} (1 + \alpha_{BC} + 2\beta_{BC}) \frac{M_0^{BC} M_{grav}^{(l)}}{d^2}$$

$$\equiv \frac{2c_t^2}{3R_\infty^2} \frac{M_{courbure}^{BC} R_l^3}{d^2} + \frac{2c_t^2}{3R_\infty^2} (1 + \alpha_{BC} + 2\beta_{BC}) \frac{M_0^{BC} R_l^3}{d^2}$$

$$F_{grav}^{BM-l} \equiv 4G_{grav} [1 + \alpha_{BM} + 2\beta_{BM}] \frac{M_0^{BM} M_{grav}^{(l)}}{d^2} \equiv \frac{2c_t^2}{3R_\infty^2} [1 + \alpha_{BM} + 2\beta_{BM}] \frac{M_0^{BM} R_l^3}{d^2}$$

$$F_{grav}^{L-L} \equiv \frac{8G_{grav}}{(1 + \tau_0)} \frac{M_{grav(1)}^{(L)} M_{grav(2)}^{(L)}}{d^2} \equiv \frac{c_t^4 (1 + \tau_0)}{2G_{grav}} \frac{R_{L(1)} R_{L(2)}}{d^2}$$

$$F_{grav}^{l-l} \equiv 2G_{grav} \frac{M_{grav(1)}^{(l)} M_{grav(2)}^{(l)}}{d^2} \equiv \frac{c_t^4}{18G_{grav} R_\infty^4} \frac{R_{l(1)}^3 R_{l(2)}^3}{d^2}$$

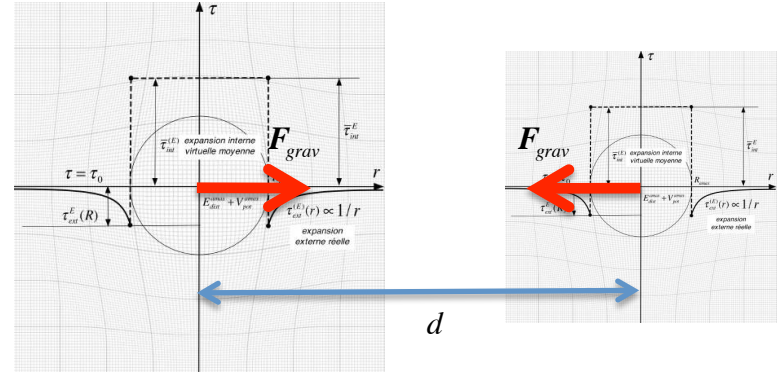
$$F_{grav}^{L-l} \equiv 4G_{grav} \frac{2 + \tau_0}{1 + \tau_0} \frac{M_{grav}^{(L)} M_{grav}^{(l)}}{d^2} \equiv \frac{c_t^4}{6R_\infty^2} \frac{2 + \tau_0}{G_{grav}} \frac{R_L R_l^3}{d^2}$$

BV=screw disclination loop
BC=edge dislocation loop
BM=mixed dislocation loop

L=macroscopic vacancy
l=macroscopic interstitial



Gravitational interaction force between two clusters of elementary singularities



$$F_{grav} \equiv G_{grav} \frac{M_{0(1)}^{amas} M_{0(2)}^{amas}}{d^2} \left(1 - \frac{G_{grav}}{4c_t^2} \frac{(M_{0(1)}^{amas} + M_{0(2)}^{amas})}{d} + \dots \right)$$

$$G_{grav} = \frac{c_t^4}{8\pi(K_0 - 4K_2/3 - 2K_1(1 + \tau_0))R_\infty^2} \begin{cases} > 0 & \text{si } \tau_0 < \tau_{0cr} \\ < 0 & \text{si } \tau_0 > \tau_{0cr} \end{cases}$$

$$\tau_{ext}(r) \equiv -\frac{4G_{grav} M_0^{amas}}{c_t^2 r}$$



1/ Analogy with **Newton gravitation**

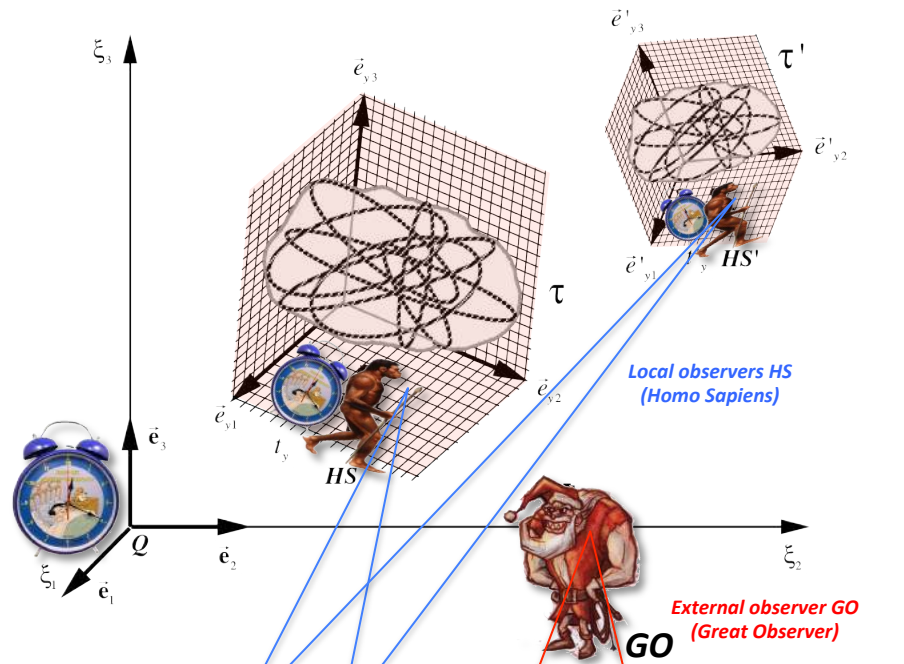
2/ **Small corrections at very short distances as in general relativity, but different!**

3/ **Gravitational parameter G is not a constant. It depends on the expansion background**

Invariance of the Maxwellian formulation of the physics laws for the local observers HS

Absolute frame of the external observer GO and local frames of the observers HS

Behaviours of the measuring rods and local clock of the HS observers insuring the invariance of their physics laws



$$\left\{ \begin{array}{l} y_i = e^{\frac{G_{grav} M_0^{amas}}{c_t^2 r}} \xi_i \\ t_y = e^{-\frac{G_{grav} M_0^{amas}}{c_t^2 r}} t \end{array} \right. \quad \left\{ \begin{array}{l} \xi_i \equiv \left(1 + \frac{G_{grav} M_0^{amas}}{c_t^2 r} \right) \xi_i \\ t \equiv \left(1 - \frac{G_{grav} M_0^{amas}}{c_t^2 r} \right) t \end{array} \right.$$

Relations of our theory Relations of the Schwarzschild metric in general relativity

Invariant Maxwell equations

$$\left\{ \begin{array}{l} -\frac{\partial(2\tilde{\omega}_{(y)}^{ot})}{\partial t_y} + \overline{\text{rot}}_y \tilde{\phi}_{(y)}^{ot} \equiv (2\tilde{J}_{(y)}) \\ \text{div}_y (2\tilde{\omega}_{(y)}^{ot}) = (2\tilde{\lambda}_{(y)}) \\ \frac{\partial(n_0 \tilde{p}_{(y)}^{ot})}{\partial t_y} \equiv -\overline{\text{rot}}_y \left(\frac{\tilde{m}_{(y)}}{2} \right) + 2K_2 \tilde{\lambda}_{(y)}^{ot} \\ \text{div}_y (n_0 \tilde{p}_{(y)}^{ot}) = 0 \\ (2\tilde{\omega}_{(y)}^{ot}) = \frac{1}{(K_2 + K_3)} \left(\frac{\tilde{m}_{(y)}}{2} \right) + (2\tilde{\omega}_{(y)}^{ot}) \\ (n_0 \tilde{p}_{(y)}^{ot}) = (n_0 m) \left[\tilde{\phi}_{(y)}^{ot} + (C_{I(y)} - C_{L(y)}) \tilde{\phi}_{(y)}^{ot} + \left(\frac{1}{n_0} (\tilde{J}_{I(y)}^{ot} - \tilde{J}_{L(y)}^{ot}) \right) \right] \\ \frac{\partial(2\tilde{\lambda}_{(y)})}{\partial t_y} \equiv -\text{div}_y (2\tilde{J}_{(y)}) \\ c_{t0} = \sqrt{\frac{K_2 + K_3}{m n_0}} = cste \end{array} \right.$$

Maxwell equations depending on the local expansion

$$\left\{ \begin{array}{l} -\frac{\partial(2\tilde{\omega}^{ot})}{\partial t} + \overline{\text{rot}} \tilde{\phi}^{ot} \equiv (2\tilde{J}) \\ \text{div} (2\tilde{\omega}^{ot}) = (2\tilde{\lambda}) \\ \frac{\partial(n \tilde{p}^{ot})}{\partial t} \equiv -\overline{\text{rot}} \left(\frac{\tilde{m}}{2} \right) + 2K_2 \tilde{\lambda}^{ot} \\ \text{div} (n \tilde{p}^{ot}) = 0 \\ (2\tilde{\omega}^{ot}) = \frac{1}{(K_2 + K_3)} \left(\frac{\tilde{m}}{2} \right) + (2\tilde{\omega}^{ot}) + (2\tilde{\omega}_0(t)) \\ (n \tilde{p}^{ot}) = (nm) \left[\tilde{\phi}^{ot} + (C_I - C_L) \tilde{\phi}^{ot} + \left(\frac{1}{n} (\tilde{J}_I^{ot} - \tilde{J}_L^{ot}) \right) \right] \\ \frac{\partial(2\tilde{\lambda})}{\partial t} \equiv -\text{div}(2\tilde{J}) \\ c_t = \sqrt{\frac{K_2 + K_3}{m n}} = \sqrt{\frac{K_2 + K_3}{m n_0}} e^{\tau_0} \neq cste \end{array} \right.$$

- 1/ Analogy with the Scharzschild metric of the general relativity
- 2/ Measuring rods and clocks of the HS observers depend on local expansion of the lattice
- 3/ Phisics laws are invariant for the local observers HS
- 4/ Only an external observer GO can describe the effects of the local expansion, because he owns universal measuring rods and clock



Agreement and disagreement with the general relativity

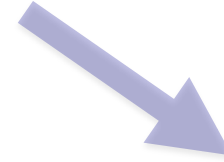
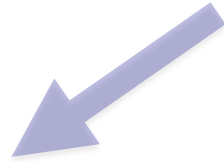


Karl Schwarzschild (1873-1916)

$$\left\{ \begin{array}{l} y_i = e^{\frac{G_{\text{grav}} M_0^{\text{amas}}}{c_t^2 r}} \xi_i \\ t_y = e^{\frac{G_{\text{grav}} M_0^{\text{amas}}}{c_t^2 r}} t \end{array} \right. \cong \left\{ \begin{array}{l} \left(1 + \frac{G_{\text{grav}} M_0^{\text{amas}}}{c_t^2 r} \right) \xi_i \\ \left(1 - \frac{G_{\text{grav}} M_0^{\text{amas}}}{c_t^2 r} \right) t \end{array} \right.$$

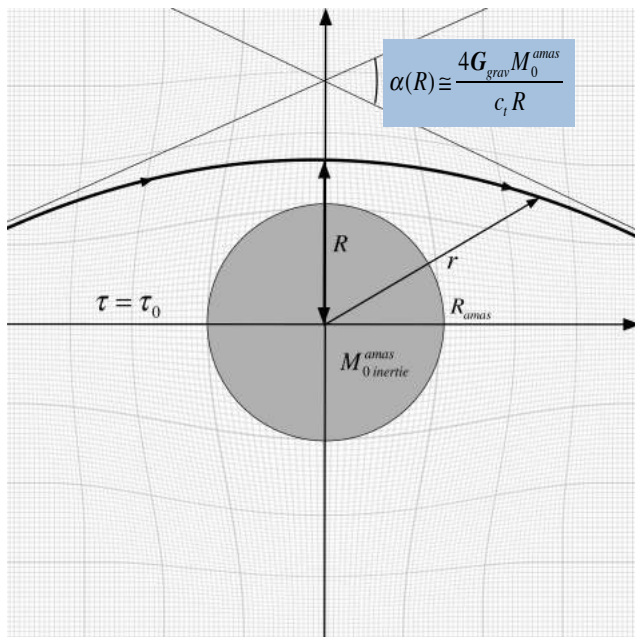
Relations of our theory

Relations of the Schwarzschild metric in general relativity



At long distances, perfect agreement with general relativity: **example of the light rays curvature**

At very short distances, disagreement with general relativity: **example of the characteristic radii of black holes**



Schwarzschild radius

Radius of photon sphere

Radius where the time dilation of falling observers becomes infinite

Our theory

General relativity

$$R_{\text{Schwarzschild}} = \frac{2G_{\text{grav}} M_0^{\text{amas}}}{c_t^2}$$

$$R_{\text{Schwarzschild}} = \frac{2G_{\text{grav}} M_0^{\text{amas}}}{c_t^2}$$

$$R_{\text{photon}} = \frac{2G_{\text{grav}} M_0^{\text{amas}}}{c_t^2}$$

$$R_{\text{photon}} = \frac{3G_{\text{grav}} M_0^{\text{amas}}}{c_t^2}$$

$$R_{\text{time dilation} \rightarrow \infty} \rightarrow 0$$

$$R_{\text{time dilation} \rightarrow \infty} \cong \frac{G_{\text{grav}} M_0^{\text{amas}}}{c_t^2}$$



The characteristic radii of a black hole obtained by our theory **seem much more satisfactory** than those obtained from the Schwarzschild metric of general relativity

Spatial curvature of the lattice as seen by the observer GO compared to the spatio-temporal curvature of the general relativity

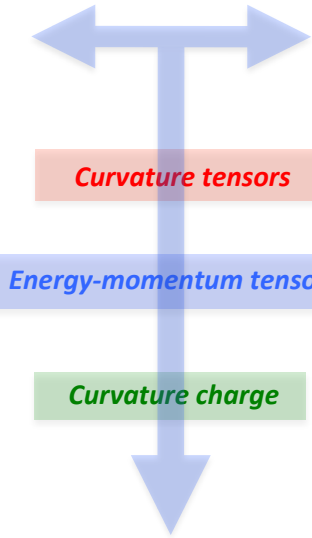
Einstein equations of the 4D curvature of space-time in general relativity

$$G = 8\pi T$$

$$G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R$$

$$\vec{\nabla} \cdot G = \vec{\nabla} \cdot T = \vec{\nabla} \cdot T [\dots] = 0$$

Motion equation



Equations of the 3D space curvature of the lattice as seen by the external observer GO

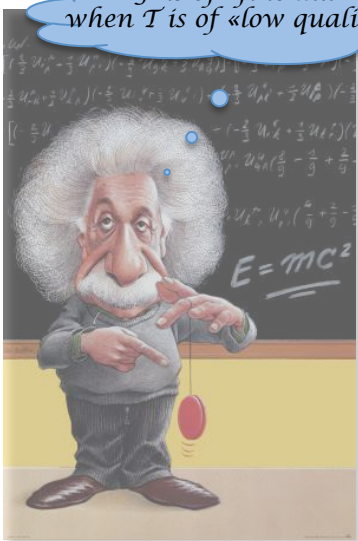
$$\vec{\chi} = \frac{1}{2K_2} \left[n \frac{d\vec{p}}{dt} - \left(\frac{4K_2}{3} + 2K_1 \right) \overrightarrow{\text{grad}} \tau - \overrightarrow{\text{grad}} F^{el} \right]$$

$$\vec{\chi} = -\overrightarrow{\text{rot}} \vec{\omega}^{el} + \vec{\lambda}$$

$$\text{div} \vec{\chi} = \frac{1}{2K_2} \left[\text{div} \left(n \frac{d\vec{p}}{dt} \right) - \left(\frac{4K_2}{3} + 2K_1 \right) \Delta \tau - \Delta F^{el} \right] = \text{div} \vec{\lambda} = \theta$$

Newton equation of the lattice!

G is of «fine marble»,
when T is of «low quality wood»!



Albert Einstein
(1879-1955)



1/ Analogy with the general relativity:

- curvature equations with curvature tensors and energy-momentum tensors
- divergence of the curvature tensors -> motion equations

2/ For the external observer GO, who owns an universal clock,
the lattice curvature is purely spatial

3/ For the local observers HS, who own local clocks,
the curvature has to be a space-time curvature

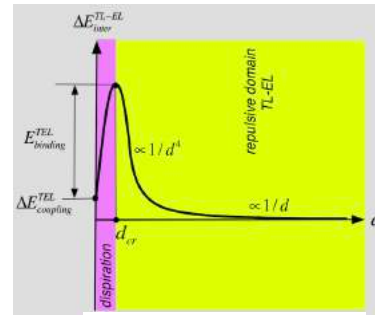
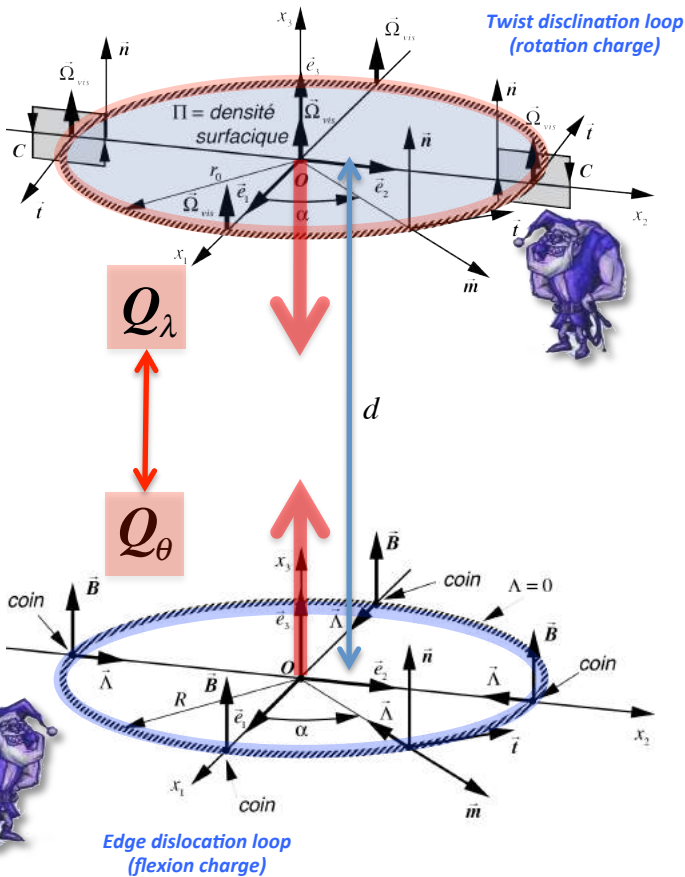
4/ The concept of curvature charge is COMPLETELY NEW,
as it does not exist in general relativity

Weak interaction in the case of a dispiration formed by a twist disclination loop associated to an edge dislocation loop

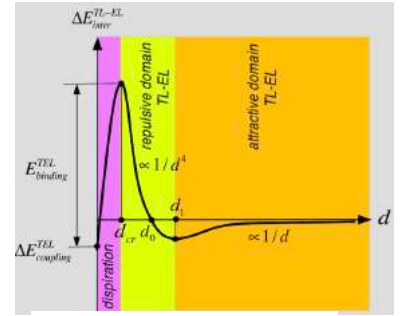
Combination of a twist disclination loop with an edge dislocation loop to form a dispiration loop



Weak interaction capture potential between Q_λ and Q_θ with a very short range



Twist disclination loop with interstitial type edge dislocation loop

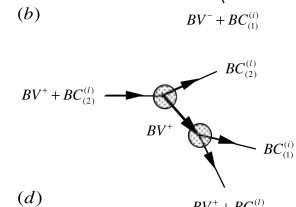
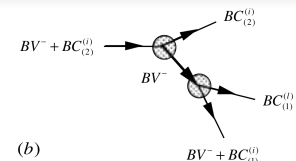
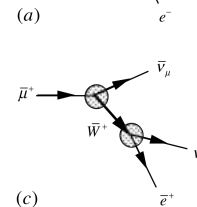
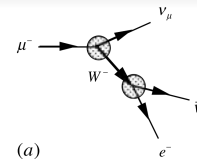


Twist disclination loop with vacancy type edge dislocation loop



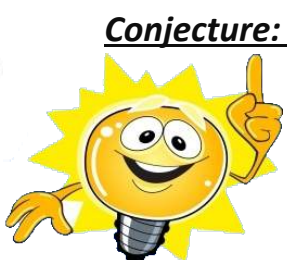
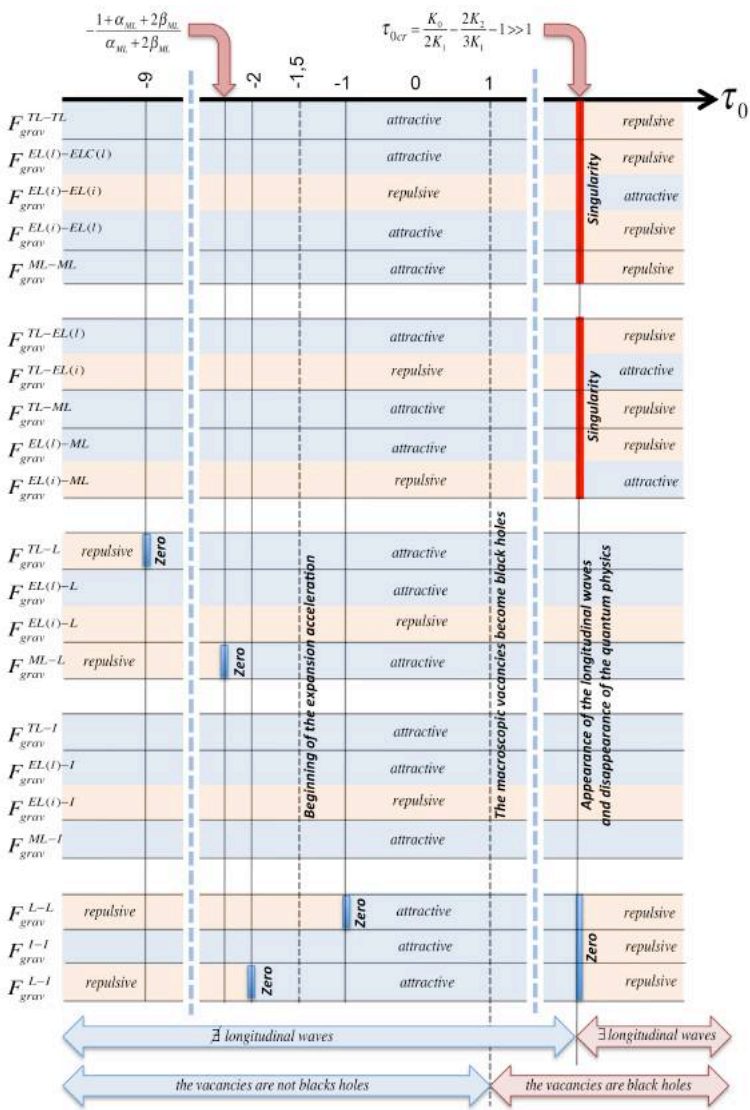
1/ Analogy with the weak interaction force of the standard model of particles

2/ The weak interaction is strongly associated to the gravitational interaction between a flexion charge and a rotation charge



Hierarchy of the gravitational interactions

Behaviours of the gravitational interaction forces as a function of the lattice expansion background



Hierarchy of the gravitational interactions (effects of the curvature mass associated to the flexion charge)

- $X \Rightarrow$ particles (dispirations containing interstitial edge dislocation loop)
- $\bar{X} \Rightarrow$ anti-particle (dispirations containing vacancy edge dislocation loop)
- $v^0 \Rightarrow$ neutrino (pure interstitial edge dislocation loop)
- $\bar{v}^0 \Rightarrow$ anti-neutrino (pure vacancy edge dislocation loop)

$$\left\{ \begin{array}{l} M_0^X = M_0^{\bar{X}} > 0 \\ M_{courbure}^{\bar{X}} > 0 ; M_{courbure}^X < 0 \\ |M_{courbure}^X| = M_{courbure}^{\bar{X}} \ll M_0^X = M_0^{\bar{X}} \end{array} \right. \quad \left\{ \begin{array}{l} M_0^{v^0} = M_0^{\bar{v}^0} > 0 \\ M_{courbure}^{v^0} > 0 ; M_{courbure}^{\bar{v}^0} < 0 \\ |M_{courbure}^{v^0}| = M_{courbure}^{\bar{v}^0} \gg M_0^{v^0} = M_0^{\bar{v}^0} \end{array} \right.$$

$$\left\{ \begin{array}{l} F_{grav}^{X-X} \lesssim F_{grav}^{X-\bar{X}} \lesssim F_{grav}^{\bar{X}-\bar{X}} \\ F_{grav}^{X-Y} \lesssim F_{grav}^{\bar{X}-Y} \cong F_{grav}^{X-\bar{Y}} \lesssim F_{grav}^{\bar{X}-\bar{Y}} \\ F_{grav}^{v^0-v^0} < 0 ; F_{grav}^{\bar{v}^0-\bar{v}^0} > 0 ; F_{grav}^{v^0-\bar{v}^0} \cong 0 ; F_{grav}^{v^0-v^0} = -F_{grav}^{\bar{v}^0-\bar{v}^0} \\ F_{grav}^{X-v^0} < 0 ; F_{grav}^{X-\bar{v}^0} \cong 0 ; F_{grav}^{\bar{X}-v^0} \cong 0 ; F_{grav}^{\bar{X}-\bar{v}^0} > 0 \end{array} \right.$$



1/ The interactions v^0-v^0 and $X-v^0$ with a neutrino are repulsive!!!

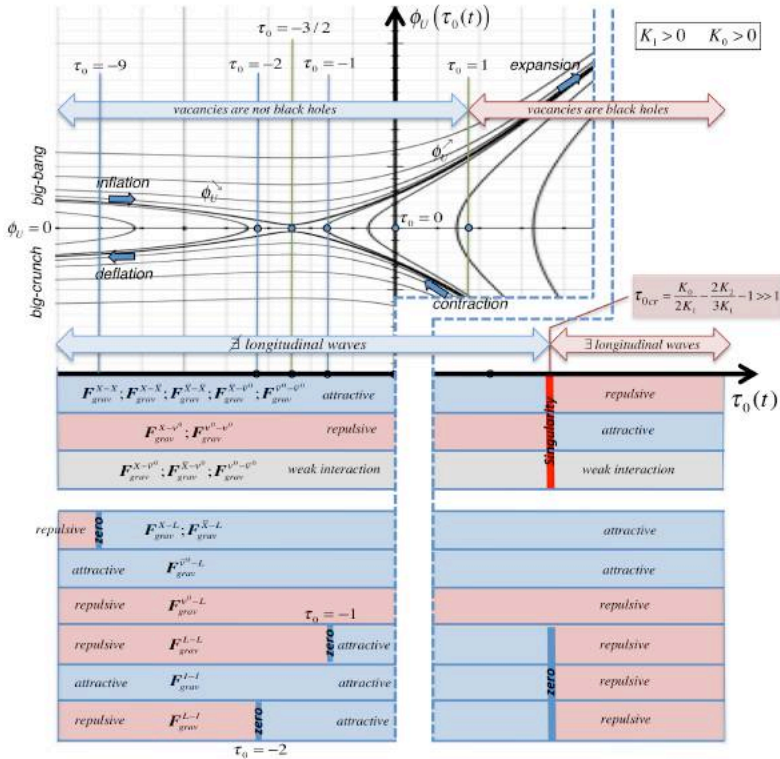
2/ All the other interactions are attractive (or very small)

3/ Attractive interaction between particles is slightly lower than attractive interaction between anti-particles

4/ The slight assymetry existing between matter and anti-matter is due to the flexion charge of the edge dislocation loops (which DOES NOT EXIST in all other theories!)

Plausible scenario of cosmological evolution of matter in our universe

Stages of cosmologic expansion of the lattice



1/ big-bang

2/ inflation and hypothetic solidification of the lattice with formation of numerous topological singularities

3/ annihilation of topological singularities with formation of photons coupled to the topological singularities

4/ condensation of the remaining topological loops in particles and anti-particles

5/ decoupling of matter and photons to form the cosmic microwave background

6/ phase transition by precipitation of clusters of particles and anti-particles to form galaxies inside a sea of repulsive neutrinos

7/ segregation of the anti-matter in the center of the galaxies due to the slightly higher gravity of anti-matter

8/ under gravity, collapse of the anti-matter nucleus in gigantic black holes (macroscopic vacancies) in the center of galaxies

9/ evolution of the remaining matter to form the stars and planet systems

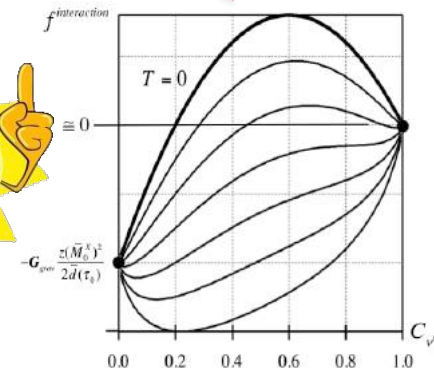
10/ under gravity, collapse of stars of matter to form pulsars (macroscopic interstitial clusters)

1/ Explains the formation of the galaxies and of gigantic black holes in the center of the galaxies

2/ Explains the disappearance of anti-matter inside the universe

3/ Explains the «dark matter»: the repulsive neutrino sea acts as a strong pressure on the galaxy periphery

4/ Explains simply the Hubble constant, the galaxy redshift and the cooling of the cosmic microwave background

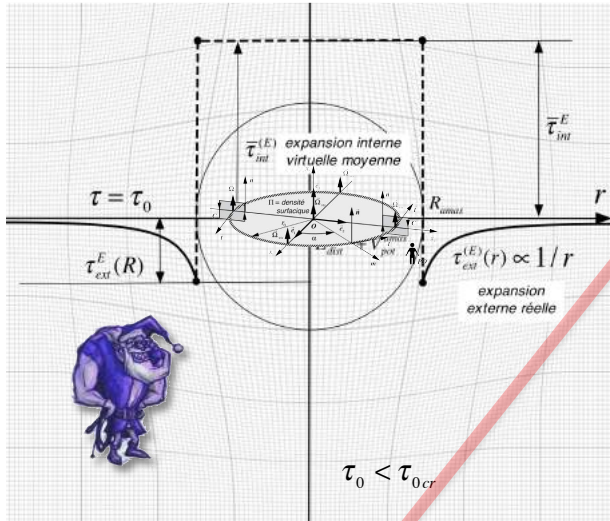


II D - Quantum physics and standard model of particles

Gravitational fluctuations of the expansion field associated to a mobile singularity

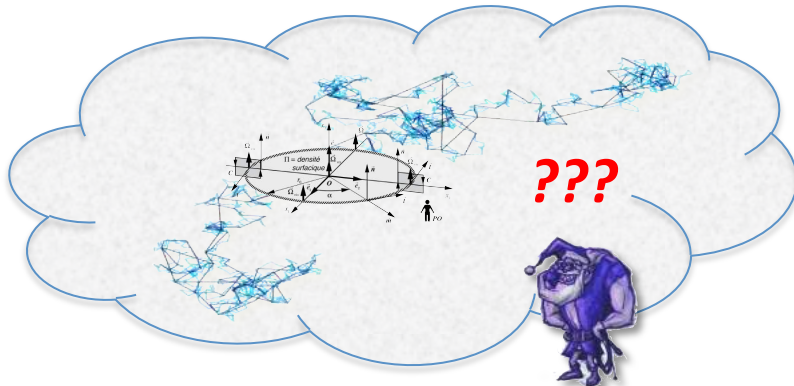
Immobile singularity

=> static external gravitational field



Mobile singularity

=> dynamic external gravitational field



Second partial Newton equation
(in the dynamic case)

$$\frac{\partial^2 \tau^{(p)}}{\partial t^2} \cong -\frac{K_0}{mn} \Delta \tau^{(p)} = -c_i^2 \Delta \tau^{(p)}$$

Dynamic solution

$$\underline{\tau}^{(p)}(\vec{r}, t) \cong \underline{\psi}(\vec{r}, t) e^{\pm i\omega_f(\vec{r}, t)t}$$

Wave equation for the amplitude and phase of the dynamic fluctuations of the gravitational field,

which

should contain information on relativistic energy and relativistic momentum of the singularity

$$\frac{\partial^2 \underline{\psi}}{\partial t^2} \pm 2i\omega_f \frac{\partial \underline{\psi}}{\partial t} - \omega_f^2 \underline{\psi} \cong -c_i^2 \Delta \underline{\psi}$$

Conjecture:

Use « a priori » the quantum physics operators with the relativistic dynamic relations

$$\left\{ \begin{array}{l} -\hbar^2 \frac{\partial^2}{\partial t^2} \underline{\psi} \rightarrow E_v^2 \underline{\psi} \\ -\hbar^2 \Delta \underline{\psi} \rightarrow \vec{P}_v^2 \underline{\psi} \end{array} \right.$$

$$\left\{ \begin{array}{l} E_v = \frac{M_0 c_i^2}{\gamma} = \frac{E_0^{dist} + V(\vec{r}, t)}{\gamma} \\ M_0 c_i^2 = E_0^{dist} + V(\vec{r}, t) \\ \vec{P}_v = \frac{M_0 \vec{v}}{\gamma} = \frac{E_0^{dist} + V(\vec{r}, t)}{\gamma c_i^2} \vec{v} \end{array} \right. \quad \gamma = \sqrt{1 - \frac{\vec{v}^2}{c_i^2}}$$

$$\hbar \omega_f = \pm \frac{E_0^{dist} + V(\vec{r}, t)}{\gamma} \left(1 \pm i \frac{\vec{v}}{c_i} \right)$$

Complex frequency of the gravitational fluctuations, and relativistic wave equation (different from Dirac equation!)

$$\hbar^2 \frac{\partial^2 \underline{\psi}}{\partial t^2} + 2 \frac{E_0^{dist} + V(\vec{r}, t)}{\gamma} \left(1 \pm i \frac{\vec{v}}{c_i} \right) i \hbar \frac{\partial \underline{\psi}}{\partial t} - \frac{(E_0^{dist} + V(\vec{r}, t))^2}{\gamma^2} \left(1 \pm i \frac{\vec{v}}{c_i} \right)^2 \underline{\psi} \cong -c_i^2 \hbar^2 \Delta \underline{\psi}$$

Solution for a relativistic quasi-free singularity

$$\tau_{\text{réel}}^{(p)}(\vec{r}, t) \equiv \psi_0 e^{-\frac{1}{\hbar c_t \gamma} (E_0^{\text{dist}} + V(\vec{r}, t)) |x_2 \mp \mathbf{v}|} \cos \left[\frac{1}{\hbar \gamma} (E_0^{\text{dist}} + V(\vec{r}, t)) t \right] \cos \left[\frac{1}{\hbar \gamma} (E_0^{\text{dist}} + V(\vec{r}, t)) \frac{\mathbf{v}}{c_t^2} x_2 \right] \mp \psi_0 e^{-\frac{1}{\hbar c_t \gamma} (E_0^{\text{dist}} + V(\vec{r}, t)) |x_2 \mp \mathbf{v}|} \sin \left[\frac{1}{\hbar \gamma} (E_0^{\text{dist}} + V(\vec{r}, t)) t \right] \sin \left[\frac{1}{\hbar \gamma} (E_0^{\text{dist}} + V(\vec{r}, t)) \frac{\mathbf{v}}{c_t^2} x_2 \right]$$

Oscillations with a frequency, a wave length and a range which depend on the relativistic velocity:

$$f = \frac{E_0^{\text{dist}} + V(\vec{r}, t)}{2\pi \hbar \gamma} = \frac{E_0^{\text{dist}} + V(\vec{r}, t)}{2\pi \hbar \sqrt{1 - \vec{v}^2 / c_t^2}} \quad \lambda = \frac{2\pi \hbar c_t^2 \gamma}{(E_0^{\text{dist}} + V(\vec{r}, t)) \mathbf{v}} = \frac{2\pi \hbar c_t^2}{(E_0^{\text{dist}} + V(\vec{r}, t)) \mathbf{v}} \sqrt{1 - \vec{v}^2 / c_t^2} \quad \delta = \frac{\hbar c_t \gamma}{E_0^{\text{dist}} + V(\vec{r}, t)} = \frac{\hbar c_t}{E_0^{\text{dist}} + V(\vec{r}, t)} \sqrt{1 - \vec{v}^2 / c_t^2}$$

Schrödinger equation for a non-relativistic singularity submitted to a potential

$$\gamma = \sqrt{1 - \frac{\vec{v}^2}{c_t^2}} \rightarrow 1 \quad \& \quad \hbar^2 \frac{\partial^2 \underline{\psi}}{\partial t^2} = -E_v^2 \underline{\psi} \rightarrow -(E_0^{\text{dist}} + V(\vec{r}, t))^2 \underline{\psi} \Rightarrow \text{Schrödinger equation} \quad i\hbar \frac{\partial \underline{\psi}}{\partial t} \equiv -\frac{\hbar^2}{2M_0} \Delta \underline{\psi} + (E_0^{\text{dist}} + V(\vec{r}, t)) \underline{\psi}$$

Justify « a fortiori » the conjecture of using the quantum physics operators with the relativistic dynamic relations

$$\underline{\tau}^{(p)}(\vec{r}, t) \equiv \underline{\psi}(\vec{r}, t) e^{\pm i\omega_f(\vec{r}, t)t} \equiv \underline{\psi}(\vec{r}, t) e^{\pm \frac{E_0^{\text{dist}} + V(\vec{r}, t)}{\hbar} t}$$

Oscillations of the dynamic gravitational field



Erwin Schrödinger
(1887-1961)



1/ The schrödinger equation is a wave equation deduced from the second partial Newton equation of the cosmic lattice

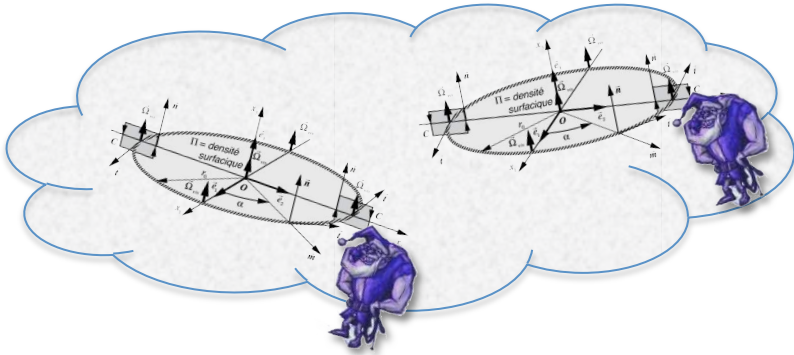
2/ It allows one to calculate the amplitude and the phase of the gravitational fluctuations of frequency $\omega_f(\vec{r}, t)$ associated to a non-relativistic moving singularity submitted to a potential

3/ All the well known consequences of quantum physics can be applied: stationary wave equation, commutators, uncertainty principle of Heisenberg, probabilistic interpretation of the wave function, etc.

Stationary state of two coupled mobile singularities

$$\begin{cases} -\frac{\hbar^2}{2M_0} \Delta \underline{\psi}_n(\vec{r}_a) + V(\vec{r}_a) \underline{\psi}_n(\vec{r}_a) = E_n \underline{\psi}_n(\vec{r}_a) \\ -\frac{\hbar^2}{2M_0} \Delta \underline{\psi}_m(\vec{r}_b) + V(\vec{r}_b) \underline{\psi}_m(\vec{r}_b) = E_m \underline{\psi}_m(\vec{r}_b) \end{cases}$$

Stationary Schrödinger equations



Stationary coupled Schrödinger equation

$$-\frac{\hbar^2}{2M_0} \Delta [\underline{\psi}_n(\vec{r}_a) \underline{\psi}_m(\vec{r}_b)] + [V(\vec{r}_a) + V(\vec{r}_b)] \underline{\psi}_n(\vec{r}_a) \underline{\psi}_m(\vec{r}_b) = (E_n + E_m) \underline{\psi}_n(\vec{r}_a) \underline{\psi}_m(\vec{r}_b)$$

$$\underline{\tau}(\vec{r}_a, \vec{r}_b, t) = \underline{\psi}_n(\vec{r}_a) e^{\pm i\omega_f(\vec{r}_a)t} \underline{\psi}_m(\vec{r}_b) e^{\pm i\omega_f(\vec{r}_b)t} = \underline{\psi}_n(\vec{r}_a) e^{\pm i\frac{1}{\hbar}(E_0^{dist} + V(\vec{r}_a))t} \underline{\psi}_m(\vec{r}_b) e^{\pm i\frac{1}{\hbar}(E_0^{dist} + V(\vec{r}_b))t}$$

Two possible solutions for the gravitational fluctuations with frequency oscillations:

$$\begin{cases} \underline{\tau}_{boson}(\vec{r}_a, \vec{r}_b, t) = \underline{\psi}_n(\vec{r}_a) \underline{\psi}_m(\vec{r}_b) e^{\pm i\frac{1}{\hbar}(2E_0^{dist} + V(\vec{r}_a) + V(\vec{r}_b))t} \\ \underline{\tau}_{fermion}(\vec{r}_a, \vec{r}_b, t) = \underline{\psi}_n(\vec{r}_a) \underline{\psi}_m(\vec{r}_b) e^{\pm i\frac{1}{\hbar}(V(\vec{r}_a) - V(\vec{r}_b))t} \end{cases}$$

$$\begin{cases} \omega_{boson}(\vec{r}_a, \vec{r}_b) = \pm \frac{1}{\hbar} (2E_0^{dist} + V(\vec{r}_a) + V(\vec{r}_b)) \rightarrow \pm \frac{2E_0^{dist}}{\hbar} \text{ si } \vec{r}_a \rightarrow \vec{r}_b \\ \omega_{fermion}(\vec{r}_a, \vec{r}_b) = \pm \frac{1}{\hbar} (V(\vec{r}_a) - V(\vec{r}_b)) \rightarrow 0 \text{ si } \vec{r}_a \rightarrow \vec{r}_b \rightarrow \text{impossible} \end{cases}$$

1/ There are two possible solutions for the gravitational perturbations of two coupled singularities: **the bosons solution and the fermions solution**

2/ For the fermions solution, superposition of the two singularities is impossible because the gravitational fluctuations will disappear in this case!
=> **Pauli exclusion principle for the fermions solution**

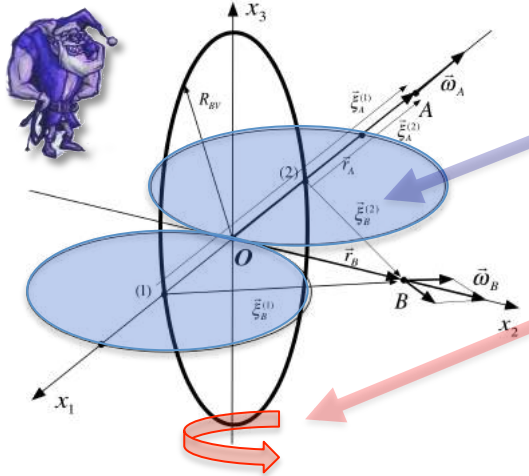
3/ All the well known consequences of quantum physics can be applied: **indiscernability principle, symmetric and antisymmetric solutions, etc.**



Dynamic internal gravitational field of a singularity: **the spin of the singularity**

Second partial Newton equation
(in the static case)

$$K_1 (\tau^{(p)}(\vec{r}))^2 + [4K_2/3 + 2K_1(1 + \tau_0 + \tau^{ext}(\vec{r}) + \tau^{ch}(\vec{r})) - K_0] \tau^{(p)}(\vec{r}) + (F_{dist}^{ch}(\vec{r}) + F_{pot}^{ch}(\vec{r})) = cste = 0$$



There is no static solution
in the heart of the singularity if:

$$K_1 > K_{1cr} = K_0 \frac{2\pi^4 R_{BV}^2}{q_{\lambda BV}^2} \cong 10^{-21}$$

Need for a dynamic solution:
rotation of the loop around a diameter



Solution of the stationary
Schrödinger equation:

$$\begin{cases} \epsilon_j = \frac{\hbar^2}{2I} j(j+1) \\ m_z = j, j-1, \dots, 1-j, -j \end{cases}$$

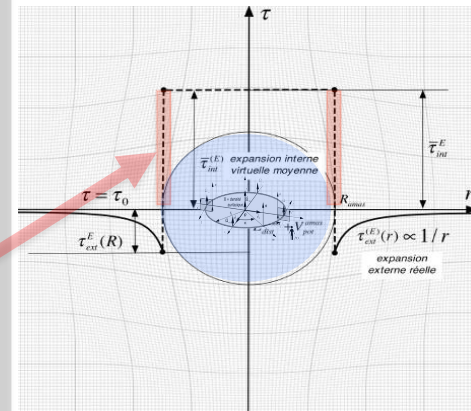
**Quantification of the angular momentum
and the magnetic momentum of the loop,**
with right value of the Bohr magneton!

$$\begin{cases} E_{rotation BV}^{cin} = \hbar^2 j(j+1) / 2I_{BV} \\ |\vec{L}_{BV}| = \sqrt{2I_{BV} E_{rotation BV}^{cin}} = \hbar \sqrt{j(j+1)} \\ L_z = \hbar m_z \end{cases} \Leftrightarrow \begin{cases} I_{BV} = \delta_1 \frac{M_0^{BV} R_{BV}^2}{4} \\ \vec{\mu}_{BVz} \cong \underbrace{g_{BV}}_{\cong 2} \frac{\hbar q_{\lambda BV}}{2M_0^{BV}} m_z \vec{e}_z \end{cases}$$

1/ No static solution for the internal gravitational field of a singularity loop if $K_1 > 10^{-21}$
=> the singularity loop has really to turn around an axis

2/ Solution of the stationary Schrödinger equation:
=> quantified spin of the singularity loop, with $j=1/2, 1, \dots$

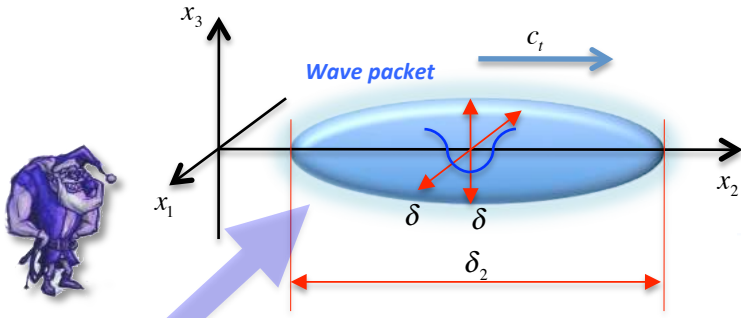
3/ The argument of the pionners of quantum physics against a real rotation of the charge
based on the fact that the equatorial velocity of the charge would be higher
than the light velocity is wrong if $K_1 < 1,8 \cdot 10^9$
due to the enormous static expansion in the vicinity of the loop.



Transversal wave packets: the photons

Transversal wave packets need helicity to present a constant energy

$$\begin{cases} \underline{\omega}_1(x_2, t) = \omega_{10} e^{\frac{|x_1|}{\delta}} e^{\frac{|x_3|}{\delta}} e^{\frac{|x_2 - ct|}{\delta_2}} e^{i\frac{\omega}{c_t}(x_2 - ct)} \\ \underline{\omega}_3(x_2, t) = \pm i\omega_{10} e^{\frac{|x_1|}{\delta}} e^{\frac{|x_3|}{\delta}} e^{\frac{|x_2 - ct|}{\delta_2}} e^{i\frac{\omega}{c_t}(x_2 - ct)} \end{cases} \quad \begin{cases} \underline{\phi}_3(x_2, t) = -2c_t\omega_{10} e^{\frac{|x_1|}{\delta}} e^{\frac{|x_3|}{\delta}} e^{\frac{|x_2 - ct|}{\delta_2}} e^{i\frac{\omega}{c_t}(x_2 - ct)} \\ \underline{\phi}_1(x_2, t) = \pm 2c_t\omega_{10} e^{\frac{|x_1|}{\delta}} e^{\frac{|x_3|}{\delta}} e^{\frac{|x_2 - ct|}{\delta_2}} e^{i\frac{\omega}{c_t}(x_2 - ct)} \end{cases}$$



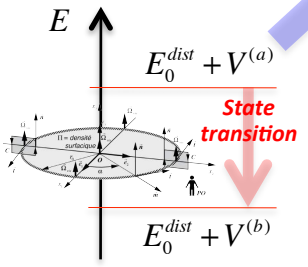
Constant energy of the wave packet with helicity

$$E^{fluctuation} = 4K_3\omega_{10}^2\delta^2\delta_2$$

$$\Delta E_{perdue} = E_0^{dist} + V^{(a)} - (E_0^{dist} + V^{(b)}) = V^{(a)} - V^{(b)} = \hbar\omega_f^{(a)} - \hbar\omega_f^{(b)} = \hbar(\omega_f^{(a)} - \omega_f^{(b)})$$

Energy of formation

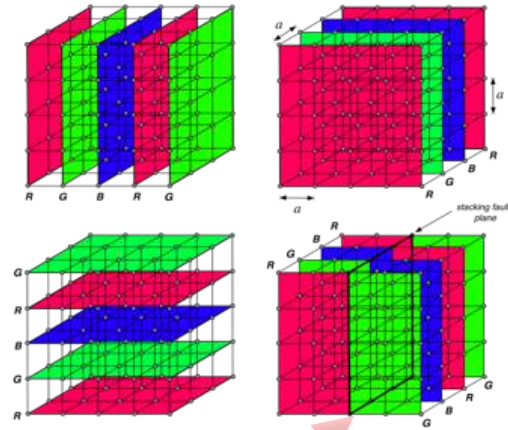
$$E^{fluctuation} = 4K_3\omega_{10}^2\delta^2\delta_2 = \hbar(\omega_f^{(a)} - \omega_f^{(b)}) = \hbar\omega_{fluctuation}$$



- 1/ A constant energy of the wave packet needs helicity
=> energy of the wave packet depends on packet physical dimensions and wave amplitude
- 2/ The energy of formation is related to a state transition of a topological singularity
=> quantified energy of the wave packet proportional to the frequency of the wave
- 3/ there is a « plasticity » of the physical dimensions of the wave packet
=> explanations of non-locality, momentum, wave-particle duality, diffraction, interference, entanglement, decoherence, etc.



Standard model of elementary particles: a « coloured » cubic lattice



1/ Introduce a « coloured » cubic lattice with three simple rules concerning the alternance and the rotation of the coloured planes

The three rules

Rule 1: the alternation of planes R, G, B cannot be broken (either by impossibility or by a very large energy associated with a surface stacking fault energy),

Rule 2: in a given direction of space, there may appear a stacking fault corresponding to a shift in the alternation of planes R, G, B, which possesses a surface stacking fault energy which is not null.

Rule 3: if a plane with a given color undergoes a rotation by an angle, or it changes color according to table 31.1, which corresponds to the existence of a given axial property of the lattice. |



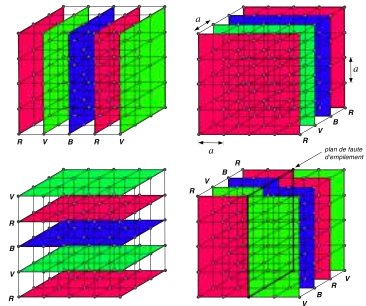
Stacking fault energy

rotation angle Ω_{TL}	color change	colors R, G, B and complementary colors $\bar{R}, \bar{G}, \bar{B}$
$\left\{ \begin{array}{l} +3\pi/2 \\ 0 \\ -3\pi/2 \end{array} \right.$	$\left\{ \begin{array}{l} R \rightarrow R \\ G \rightarrow G \\ B \rightarrow B \end{array} \right.$	
$\left\{ \begin{array}{l} +\pi/2 \\ -\pi \end{array} \right.$	$\left\{ \begin{array}{l} R \rightarrow G \\ G \rightarrow B \\ B \rightarrow R \end{array} \right.$	
$\left\{ \begin{array}{l} -\pi/2 \\ +\pi \end{array} \right.$	$\left\{ \begin{array}{l} R \rightarrow B \\ G \rightarrow R \\ B \rightarrow G \end{array} \right.$	



Steven Weinberg, Abdus Salam and Sheldon Glashow

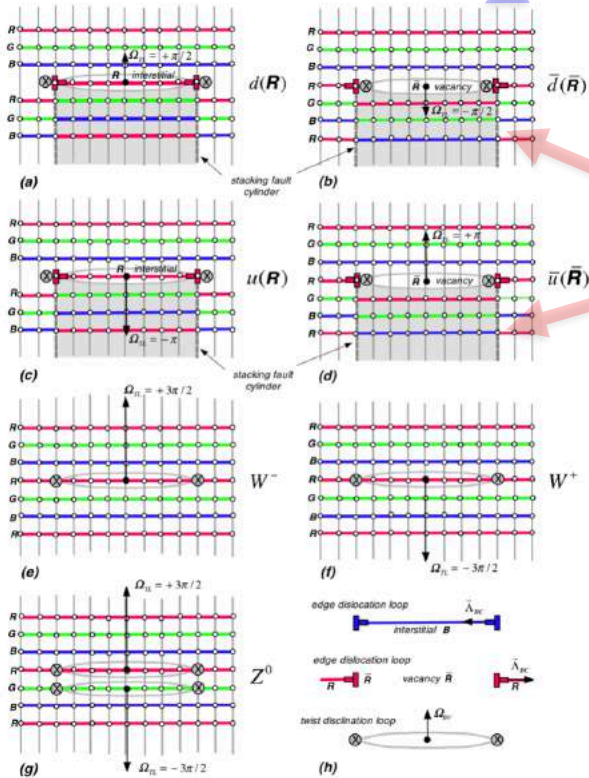
Standard model of elementary particles: **quarks and leptons**



2/ Combine edge dislocation loops and screw disclination loops

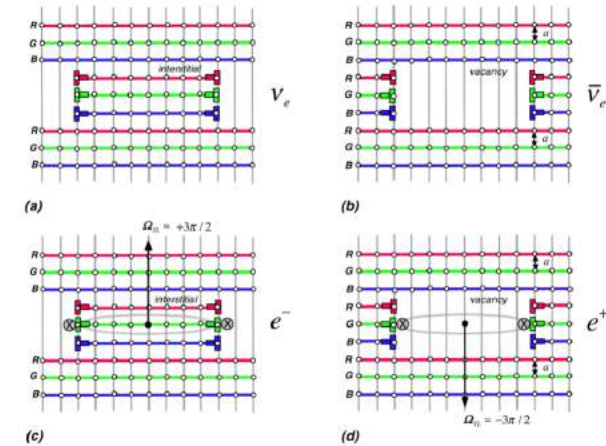
quarks
gauge bosons

leptons



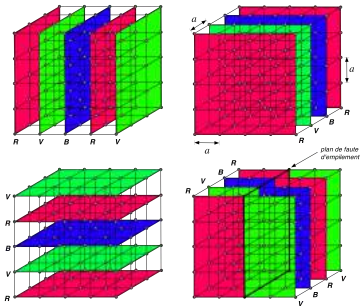
Stacking fault energy

name	Ω_{TL}	$q_{\Delta TL}$	edge loop	$q_{\theta EL}$	color
d	$+\pi/2$	$-\pi^2 R_{TL}^2/2$	interstitial	$-2\pi a$	R, G or B
\bar{d}	$-\pi/2$	$+\pi^2 R_{TL}^2/2$	vacancy	$+2\pi a$	\bar{R}, \bar{G} or \bar{B}
u	$-\pi$	$+\pi^2 R_{TL}^2$	interstitial	$-2\pi a$	R, G or B
\bar{u}	$+\pi$	$-\pi^2 R_{TL}^2$	vacancy	$+2\pi a$	\bar{R}, \bar{G} or \bar{B}
W^-	$+3\pi/2$	$-3\pi^2 R_{TL}^2/2$	-	0	-
W^+	$-3\pi/2$	$+3\pi^2 R_{TL}^2/2$	-	0	-
Z^0	$(+3\pi/2)+(-3\pi/2)$	0	-	0	-



symbol	Ω_{TL}	$q_{\Delta TL}$	edge loop	$q_{\theta EL}$
ν_e	$+3\pi/2$	0	interstitial	$-6\pi a$
$\bar{\nu}_e$	$-3\pi/2$	0	vacancy	$6\pi a$
e^-	0	$-3\pi^2 R_{TL}^2/2$	interstitial	$-6\pi a$
e^+	-3π	$+3\pi^2 R_{TL}^2/2$	vacancy	$6\pi a$
W^-	$+3\pi/2$	$-3\pi^2 R_{TL}^2/2$	-	0
W^+	$-3\pi/2$	$+3\pi^2 R_{TL}^2/2$	-	0
Z^0	$(+3\pi/2)+(-3\pi/2)$	0	-	0

Standard model of elementary particles: **baryons, mesons and strong interaction**

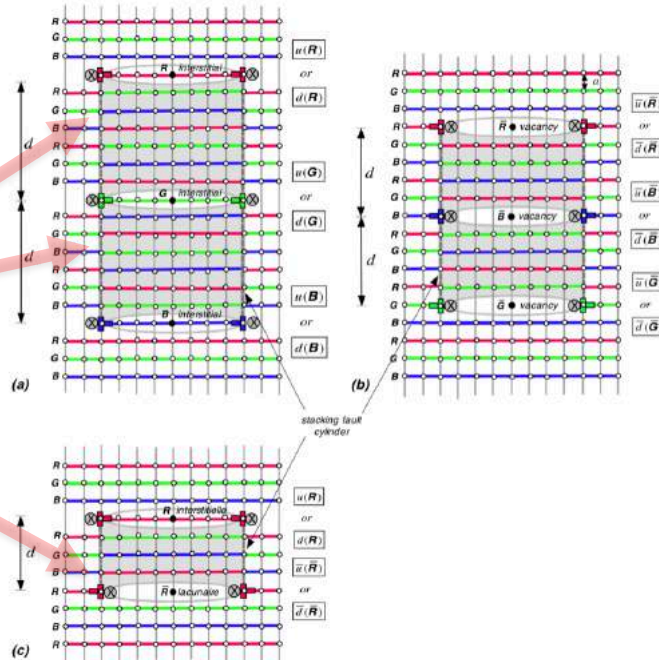


3/ Combine two or three dispiration loops (quarks)

baryons and mesons
strong interactions



Stacking fault energy
=> strong interaction

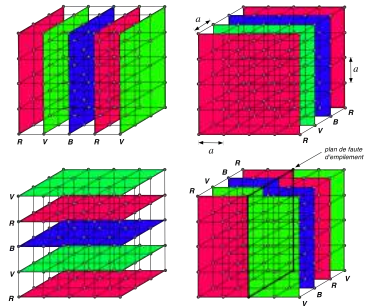


combination	symbol	Ω_{TL}	$q_{\lambda TL}$	edge loop	$q_{\theta EL}$
ddd	Δ^-	$+3\pi/2$	$-3\pi^2 R_{TL}^2/2$	interstitial	$-6\pi a$
dud	n, Δ^0	0	0	interstitial	$-6\pi a$
udu	p, Δ^+	$-3\pi/2$	$+3\pi^2 R_{TL}^2/2$	interstitial	$-6\pi a$
uuu	Δ^{++}	-3π	$+3\pi^2 R_{TL}^2$	interstitial	$-6\pi a$
$\bar{d}\bar{d}\bar{d}$	$\bar{\Delta}^+$	$-3\pi/2$	$+3\pi^2 R_{TL}^2/2$	vacancy	$6\pi a$
$\bar{d}\bar{u}\bar{d}$	$\bar{n}, \bar{\Delta}^0$	0	0	vacancy	$6\pi a$
$\bar{u}\bar{d}\bar{u}$	$\bar{p}, \bar{\Delta}^-$	$+3\pi/2$	$-3\pi^2 R_{TL}^2/2$	vacancy	$6\pi a$
$\bar{u}\bar{u}\bar{u}$	$\bar{\Delta}^-$	$+3\pi$	$-3\pi^2 R_{TL}^2$	vacancy	$6\pi a$

combination	symbol	Ω_{TL}	$q_{\lambda TL}$	edge loop	$q_{\theta EL}$
$d\bar{d}$	π^0, ρ^0	0	0	-	0
$d\bar{u}$	π^-, ρ^-	$+3\pi/2$	$-3\pi^2 R_{TL}^2/2$	-	0
$\bar{d}u$	π^+, ρ^+	$-3\pi/2$	$+3\pi^2 R_{TL}^2/2$	-	0
$u\bar{u}$	η^0, ω^0	0	0	-	0

Standard model of elementary particles: *gluons, strong and weak interactions*

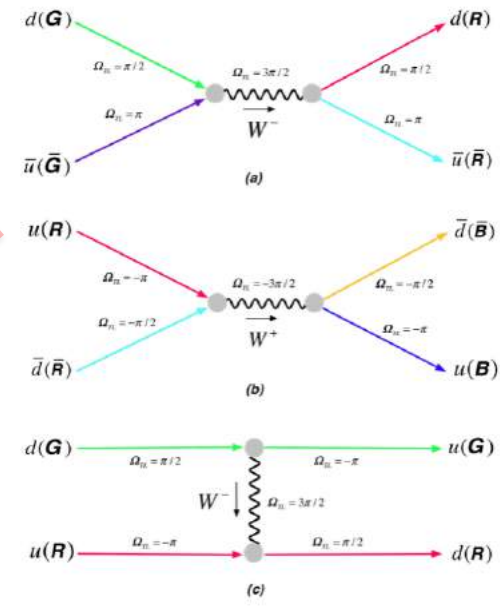
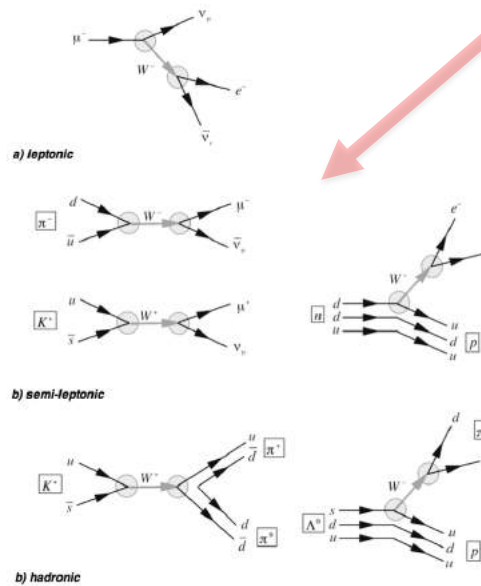
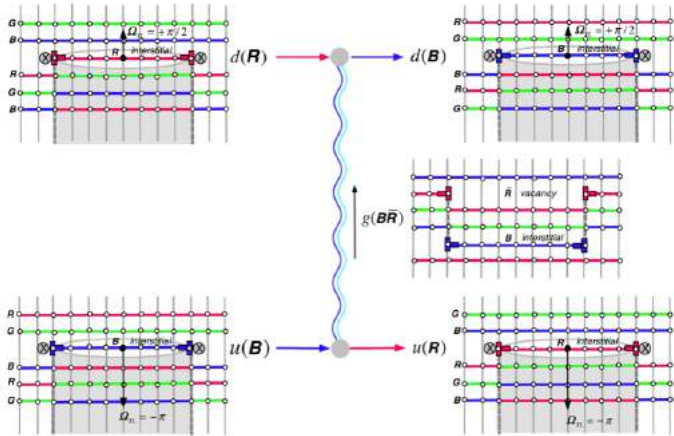
4/ Exchange edge dislocation loops or twist disclination loops



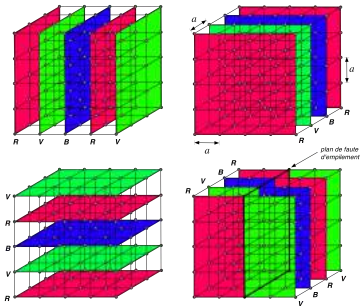
gluons
strong interactions



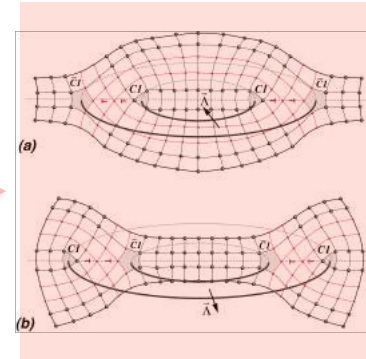
gauge bosons
weak interactions



Standard model of elementary particles: the three families of particles



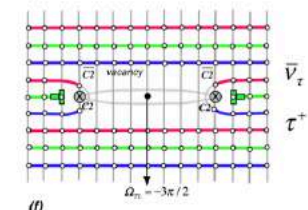
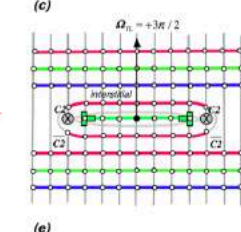
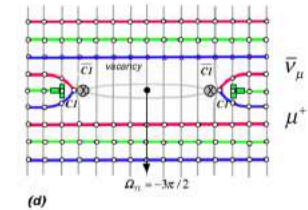
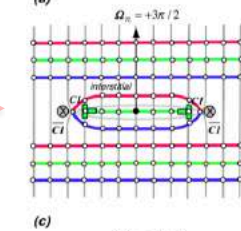
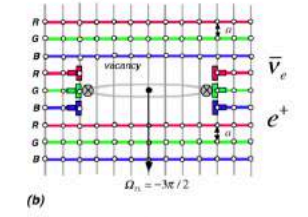
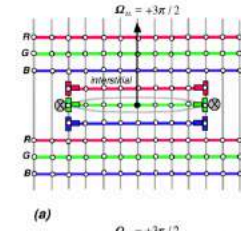
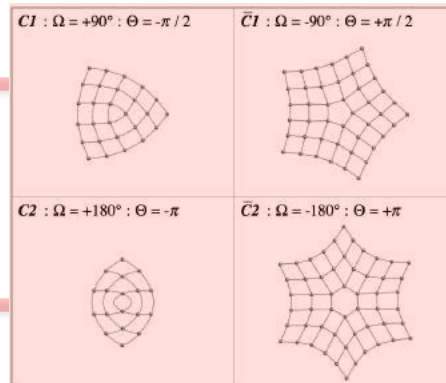
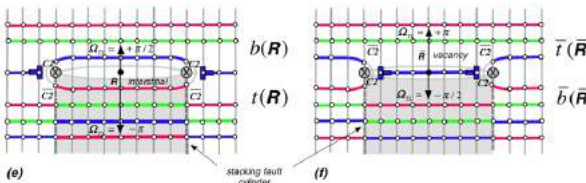
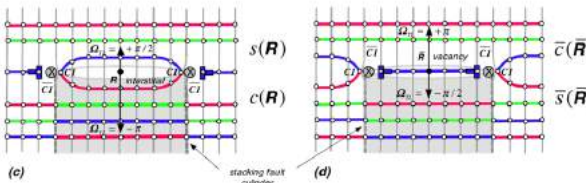
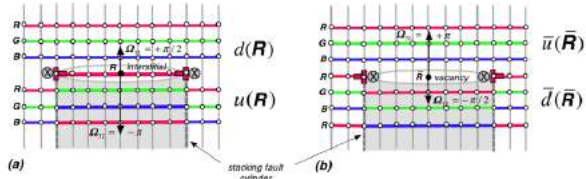
5/ Replace edge dislocation loops by wedge disclination loops



three families of quarks

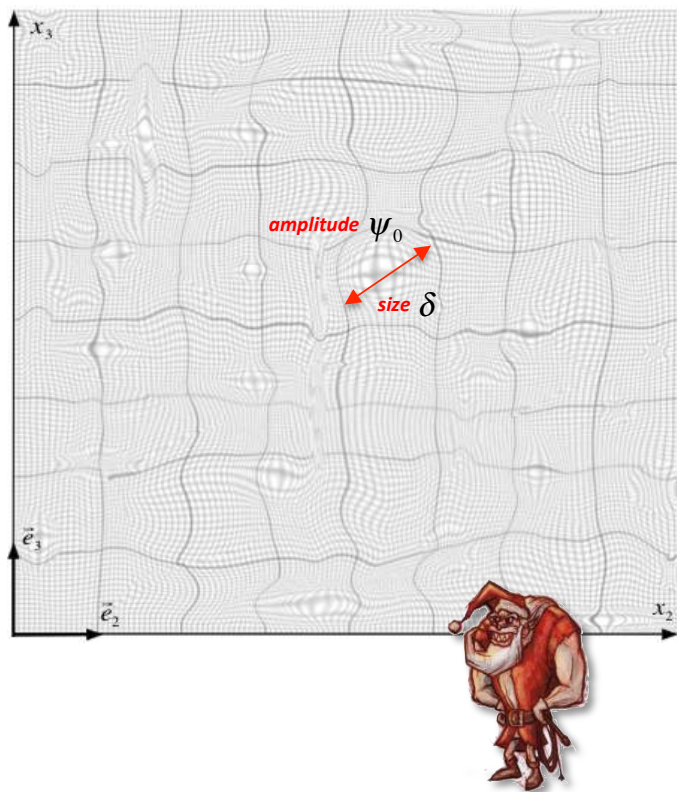


three families of leptons



II E - Some other hypothetical consequences of the cosmic lattice

Gravitational fluctuations of the expansion: quantum vacuum state



Distortion energy of each fluctuation

$$E^{\text{fluctuation}}(t) \equiv E^{\text{dist}}(t) \equiv -8K_0\psi_0\delta^3 \cos\omega t$$

Superposition of numerous fluctuations

$$\tau^{(p)}(\vec{r}, t) = \sum_k \psi_{0k} e^{\frac{|x_1-x_{1k}|}{\delta_{1k}}} e^{\frac{|x_2-x_{2k}|}{\delta_{2k}}} e^{\frac{|x_3-x_{3k}|}{\delta_{3k}}} e^{-i(\omega_k t + \varphi_k)}$$

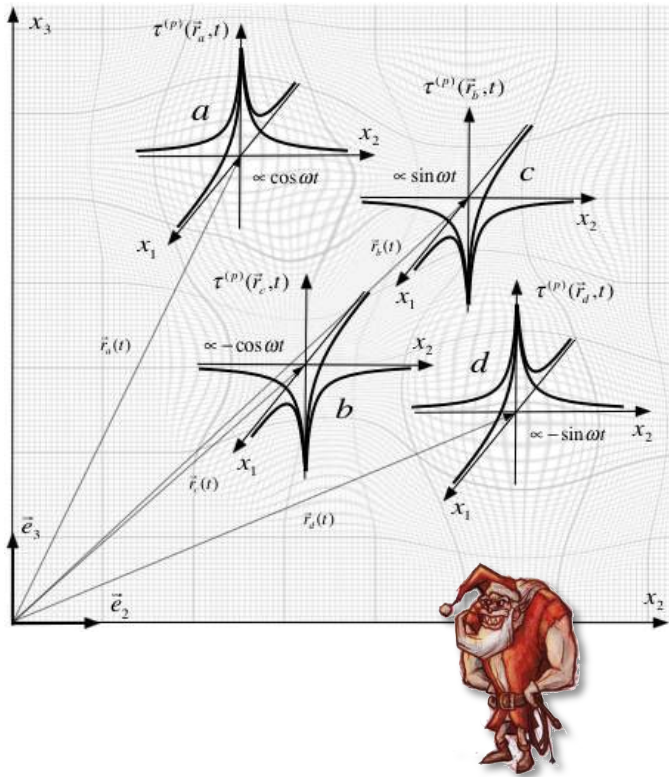
Zero average energy of all fluctuations

$$\langle E^{\text{fluctuation}}(t) \rangle = 0$$



1/ It could exist gravitational fluctuations of the expansion field with zero average energy (corresponding to **distortion energy**)
=> analogy with quantum vacuum state

Stable gravitational fluctuations of the expansion: **multiverses and gravitons**



Coupling of four gravitational fluctuations

$$\tau^{(p)}(\vec{r}, t) \equiv \begin{bmatrix} +\Psi_{0a} e^{\frac{|x_1-x_{a1}(t)|}{\delta_{a1}}} e^{\frac{|x_2-x_{a2}(t)|}{\delta_{a2}}} e^{\frac{|x_3-x_{a3}(t)|}{\delta_{a3}}} \cos \omega t - \Psi_{0b} e^{\frac{|x_1-x_{b1}(t)|}{\delta_{b1}}} e^{\frac{|x_2-x_{b2}(t)|}{\delta_{b2}}} e^{\frac{|x_3-x_{b3}(t)|}{\delta_{b3}}} \cos \omega t \\ \pm \Psi_{0c} e^{\frac{|x_1-x_{c1}(t)|}{\delta_{c1}}} e^{\frac{|x_2-x_{c2}(t)|}{\delta_{c2}}} e^{\frac{|x_3-x_{c3}(t)|}{\delta_{c3}}} \sin \omega t \mp \Psi_{0d} e^{\frac{|x_1-x_{d1}(t)|}{\delta_{d1}}} e^{\frac{|x_2-x_{d2}(t)|}{\delta_{d2}}} e^{\frac{|x_3-x_{d3}(t)|}{\delta_{d3}}} \sin \omega t \end{bmatrix}$$

Conditions for stable gravitational fluctuations with a constant energy

$$\Psi_{a0} = \Psi_{b0} = \Psi_{c0} = \Psi_{d0} = \Psi_0$$

$$\begin{cases} \delta_{a1}\delta_{a2}\delta_{a3} = \delta_{b1}\delta_{b2}\delta_{b3} = \delta_{c1}\delta_{c2}\delta_{c3} = \delta_{d1}\delta_{d2}\delta_{d3} = ABC \\ \frac{1}{\delta_{a1}^2} + \frac{1}{\delta_{a2}^2} + \frac{1}{\delta_{a3}^2} = \frac{1}{\delta_{b1}^2} + \frac{1}{\delta_{b2}^2} + \frac{1}{\delta_{b3}^2} = \frac{1}{\delta_{c1}^2} + \frac{1}{\delta_{c2}^2} + \frac{1}{\delta_{c3}^2} = \frac{1}{\delta_{d1}^2} + \frac{1}{\delta_{d2}^2} + \frac{1}{\delta_{d3}^2} = \frac{1}{A^2} + \frac{1}{B^2} + \frac{1}{C^2} \\ \delta_{a1}^2 + \delta_{a2}^2 + \delta_{a3}^2 = \delta_{b1}^2 + \delta_{b2}^2 + \delta_{b3}^2 = \delta_{c1}^2 + \delta_{c2}^2 + \delta_{c3}^2 = \delta_{d1}^2 + \delta_{d2}^2 + \delta_{d3}^2 = A^2 + B^2 + C^2 \end{cases}$$

Constant kinetic energy of the four fluctuations

$$\begin{cases} E^{\text{fluctuation}} \equiv E^{\text{cin}} \equiv \frac{K_0}{9} \Psi_0^2 ABC (A^2 + B^2 + C^2) \left(\frac{1}{A^2} + \frac{1}{B^2} + \frac{1}{C^2} \right) \\ \omega \equiv c_i \sqrt{\frac{1}{A^2} + \frac{1}{B^2} + \frac{1}{C^2}} \end{cases}$$

1/ It could exist coupled gravitational fluctuations of the expansion field with a constant energy (corresponding to **kinetic energy**)

2/ At macroscopic scale, could explain « multiverses » in an infinite cosmological lattice

2/ At microscopic scale, could correspond to stable « gravitons »



Conclusion of the second part

*pure transversal waves
coupled with longitudinal wavelets*

curvature of wave rays

special relativity

general relativity

*spatiotemporal curvature of space
for the observers \mathcal{H}*

*spatial curvature of the lattice
for the observer \mathcal{G}*

Maxwell equations

**Newton equation
of cosmological lattice**

$$n \frac{d\vec{p}}{dt} = -2(K_2 + K_3) \overline{\text{rot}} \vec{\omega}^{el} + \left(\frac{4}{3} K_2 + 2K_1 \right) \overline{\text{grad}} \tau + 2K_2 \vec{\lambda} + nm \vec{\phi}_l \frac{dC_L}{dt} - nm \vec{\phi}_l \frac{dC_L}{dt} + \overline{\text{grad}} \left(\underbrace{K_2 \sum_i (\vec{\alpha}_i^{el})^2 + K_1^{an} \sum_i (\vec{\alpha}_i^{an})^2 + 2K_3 (\vec{\omega}^{el})^2 + 2K_2^{an} (\vec{\omega}^{an})^2 + K_1 \tau^2 - K_0 \tau}_{P^{def}} \right)$$

**+ special coloured structure
of cosmological lattice**



Newtonian gravity

quantum physics

*standard model of elementary particles,
quarks, leptons, strong and weak interactions*

*relativistic and non-relativistic
Schrödinger equation*

modern cosmology

concept of spin

black holes, black matter, black energy

*bosons, fermions, uncertainty principle,
photons, gravitons, multiverses, quantum vacuum state*

exclusion principle