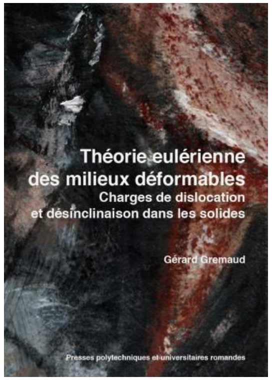
Universe and Matter conjectured as a 3-dimensional Lattice with Topological Singularities

Gérard Gremaud

2015

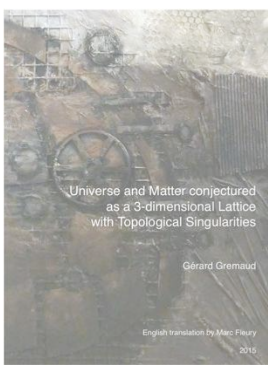
Jenny

Contents



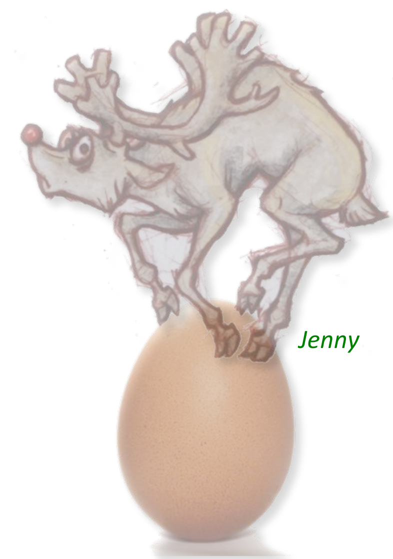
Presses polytechniques et universitaires romandes (PPUR), Lausanne, 2013, 750 pages (ISBN 978-2-88074-964-4)

Part I – Eulerian theory of deformable media



Free access e-books, http://gerardgremaud.ch Lausanne, 2015, 646 pages, (DOI: 10.13140/RG.2.1.3839.4325)

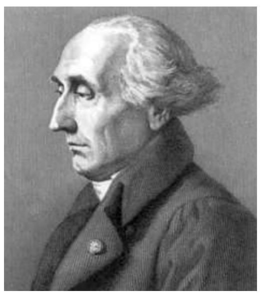
Part II – Could the universe be a 3D-lattice?



I A - Eulerian theory of newtonian deformable medias

Coordinates systems

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

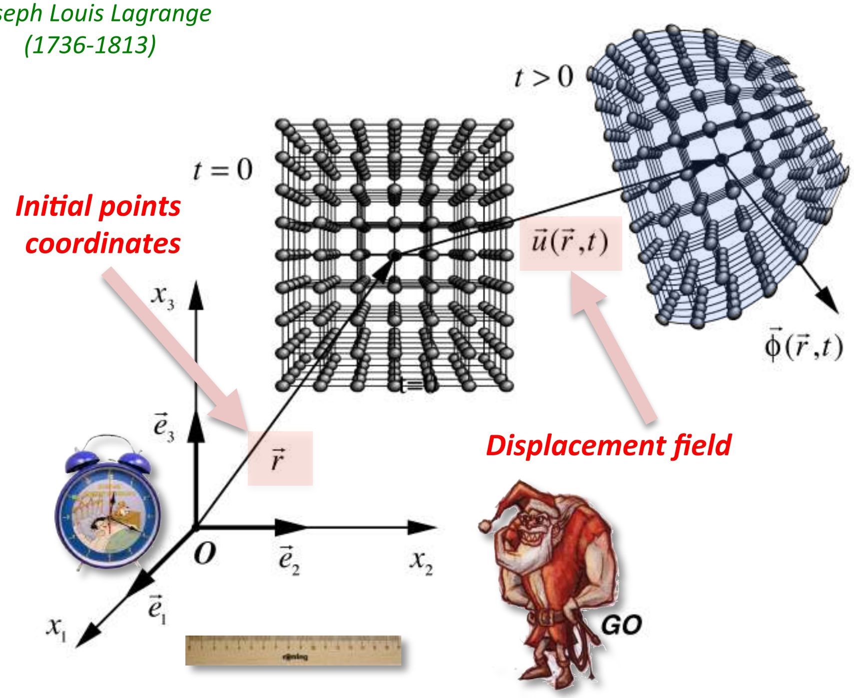


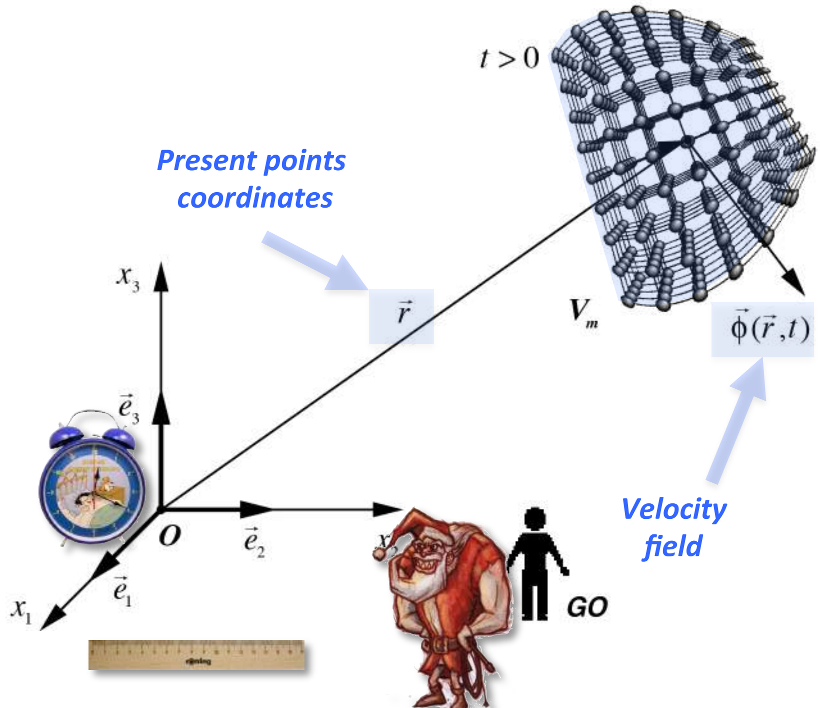
Joseph Louis Lagrange
(1736-1813)

Lagrange coordinates

Euler coordinates

Leonhard Euler (1707-1783)

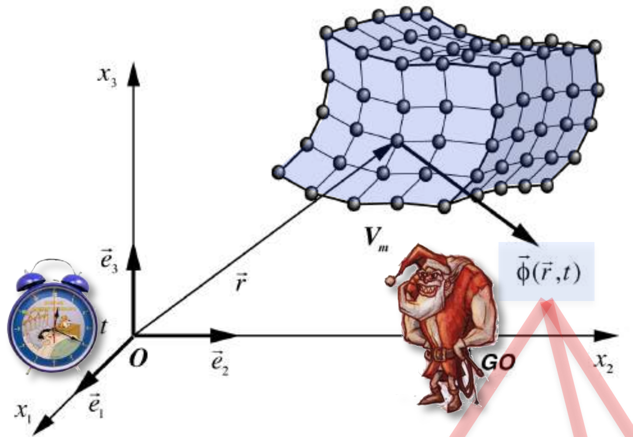




Geometrokinetic equations and distortion tensors in Euler coordinates

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

Vectorial representation of the distortion tensors



Material derivative

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

Tensor of distortion

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

trace →

Scalar of expansion

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

Antisymmetric part →

Vector of rotation

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

Distortion tensor $\vec{\beta}_i$

symmetry → $\vec{\varepsilon}_i = \vec{\beta}_i - \vec{e}_i \wedge \vec{\omega}$ → **Strain tensor** $\vec{\varepsilon}_i$

antisymmetry → $\vec{\omega} = -\frac{1}{2}\sum_k \vec{e}_k \wedge \vec{\beta}_k$ → **Rotation vector** $\vec{\omega}$

trace →

without trace → $\vec{\alpha}_i = \vec{\varepsilon}_i - \frac{1}{3}\tau\vec{e}_i$ → **Shear strain tensor** $\vec{\alpha}_i$

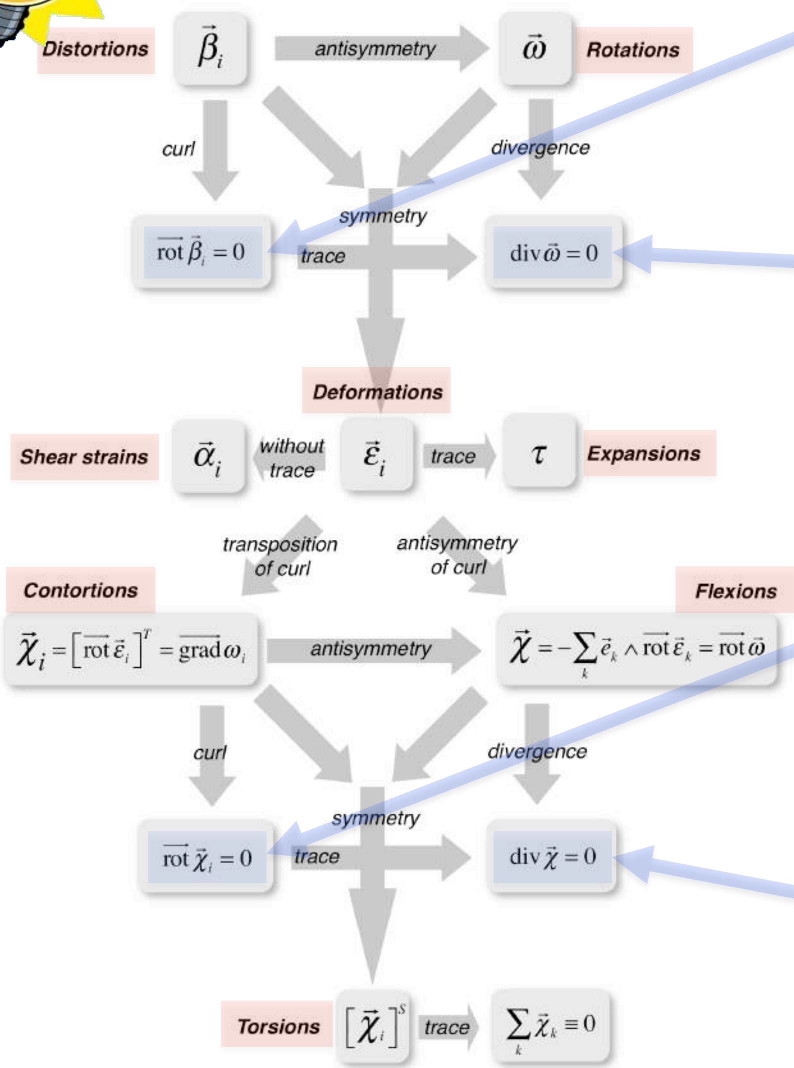
trace → $\tau = \sum_k \vec{e}_k \vec{\beta}_k = \sum_k \vec{e}_k \vec{\varepsilon}_k$ → **Volumic expansion scalar** τ

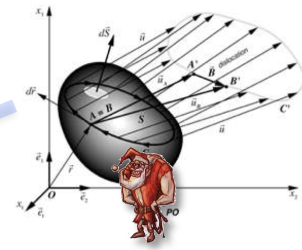
Relation with the volumic density n of sites and the volume v per site of the lattice

$$\tau = -\ln\frac{n}{n_0} = \ln\frac{v}{v_0}$$

Geometrocompatibility equations and contortion tensors in Euler coordinates

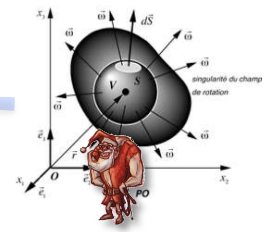
Distortion and contortion tensors and geometrocompatibility equations





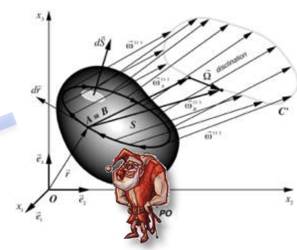
Continuity of the displacement field

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



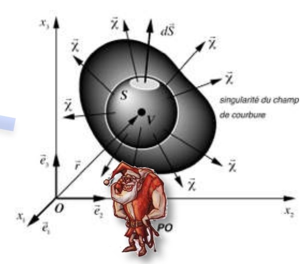
No singularity by divergence of the rotation field

$$\oiint_S \omega_\perp dS = \oiint_S \vec{\omega} d\vec{S} = \iiint_V \mathrm{div}\,\vec{\omega} dV = 0 \quad ; \quad \forall S$$



Continuity of the rotation field associated to the deformations

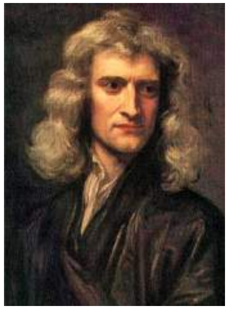
$$\oint_C d\vec{\omega}^{(\varepsilon)} = \sum_k \vec{e}_k \iint_S \overrightarrow{\mathrm{rot}}\vec{\chi}_k\, d\vec{S} = \sum_k \vec{e}_k \iint_S \overrightarrow{\mathrm{rot}}\left[\overrightarrow{\mathrm{rot}}\,\vec{\varepsilon}_k\right]^T d\vec{S} = 0$$



No singularity by divergence of the flexion field

$$\oiint_S \chi_\perp dS = \oiint_S \vec{\chi} d\vec{S} = \iiint_V \mathrm{div}\,\vec{\chi} dV = \sum_k \vec{e}_k \iiint_V \overrightarrow{\mathrm{rot}}\,\overrightarrow{\mathrm{rot}}\,\vec{\varepsilon}_k dV = 0$$

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

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

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

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

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

→

Continuity principle for the total energy

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

Sadi Carnot
(1837-1894)

Axiom of the second principle of thermodynamics

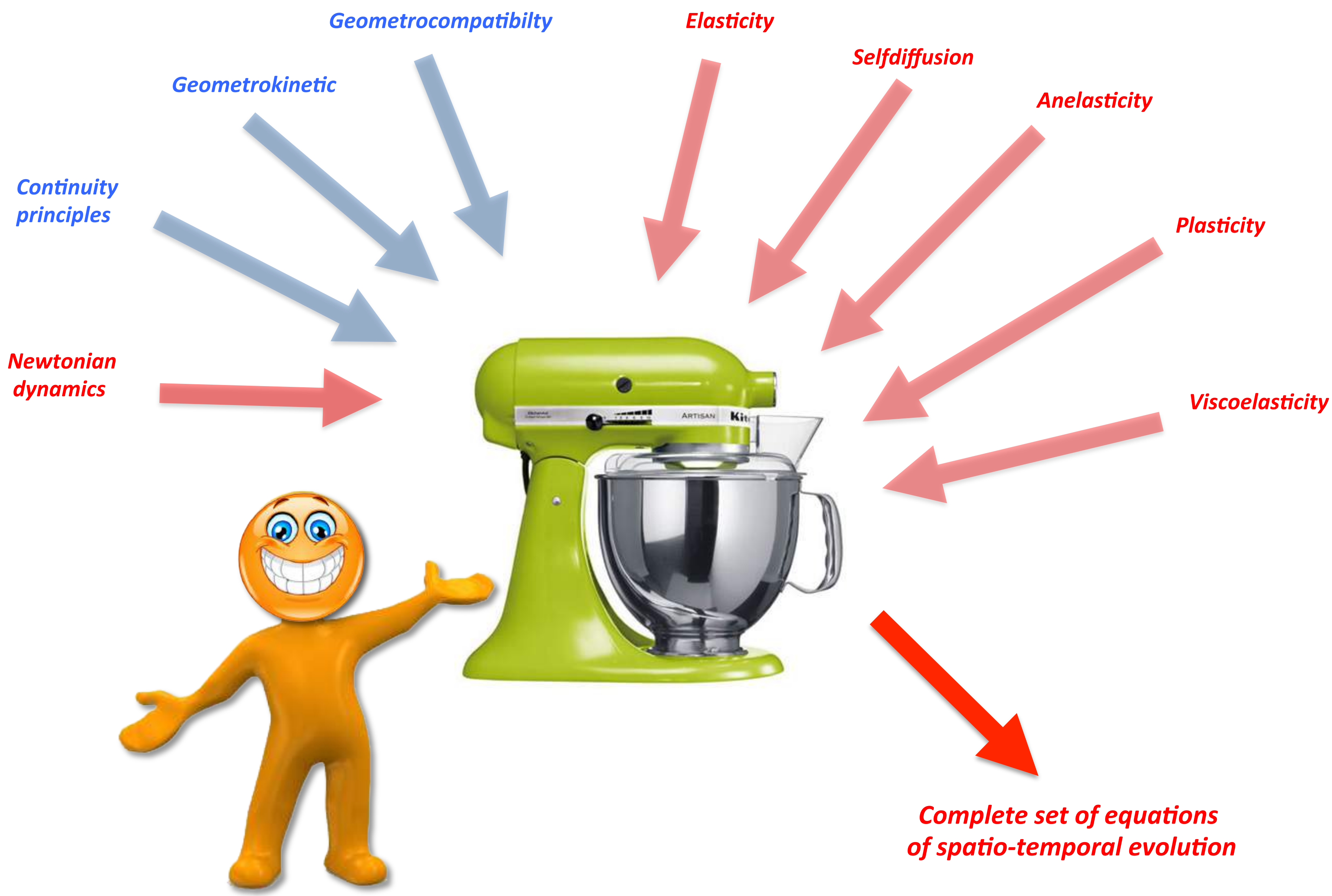
$$dS \geq \frac{\delta Q}{T}$$

→

Continuity principle for the entropy

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

Mix all these ingredients



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

Topological equations

Fundamental equations

Heat equation

Topology

Equations topologiques

$$\left\{\begin{aligned} &\frac{d\vec{\beta}_i}{dt} = \overrightarrow{\text{grad}}\,\phi_i && (1)\\ &\frac{d\vec{\omega}}{dt} = \frac{1}{2}\overrightarrow{\text{rot}}\,\vec{\phi} && (2)\\ &\frac{d\tau}{dt} = \text{div}\,\vec{\phi} && (3)\end{aligned}\right. \qquad \left\{\begin{aligned} &\overrightarrow{\text{rot}}\,\vec{\beta}_i = 0 && (4)\\ &\text{div}\,\vec{\omega} = 0 && (5)\\ &d/dt = \partial/\partial t + (\vec{\varphi}\vec{\nabla}) && (6)\\ &\vec{\varphi} = \vec{\phi} - \vec{\phi}_o(t) - \dot{\vec{\omega}}_o(t)\wedge\vec{r} && (7)\end{aligned}\right.$$

$$\left\{\begin{aligned} &\vec{\beta}_i = \vec{\beta}_i^{(\delta)} + \vec{e}_i \wedge \vec{\omega}_o(t) = \vec{\beta}_i^{\acute{e}l} + \vec{\beta}_i^{an} + \vec{\beta}_i^{pl} + \vec{e}_i \wedge \vec{\omega}_o(t) && (8)\\ &\vec{\omega} = -\frac{1}{2}\sum_k \vec{e}_k \wedge \vec{\beta}_k = \vec{\omega}^{(\delta)} + \vec{\omega}_0(t) = \vec{\omega}^{\acute{e}l} + \vec{\omega}^{an} + \vec{\omega}^{pl} + \vec{\omega}_0(t) && (9)\\ &\tau = \sum_k \vec{\beta}_k \vec{e}_k = \sum_k \vec{\beta}_k^{(\delta)} \vec{e}_k = \tau^{\acute{e}l} + \tau^{pl} \qquad (\tau^{an} \equiv 0 \text{ par hypothèse}) && (10)\\ &\vec{\varepsilon}_i = \vec{\beta}_i - \vec{e}_i \wedge \vec{\omega} = \vec{\beta}_i^{(\delta)} - \vec{e}_i \wedge \vec{\omega}^{(\delta)} = \vec{\varepsilon}_i^{\acute{e}l} + \vec{\varepsilon}_i^{an} + \vec{\varepsilon}_i^{pl} && (11)\\ &\vec{\alpha}_i = \vec{\varepsilon}_i - \frac{1}{3}\tau\vec{e}_i = \vec{\alpha}_i^{\acute{e}l} + \vec{\alpha}_i^{an} + \vec{\alpha}_i^{pl} && (12)\end{aligned}\right.$$

Dynamics

Equations dynamique

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

$$\left\{\begin{aligned} &n = 1/v = n_0\exp(-\tau^{\acute{e}l}) && (14)\\ &\vec{p} = m\left(\vec{\phi} + C_I\vec{\phi}_I - C_L\vec{\phi}_L\right) = m\vec{\phi} + m\left(C_I - C_L\right)\vec{\phi} + \frac{m}{n}\left(\vec{J}_I - \vec{J}_L\right) && \\ &\qquad = \left[\rho\vec{\phi} + m\left(\vec{J}_I - \vec{J}_L\right)\right]/n && (15)\\ &\rho = mn\left(1 + C_I - C_L\right) && (16)\end{aligned}\right.$$

Newton equation

Diffusion

Equations de diffusion

$$\left\{\begin{aligned} &n\frac{dC_L}{dt} = \left(S_{I-L} + S_L^{pl}\right) - C_L\left(S_L^{pl} - S_I^{pl}\right) - \text{div}\,\vec{J}_L && (17)\\ &n\frac{dC_I}{dt} = \left(S_{I-L} + S_I^{pl}\right) - C_I\left(S_L^{pl} - S_I^{pl}\right) - \text{div}\,\vec{J}_I && (18)\end{aligned}\right.$$

$$\left\{\begin{aligned} &\vec{J}_L = nC_L\Delta\vec{\varphi}_L = nC_L\left(\vec{\phi}_L - \vec{\phi}\right) = nC_L\left(\vec{\varphi}_L - \vec{\varphi}\right) && (19)\\ &\vec{J}_I = nC_I\Delta\vec{\varphi}_I = nC_I\left(\vec{\phi}_I - \vec{\phi}\right) = nC_I\left(\vec{\varphi}_I - \vec{\varphi}\right) && (20)\end{aligned}\right.$$

Selfdiffusion equations

Thermic

Equations thermiques

$$\begin{aligned} nT\frac{ds}{dt} = &-\left(\mu_L^* + \mu_I^*\right)S_{I-L} - \left(\mu_L^* + h^*\right)S_L^{pl} - \left(\mu_I^* - h^*\right)S_I^{pl} + T\vec{J}_L\vec{X}_L\\ &+ T\vec{J}_I\vec{X}_I + \vec{s}_k^{\,dis}\frac{d\vec{\beta}_k^{an}}{dt} + \vec{m}^{dis}\frac{d\vec{\omega}^{an}}{dt} + \vec{s}_k\frac{d\vec{\beta}_k^{pl}}{dt} + \vec{m}\frac{d\vec{\omega}^{pl}}{dt} - \text{div}\,\vec{J}_q \end{aligned} \qquad (21)$$

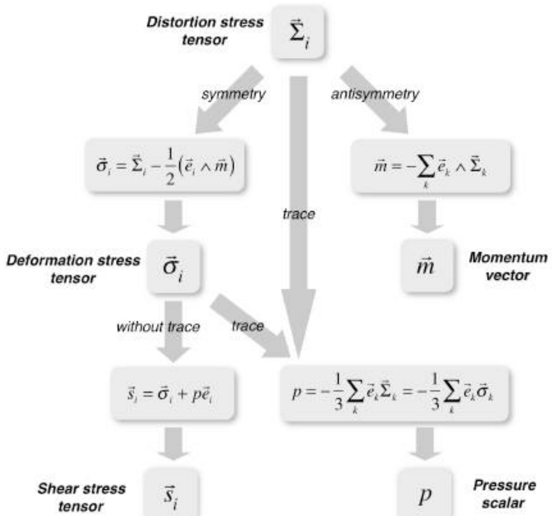
$$\left\{\begin{aligned} &\mu_L^* = \mu_L - \frac{1}{2}m\left(\vec{\phi}_L^{\,2} - 2\Delta\vec{\varphi}_L^2\right) && (22)\\ &\mu_I^* = \mu_I + \frac{1}{2}m\vec{\phi}_I^{\,2} && (23)\end{aligned}\right.$$

$$\left\{\begin{aligned} &\vec{X}_q = \overrightarrow{\text{grad}}\,\frac{1}{T} && (24)\\ &\vec{X}_L = \frac{1}{T}\left(-\overrightarrow{\text{grad}}\;\mu_L^* + m\frac{d}{dt}\left(\vec{\phi}_L - 2\Delta\vec{\varphi}_L\right) - m\vec{g}\right) && (25)\\ &\vec{X}_I = \frac{1}{T}\left(-\overrightarrow{\text{grad}}\;\mu_I^* - m\frac{d}{dt}\left(\vec{\phi}_I\right) + m\vec{g}\right) && (26)\end{aligned}\right.$$

$$h^* = f + Ts + pv + \frac{1}{2}m\vec{\phi}^2 - \mu_L C_L - \mu_I C_I \qquad (27)$$

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

$$f = f\left(\alpha_{ij}^{\,\acute{e}l}, \alpha_{ij}^{\,an}, \omega_k^{\,\acute{e}l}, \omega_k^{\,an}, \tau^{\acute{e}l}, C_L, C_I, T\right) \qquad (28)$$

Elasticity

$$\begin{cases} s_{ij} = \dfrac{n}{2}\left(\dfrac{\partial f}{\partial \alpha_{ij}^{\,\acute{e}l}} + \dfrac{\partial f}{\partial \alpha_{ji}^{\,\acute{e}l}}\right) - \dfrac{n}{3}\delta_{ij}\sum_k \dfrac{\partial f}{\partial \alpha_{kk}^{\,\acute{e}l}} = s_{ij}(\alpha_{lm}^{\,\acute{e}l}, \omega_n^{\,\acute{e}l}, \tau^{\acute{e}l}, \alpha_{lm}^{\,an}, \omega_n^{\,an}, C_L, C_I, T) & (29) \\ m_k = n\dfrac{\partial f}{\partial \omega_k^{\,\acute{e}l}} = m_k(\alpha_{lm}^{\,\acute{e}l}, \omega_n^{\,\acute{e}l}, \tau^{\acute{e}l}, \alpha_{lm}^{\,an}, \omega_n^{\,an}, C_L, C_I, T) & (30) \\ p = -n\dfrac{\partial f}{\partial \tau^{\acute{e}l}} = p(\alpha_{lm}^{\,\acute{e}l}, \omega_n^{\,\acute{e}l}, \tau^{\acute{e}l}, \alpha_{lm}^{\,an}, \omega_n^{\,an}, C_L, C_I, T) & (31) \end{cases}$$

Anelasticity

$$\begin{cases} s_{ij}^{dis} = \dfrac{n}{2}\left(\dfrac{\partial f}{\partial \alpha_{ij}^{\,an}} + \dfrac{\partial f}{\partial \alpha_{ji}^{\,an}}\right) - \dfrac{n}{3}\delta_{ij}\sum_k \dfrac{\partial f}{\partial \alpha_{kk}^{\,an}} = s_{ij}^{dis}(\alpha_{lm}^{\,\acute{e}l}, \omega_n^{\,\acute{e}l}, \tau^{\acute{e}l}, \alpha_{lm}^{\,an}, \omega_n^{\,an}, C_L, C_I, T) & (32) \\ m_k^{dis} = n\dfrac{\partial f}{\partial \omega_k^{\,an}} = m_k^{dis}(\alpha_{lm}^{\,\acute{e}l}, \omega_n^{\,\acute{e}l}, \tau^{\acute{e}l}, \alpha_{lm}^{\,an}, \omega_n^{\,an}, C_L, C_I, T) & (33) \end{cases}$$

State equations

$$\begin{cases} s = -\dfrac{\partial f}{\partial T} = s(\alpha_{lm}^{\,\acute{e}l}, \omega_n^{\,\acute{e}l}, \tau^{\acute{e}l}, \alpha_{lm}^{\,an}, \omega_n^{\,an}, C_L, C_I, T) & (34) \\ \mu_L = \dfrac{\partial f}{\partial C_L} = \mu_L(\alpha_{lm}^{\,\acute{e}l}, \omega_n^{\,\acute{e}l}, \tau^{\acute{e}l}, \alpha_{lm}^{\,an}, \omega_n^{\,an}, C_L, C_I, T) & (35) \\ \mu_I = \dfrac{\partial f}{\partial C_I} = \mu_I(\alpha_{lm}^{\,\acute{e}l}, \omega_n^{\,\acute{e}l}, \tau^{\acute{e}l}, \alpha_{lm}^{\,an}, \omega_n^{\,an}, C_L, C_I, T) & (36) \end{cases}$$

Thermicity

Selfdiffusivity

Selfdiffusion

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

$$\begin{cases} \vec{J}_q = \vec{J}_q(\vec{X}_q, \vec{X}_L, \vec{X}_I, n, T, C_L, C_I, \ldots) & (37) \\ \vec{J}_L = \vec{J}_L(\vec{X}_q, \vec{X}_L, \vec{X}_I, n, T, C_L, C_I, \ldots) & (38) \\ \vec{J}_I = \vec{J}_I(\vec{X}_q, \vec{X}_L, \vec{X}_I, n, T, C_L, C_I, \ldots) & (39) \end{cases}$$

$$S_{I-L} = S_{I-L}\left(\mu_L^{\,*} + \mu_I^{\,*}, n, T, C_L, C_I, \ldots\right) \qquad (40)$$

+ Creation-annihilation of point defect pairs

Anelasticity

Equations de dissipation: anélasticité

$$\begin{cases} \vec{s}_i = \vec{s}_i^{\,cons}\left(\vec{\alpha}_m^{\,an}, v, T, \ldots\right) + \vec{s}_i^{\,dis}\left(\dfrac{d\vec{\alpha}_m^{\,an}}{dt}, v, T, \ldots\right) & (41) \\ \vec{m} = \vec{m}^{\,cons}\left(\vec{\omega}^{\,an}, v, T, \ldots\right) + \vec{m}^{\,dis}\left(\dfrac{d\vec{\omega}^{\,an}}{dt}, v, T, \ldots\right) & (42) \end{cases}$$

Plasticity

Equations de dissipation: plasticité

$$\begin{cases} \dfrac{d\tau^{pl}}{dt} = \dfrac{S_n}{n} = \dfrac{1}{n}\left(S_L^{\,pl} - S_I^{\,pl}\right) & (43) \\ S_L^{\,pl} = S_L^{\,pl}\left[\left(\mu_L^{\,*} + g^*\right), v, T, C_L, C_I, \ldots\right] & (44) \\ S_I^{\,pl} = S_I^{\,pl}\left[\left(\mu_I^{\,*} - g^*\right), v, T, C_L, C_I, \ldots\right] & (45) \end{cases}$$

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

$$\begin{cases} \dfrac{d\vec{\alpha}_i^{\,pl}}{dt} = \dfrac{d\vec{\alpha}_i^{\,pl}}{dt}(\vec{s}_m, v, T, \ldots) & (47) \\ \dfrac{d\vec{\omega}^{\,pl}}{dt} = \dfrac{d\vec{\omega}^{\,pl}}{dt}(\vec{m}, v, T, \ldots) & (48) \end{cases}$$

+ Creation-annihilation of point defects

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

Additional equations

Continuité de la masse

$$\frac{\partial \rho}{\partial t} = -\operatorname{div}\left[\rho\vec{\phi} + m\left(\vec{J}_I - \vec{J}_L\right)\right] = -\operatorname{div}\left(n\vec{p}\right) \quad \text{dans } Q\xi_1\xi_2\xi_3 \qquad (49)$$

Inertial mass continuity

Flux de travail et force de surface

$$\vec{J}_w = \mu_L^{*}\vec{J}_L + \mu_I^{*}\vec{J}_I - \phi_k\vec{s}_k - \frac{1}{2}\left(\vec{\phi}\wedge\vec{m}\right) + p\vec{\phi} \qquad (50)$$

$$\vec{F}_S = \sum_k \vec{e}_k\left(\vec{s}_k\vec{n}\right) + \frac{1}{2}\left(\vec{m}\wedge\vec{n}\right) - \vec{n}p \qquad (51)$$

Work flux

Surface forces

Source d'entropie

$$S_e = -\frac{1}{T}\left(\mu_L^{*}+\mu_I^{*}\right)S_{I-L} - \frac{1}{T}\left(\mu_L^{*}+g^{*}\right)S_L^{pl} - \frac{1}{T}\left(\mu_I^{*}-g^{*}\right)S_I^{pl} + \vec{J}_L\vec{X}_L + \vec{J}_I\vec{X}_I + \frac{1}{T}\left(\vec{s}_k^{dis}\frac{d\vec{\beta}_k^{an}}{dt} + \vec{m}^{dis}\frac{d\vec{\omega}^{an}}{dt} + \vec{s}_k\frac{d\vec{\beta}_k^{pl}}{dt} + \vec{m}\frac{d\vec{\omega}^{pl}}{dt}\right) + \vec{J}_q\,\overrightarrow{\operatorname{grad}}\left(\frac{1}{T}\right) \qquad (52)$$

Entropy source

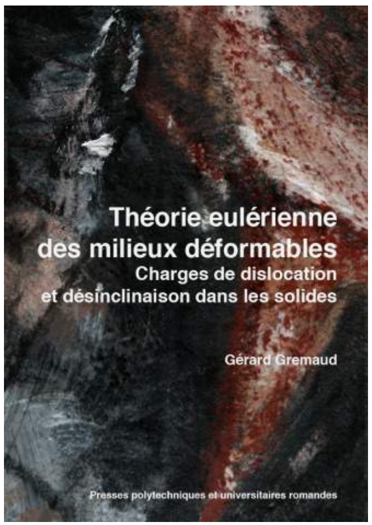
Bilan énergétique

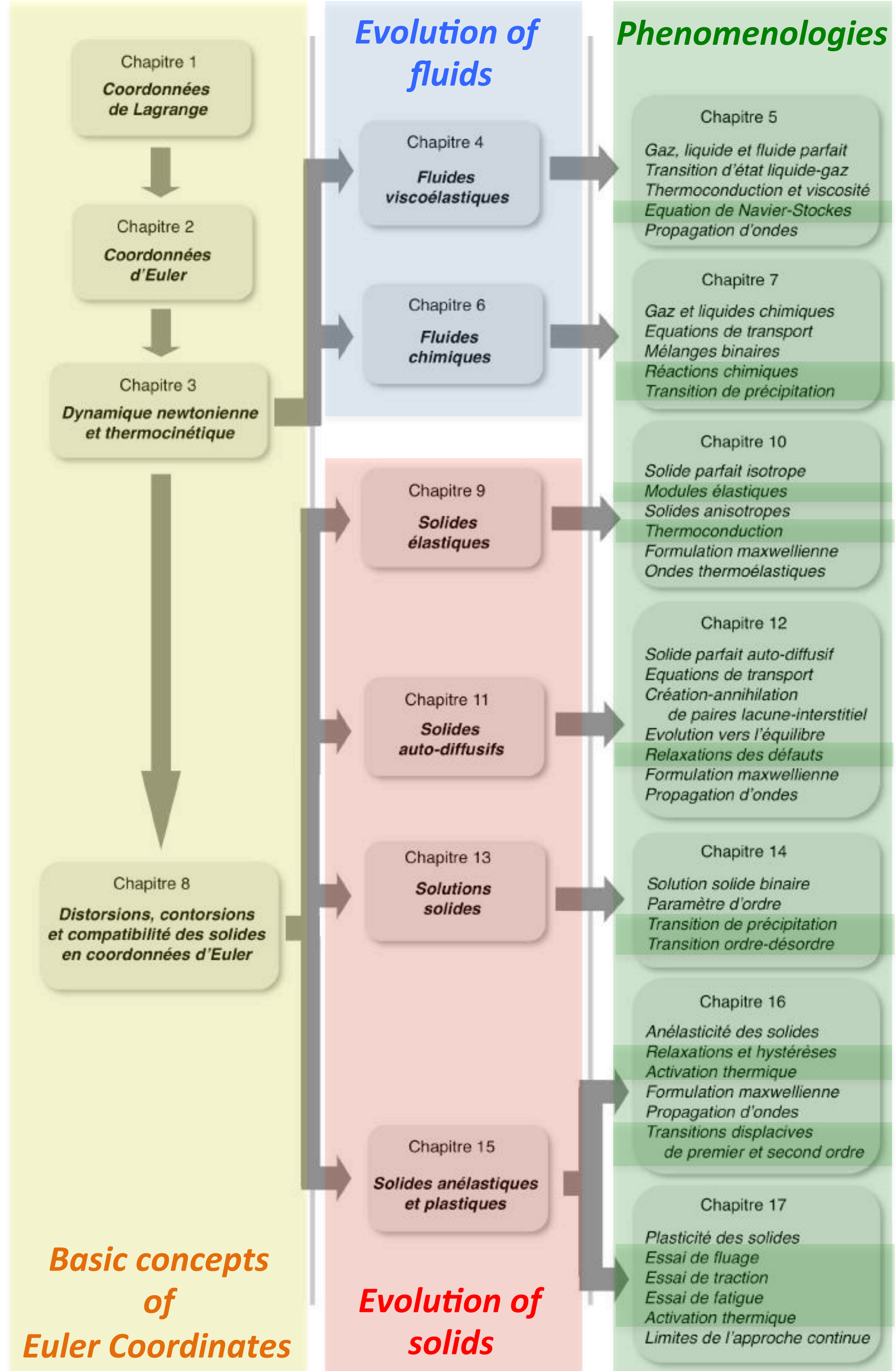
$$n\vec{\phi}\left(\frac{d\vec{p}}{dt} - m\vec{\phi}_I\frac{dC_I}{dt} + m\vec{\phi}_L\frac{dC_L}{dt}\right) + \vec{s}_k\frac{d\vec{\beta}_k}{dt} + \vec{m}\frac{d\vec{\omega}}{dt} - p\frac{d\tau}{dt} = \rho\vec{g}\vec{\phi} - \operatorname{div}\left[-\phi_k\vec{s}_k - \frac{1}{2}\left(\vec{\phi}\wedge\vec{m}\right) + p\vec{\phi}\right] \qquad (53)$$

Energy balance

Poynting vector

I B - Application: phenomenologies of usual fluids and solids





I C – Dislocation and disclination charges

What's a line of topological singularity?

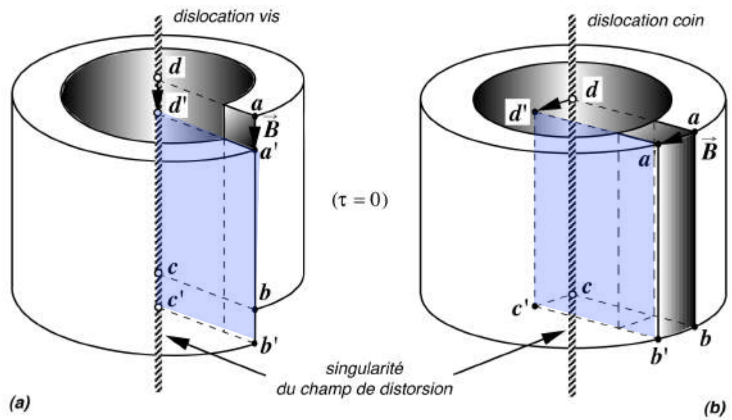
Vito Volterra
(1860-1940)

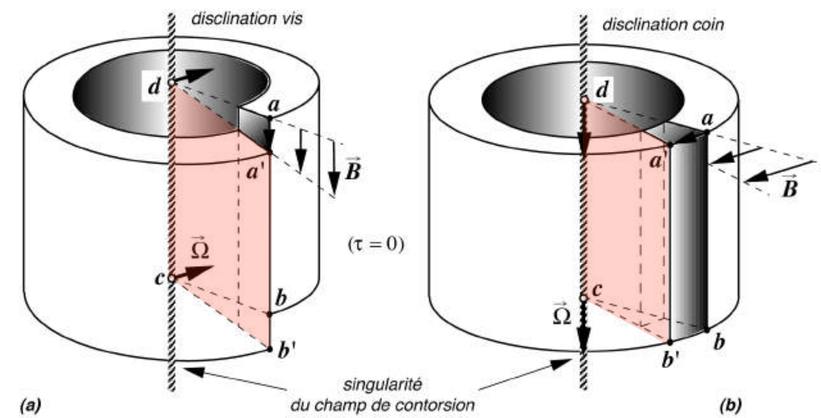
Singularity line by translation

Screw dislocation | *Edge dislocation*

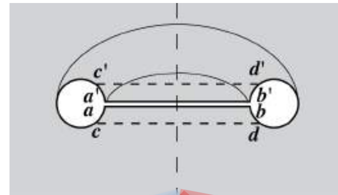
Singularity line by rotation

Twist disclination | *Wedge disclination*





What's a loop of topological singularity?

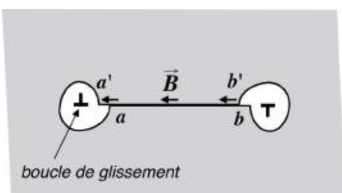


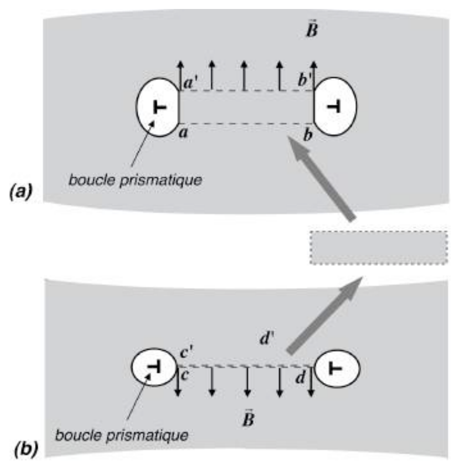
Mixed dislocation loop by translation

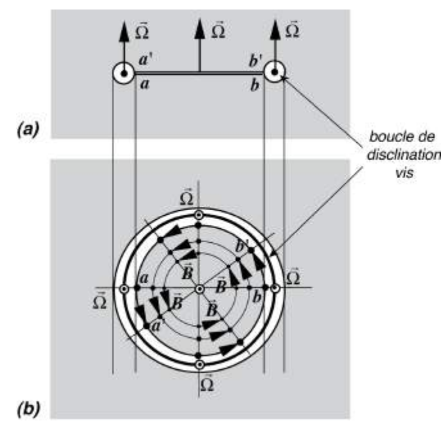
Edge dislocation loop by material addition or substraction

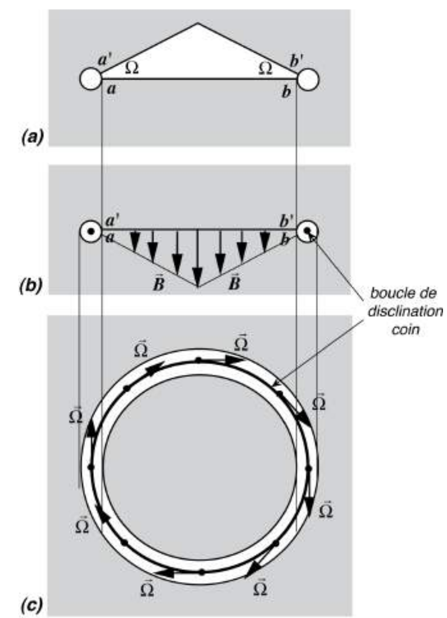
Twist disclination loop by rotation

Wedge disclination loop by material addition or substraction



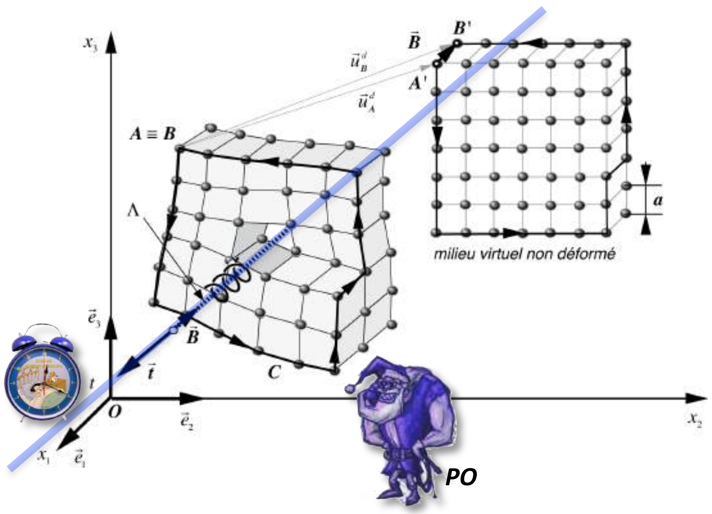




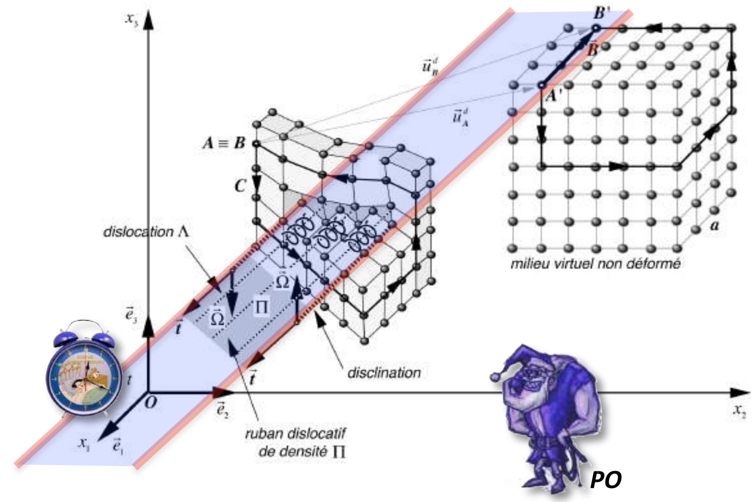


Quantification of the topological singularities as strings or membranes in solid lattices

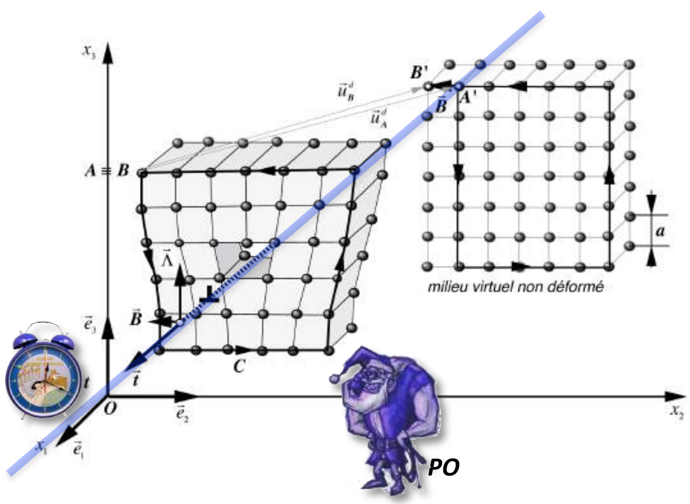
Screw dislocation string



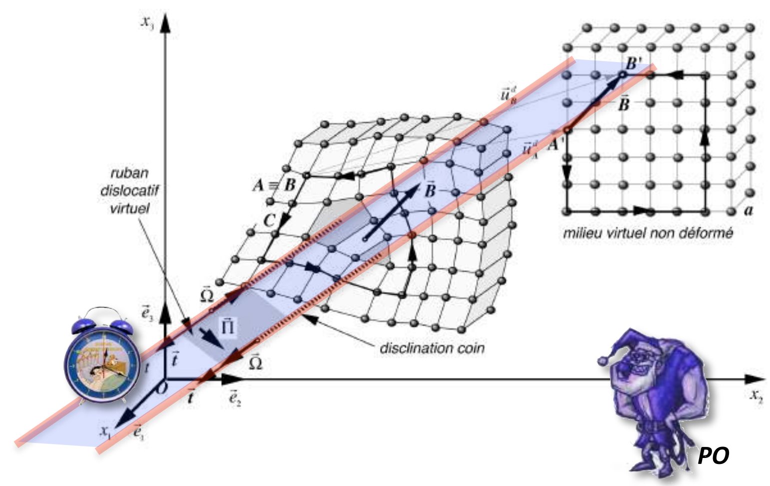
Srew dislocation membrane limited by two twist disclination strings



Edge dislocation string

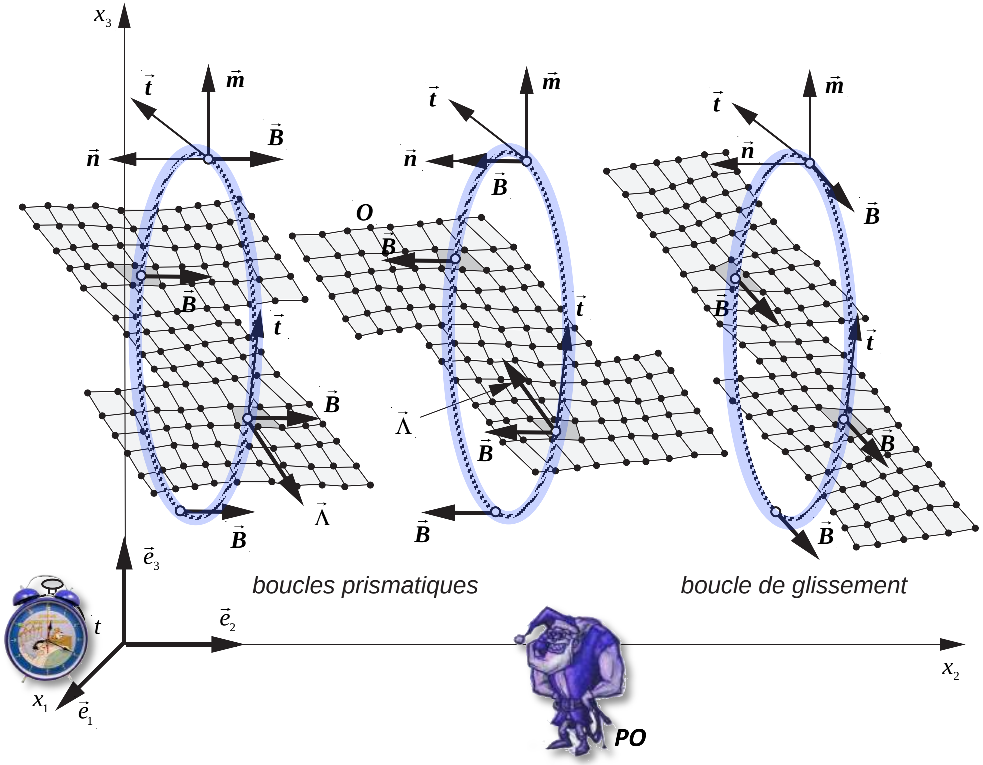


Edge dislocation membrane limited by two wedge disclination strings

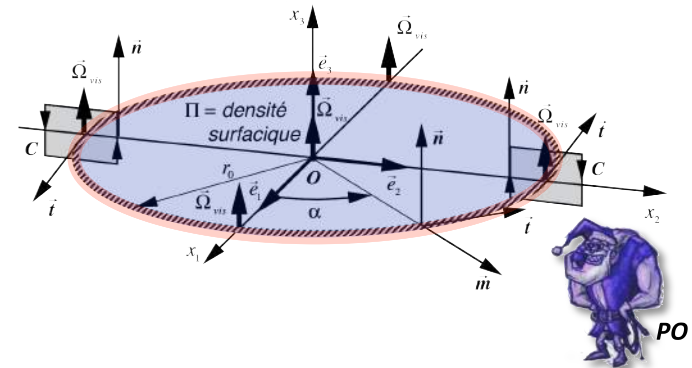


Quantification of the topological singularities as loops and membranes in solid lattices

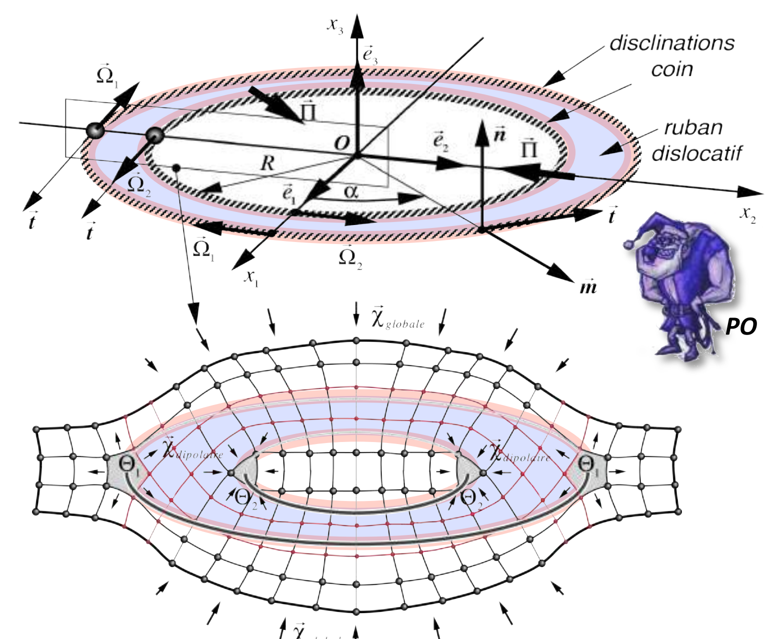
Edge and mixed dislocation loops



Twist disclination loop
with screw dislocation membrane



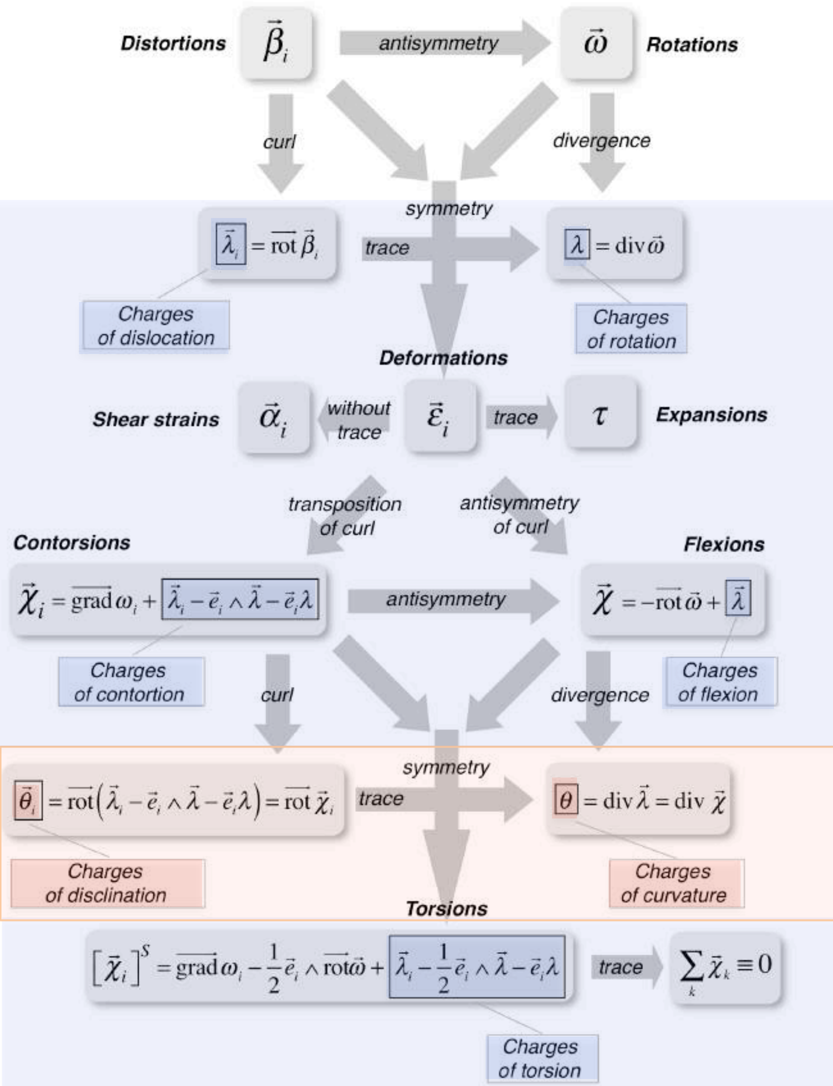
Wedge disclination loop
with edge dislocation membrane



Incompatibility charges

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

Incompatibility equations and charge tensors

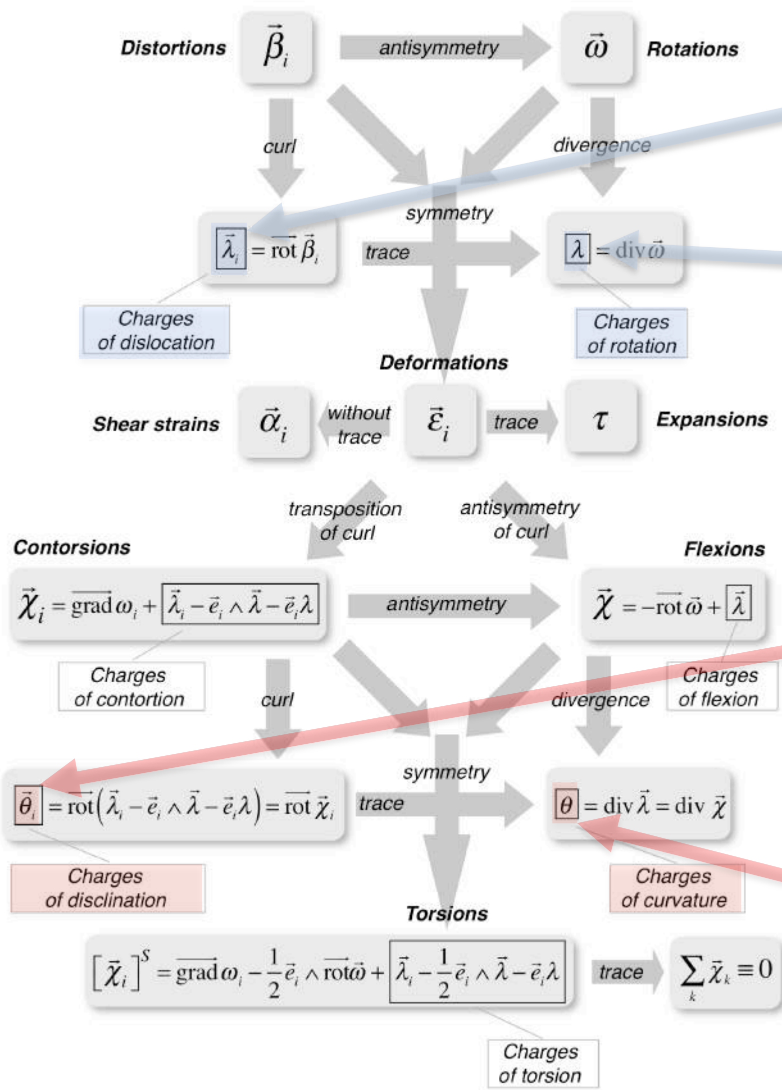


Charges of first order

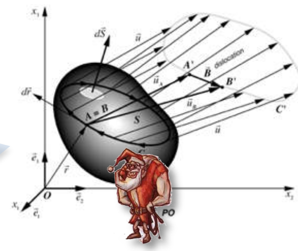
Charges of second order

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

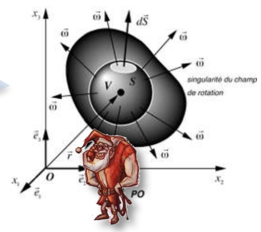


Dislocation Burgers vector

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

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

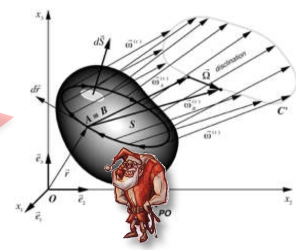
Singularity of the divergence of the rotation field



$$Q_\lambda = \oiint_S \vec{\omega}\, d\vec{S} = \iiint_V \mathrm{div}\,\vec{\omega}\, dV = \iiint_V \lambda\, dV \neq 0$$

Macroscopic scalar charge of rotation

Discontinuity of the rotation field associated to the deformations

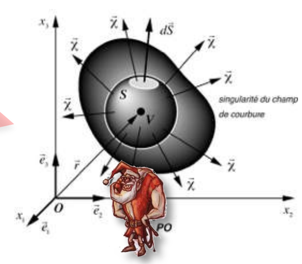


Disclination Franck vector

$$\vec{\Omega} = \oint_C \delta\vec{\omega}^{\varepsilon} = \sum_k \vec{e}_k \iint_S \overrightarrow{\mathrm{rot}}\,\vec{\chi}_k\, d\vec{S} = \sum_k \vec{e}_k \iint_S \vec{\theta}_i\, d\vec{S}$$

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

Singularity of the divergence of the flexion field

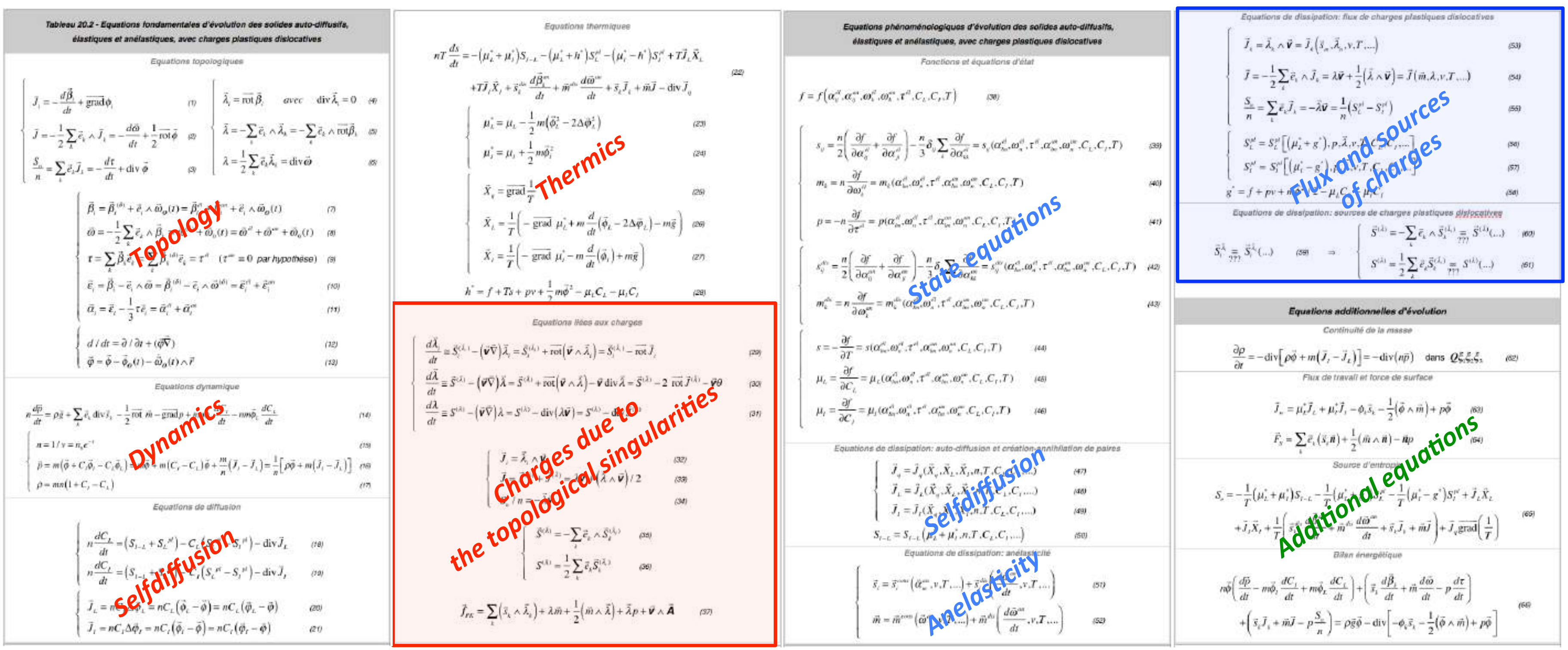


$$Q_\theta = \oiint_S \vec{\chi}\, d\vec{S} = \iiint_V \mathrm{div}\,\vec{\chi}\, dV = \iiint_V \theta\, dV \neq 0$$

Macroscopic scalar charge of flexion

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

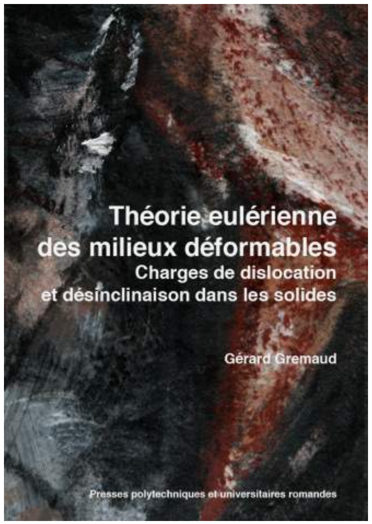
Fundamental equations | **Phenomenological equations**

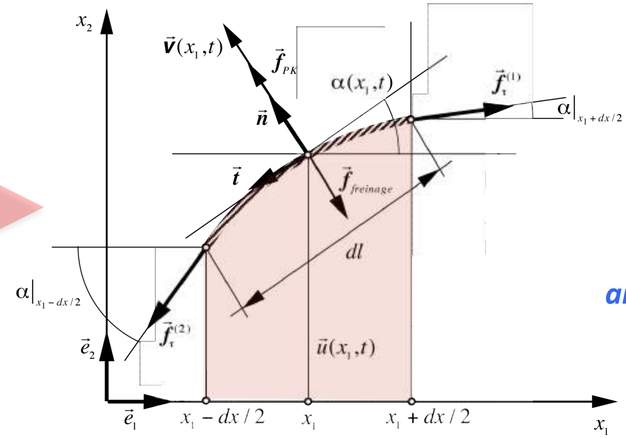


Additional equations

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

String model of a dislocation line

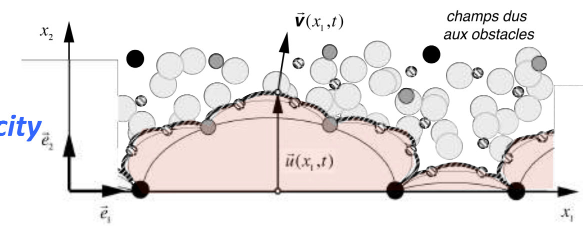




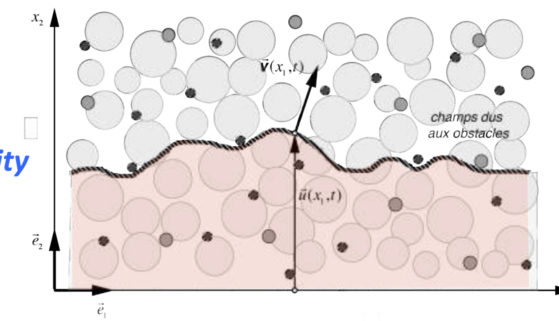
$$\left(M_0 \frac{\partial^2 u}{\partial t^2} + B_f \frac{\partial u}{\partial t}\right)\sqrt{1+\left(\partial u/\partial x_1\right)^2} - \frac{\partial}{\partial x_1}\left[\tau \frac{\partial u}{\partial x_1} \Big/ \sqrt{1+\left(\partial u/\partial x_1\right)^2}\right]$$

$$= \boldsymbol{B}s_{23} + \sum_{n=1}^{N} \boldsymbol{f}_n\left(x_1,u(x_1,t)\right) + \boldsymbol{F}_{fluctuation}\left(x_1,u(x_1,t),t\right)$$

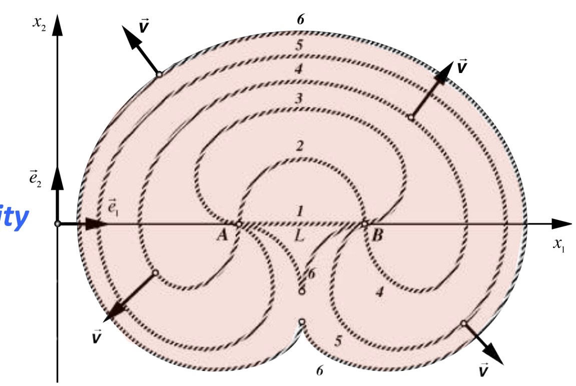
anelasticity



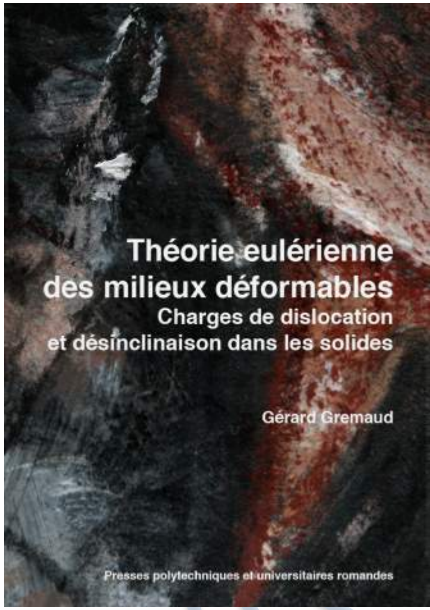
plasticity



plasticity



Other consequences



Relativistic dynamics of the charges

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

Maxwell equations and Lorentz force at constant volumic expansion

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

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

$$\begin{cases} (2\vec{\omega}) = (\frac{1}{nk_2})(\frac{\vec{m}}{2}) + (2\vec{\omega}^{an}) + (2\vec{\omega}_0(t)) \\ (n\vec{p}) = (nm)\left[\vec{\phi} + \left(C_I - C_L\right)\vec{\phi} + (\frac{1}{n}\left(\vec{J}_I - \vec{J}_L\right))\right] \end{cases} \Leftrightarrow \begin{cases} \vec{D} = \varepsilon_0\,\vec{E} + \vec{P} + \vec{P}_0(t) \\ \vec{B} = \mu_0\left[\vec{H} + \left(\chi^{para} + \chi^{dia}\right)\vec{H} + \vec{M}\right] \end{cases}$$

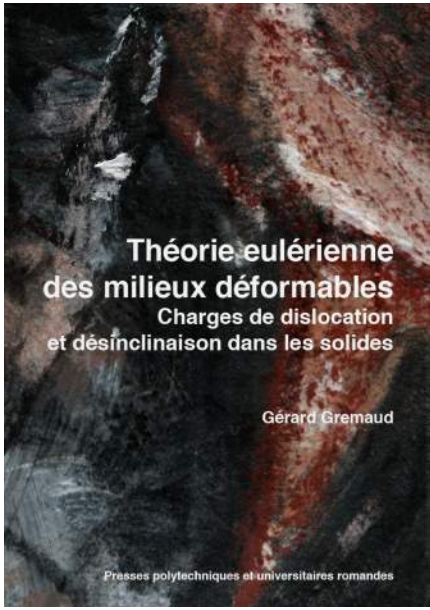
$$\left\{ \frac{d(2\lambda)}{dt} = -\mathrm{div}(2\vec{J}) \right. \Leftrightarrow \left\{ \frac{\partial \rho}{\partial t} = -\mathrm{div}\,\vec{j} \right.$$

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

$$\left\{ c_t = \sqrt{\frac{nk_2}{nm}} = \sqrt{\frac{k_2}{m}} \right. \Leftrightarrow \left\{ c = \sqrt{\frac{1}{\varepsilon_0 \mu_0}} \right.$$

$$\left\{ \vec{\boldsymbol{F}}_{PK} = 2\boldsymbol{Q}_\lambda\left(\frac{\vec{m}}{2} + \vec{\boldsymbol{v}} \wedge n\vec{p}\right) \right. \Leftrightarrow \left\{ \vec{\boldsymbol{F}} = q\left(\vec{E} + \vec{\boldsymbol{v}} \wedge \vec{B}\right) \right.$$

Conclusion of the first part



Relativistic dynamics of the charges

Maxwell equations and Lorentz force at constant volumic expansion

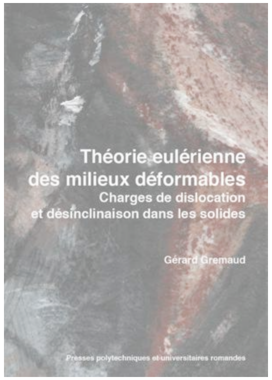
Interactions of electrical type and of gravitational type between charges

String model of the dislocation line

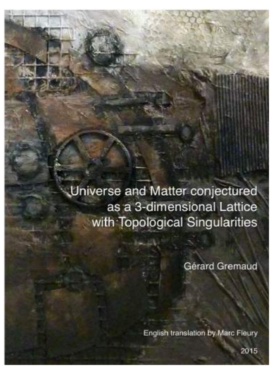
The numerous analogies which appear *between the eulerian theory of deformable media and the theories of electromagnetism, gravitation, special relativity, general relativity and even standard model of elementary particles,* ***reinforced by the absence of particles analogue to magnetic monopoles, by 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.***

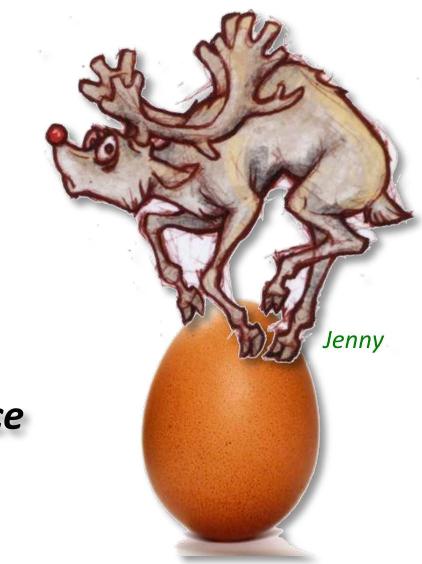
Contents



Presses polytechniques et universitaires romandes (PPUR), Lausanne, 2013, 750 pages (ISBN 978-2-88074-964-4)



Free access e-books, http://gerardgremaud.ch Lausanne, 2015, 646 pages, (DOI: 10.13140/RG.2.1.3839.4325)



II A - The « cosmic lattice »

Newton equation of usual isotropic solids

Elastic state function given per lattice site

$$f^{déf} = -k_0\tau + k_1\tau^2 + k_2\sum_i (\vec{\alpha}_i^{\,él})^2$$

Newton equation

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

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*

$$F^{déf} = -K_0\tau + K_1\tau^2 + K_2\sum_i (\vec{\alpha}_i^{\,él})^2 + 2K_3(\vec{\omega}^{\,él})^2$$

Newton equation

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

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

Circularely polarized transversal waves and longitudinal « local fluctuations »

Newton equation of the cosmic lattice

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

Purely transversal waves are necessarily circularely polarized

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

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

Analogy with the circular polarization of the photons in quantum physics

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

Pure longitudinal waves can exist

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

Conjectures:

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

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

Only longitudinal «local fluctuations» of the expansion can exist

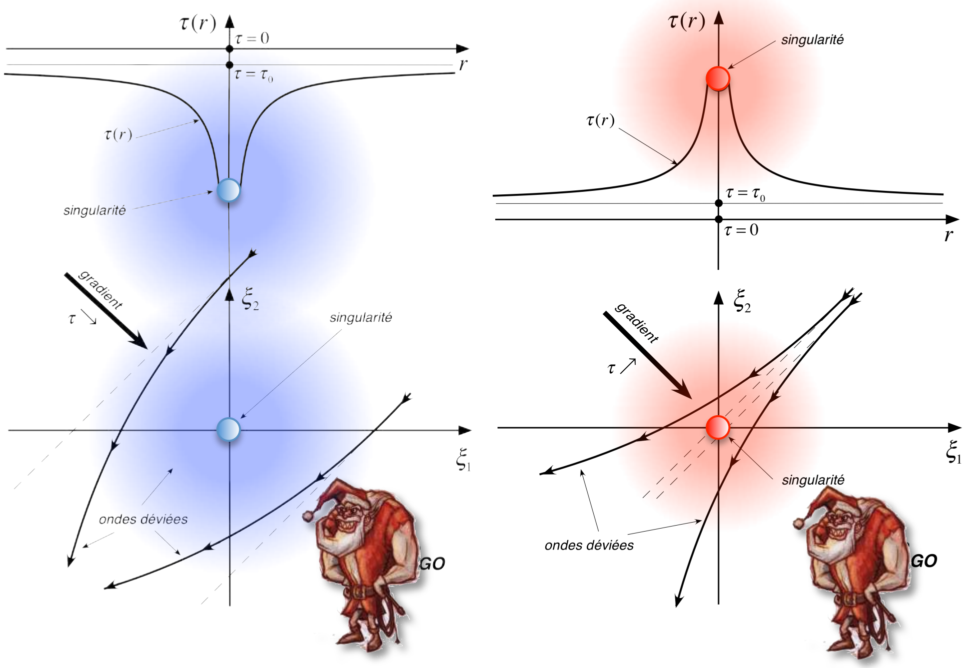
1/ Analogy with the absence of longitudinal waves in general relativity

2/ Analogy with the vacuum fluctuations in quantum physics

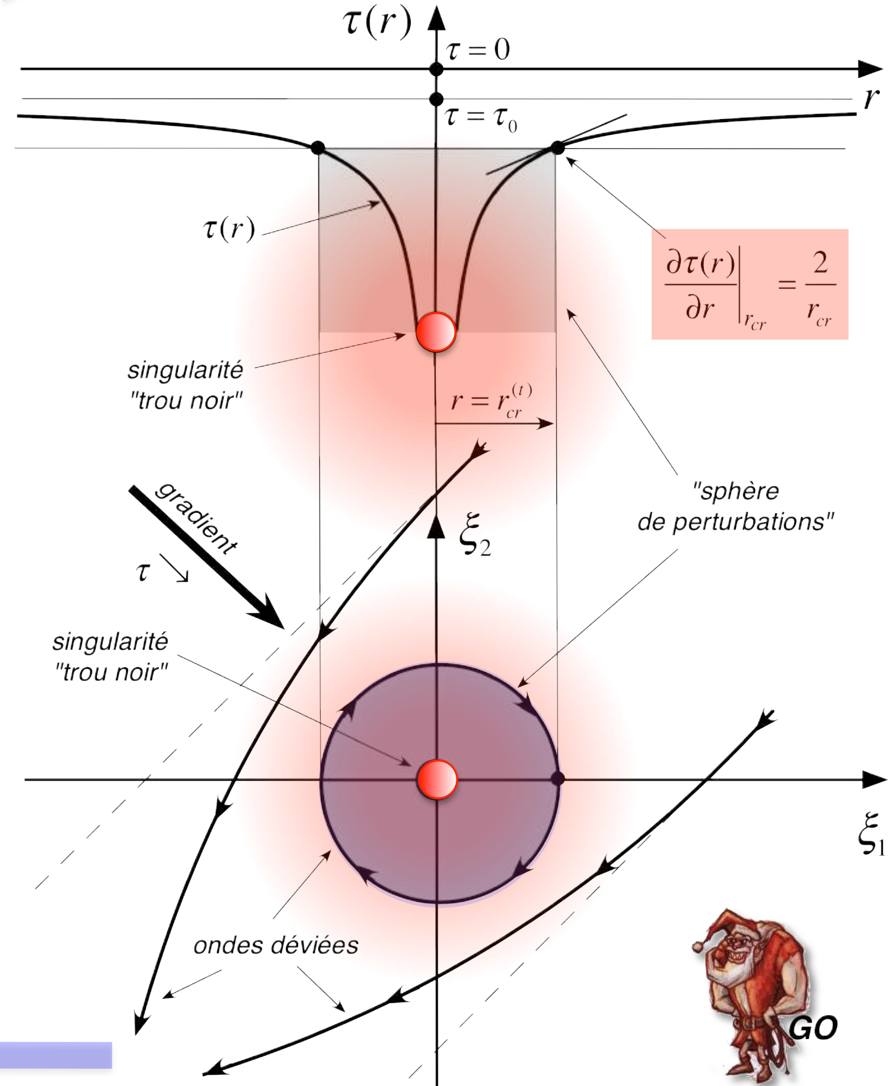
Curvature of the wave rays and « perturbation sphere »

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

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



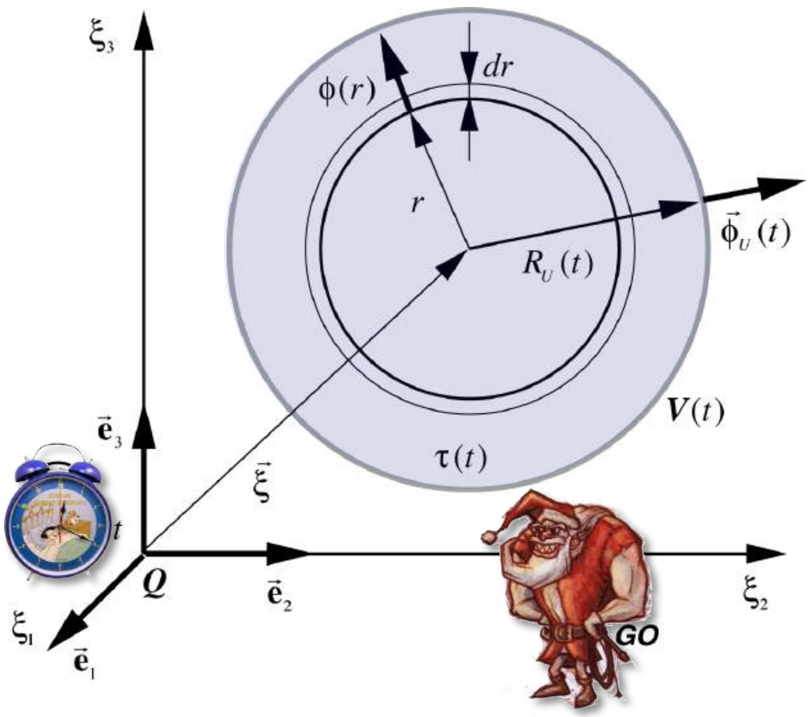
Appearance of a « perturbation sphere »



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

Cosmological behaviours of a finite cosmic lattice

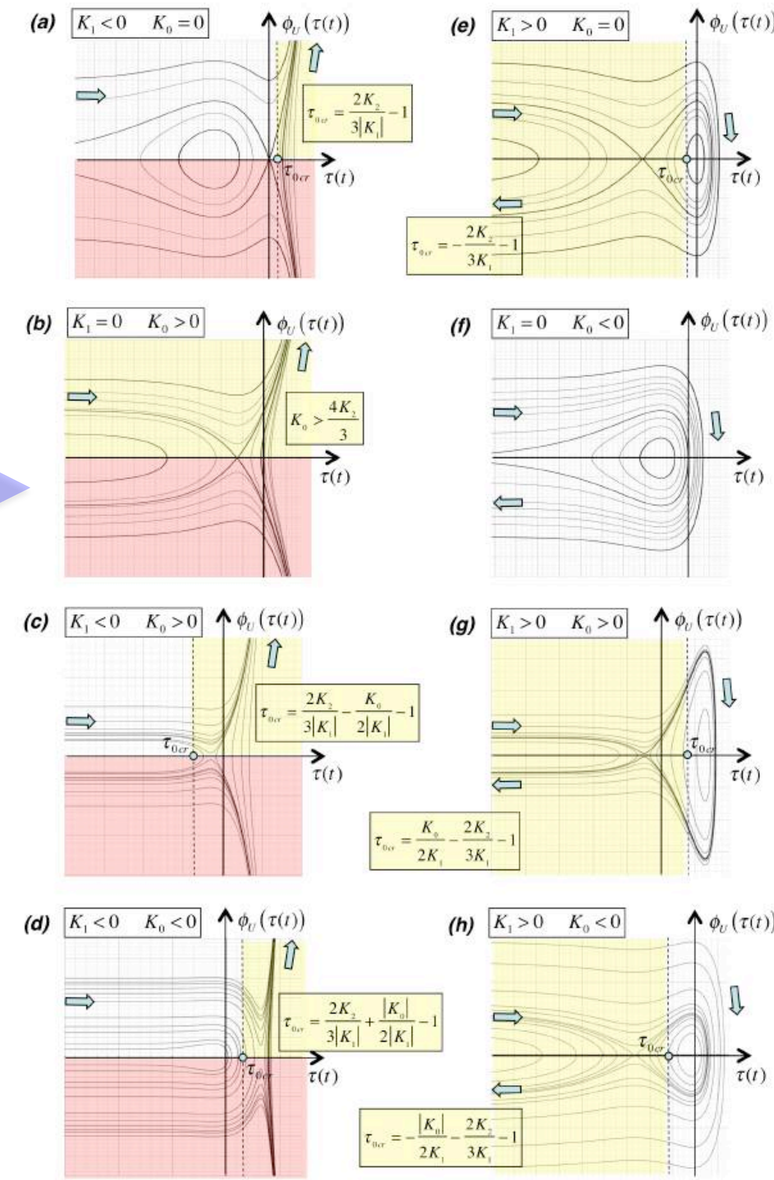
Cosmological expansion
of a spheric lattice with a given total energy



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

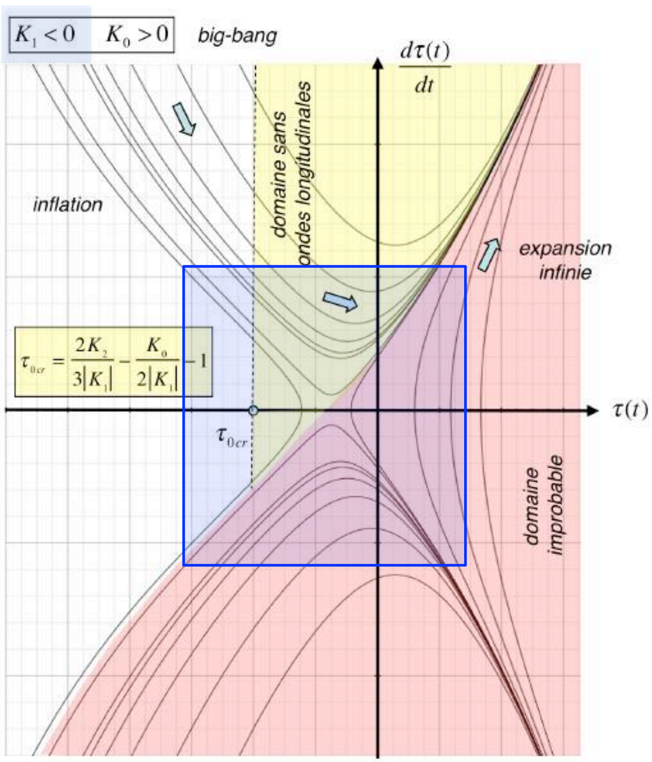
$$F = \frac{N}{n_0} \left(K_1 \tau - K_0 \right) \tau \, e^{\tau}$$

8 possible cosmological models

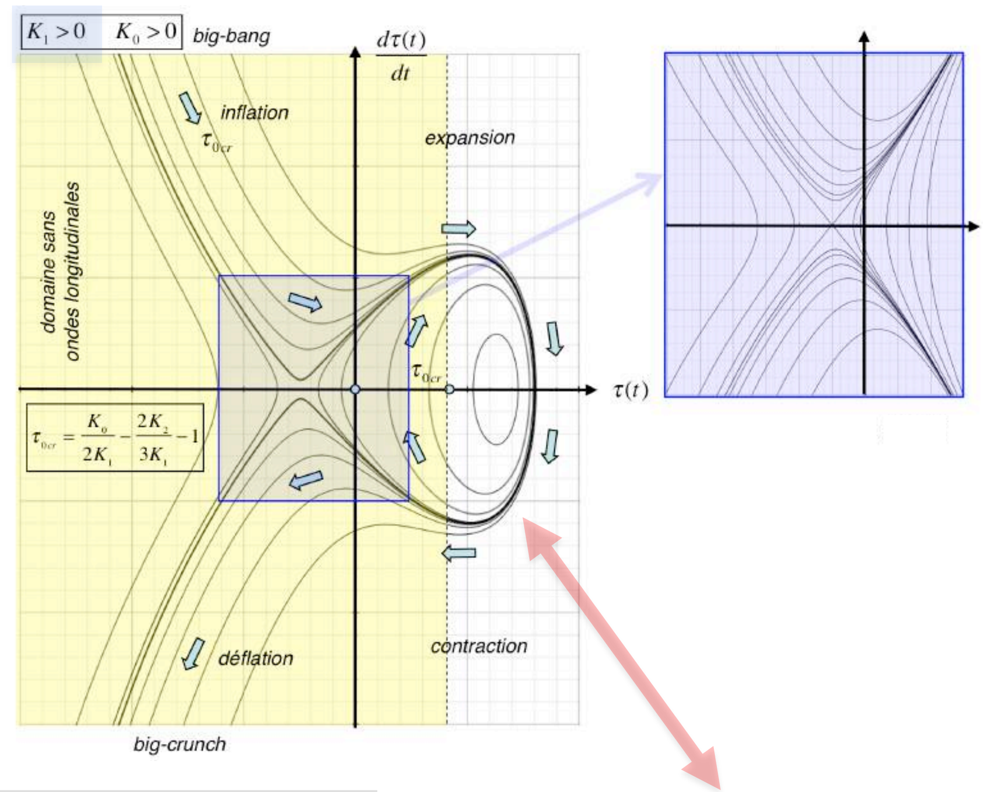


Two types of pleasant cosmological models!

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»

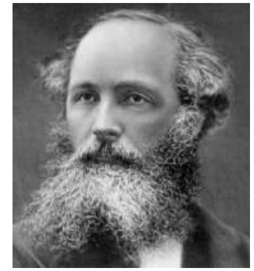
3/ Origin of the «dark energy»: $F = \frac{N}{n_0}(K_1\tau - K_0)\tau\, e^{\tau}$

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

II B - Maxwell equations and special relativity

Maxwell equations

Equations of the cosmic lattice (at constant expansion)		Maxwell equations of electromagnetism
$\begin{cases} -\dfrac{\partial(2\vec{\omega}^{él})}{\partial t} + \overrightarrow{\mathrm{rot}}\,\vec{\phi}^{rot} \cong (2\vec{J}) \\ \mathrm{div}\,(2\vec{\omega}^{él}) = (2\lambda) \end{cases}$	$\Leftrightarrow$	$\begin{cases} -\dfrac{\partial \vec{D}}{\partial t} + \overrightarrow{\mathrm{rot}}\,\vec{H} = \vec{j} \\ \mathrm{div}\,\vec{D} = \rho \end{cases}$
$\begin{cases} \dfrac{\partial(n\vec{p}^{rot})}{\partial t} \cong -\overrightarrow{\mathrm{rot}}\left(\dfrac{\vec{m}}{2}\right) + 2K_2\vec{\lambda}^{rot} \\ \mathrm{div}(n\vec{p}^{rot}) = 0 \end{cases}$	$\Leftrightarrow$	$\begin{cases} \dfrac{\partial \vec{B}}{\partial t} = -\overrightarrow{\mathrm{rot}}\,\vec{E} \\ \mathrm{div}\,\vec{B} = 0 \end{cases}$
$\begin{cases} (2\vec{\omega}^{él}) = \dfrac{1}{(K_2+K_3)}\left(\dfrac{\vec{m}}{2}\right) + (2\vec{\omega}^{an}) + (2\vec{\omega}_0(t)) \\ (n\vec{p}^{rot}) = (nm)\left[\vec{\phi}^{rot} + (C_I - C_L)\vec{\phi}^{rot} + \left(\dfrac{1}{n}\left(\vec{J}_I^{rot} - \vec{J}_L^{rot}\right)\right)\right] \end{cases}$	$\Leftrightarrow$	$\begin{cases} \vec{D} = \varepsilon_0\vec{E} + \vec{P} + \vec{P}_0(t) \\ \vec{B} = \mu_0\left[\vec{H} + \left(\chi^{para} + \chi^{dia}\right)\vec{H} + \vec{M}\right] \end{cases}$
$\left\{ \dfrac{\partial(2\lambda)}{\partial t} \cong -\mathrm{div}(2\vec{J}) \right.$	$\Leftrightarrow$	$\left\{ \dfrac{\partial \rho}{\partial t} = -\mathrm{div}\,\vec{j} \right.$
$\begin{cases} -\left(\dfrac{\vec{m}}{2}\right)(2\vec{J}) \cong \\ \vec{\phi}^{rot}\dfrac{\partial(n\vec{p}^{rot})}{\partial t} + \left(\dfrac{\vec{m}}{2}\right)\dfrac{\partial(2\vec{\omega}^{él})}{\partial t} - \mathrm{div}\left(\vec{\phi}^{rot} \wedge \left(\dfrac{\vec{m}}{2}\right)\right) \end{cases}$	$\Leftrightarrow$	$\begin{cases} -\vec{E}\vec{j} = \\ \vec{H}\dfrac{\partial \vec{B}}{\partial t} + \vec{E}\dfrac{\partial \vec{D}}{\partial t} - \mathrm{div}\left(\vec{H} \wedge \vec{E}\right) \end{cases}$
$\left\{ c_t = \sqrt{\dfrac{K_2+K_3}{mn}} \right.$	$\Leftrightarrow$	$\left\{ c = \sqrt{\dfrac{1}{\varepsilon_0\mu_0}} \right.$
$\left\{ \boldsymbol{\vec{F}}_{PK} = 2\boldsymbol{Q}_\lambda\left(\dfrac{\vec{m}}{2} + \boldsymbol{\vec{v}} \wedge n\vec{p}\right) \right.$	$\Leftrightarrow$	$\left\{ \boldsymbol{\vec{F}} = q\left(\vec{E} + \boldsymbol{\vec{v}} \wedge \vec{B}\right) \right.$



James Clerk Maxwell
(1831-1879)

$$\vec{D} \Leftrightarrow \vec{\omega}$$
$$\vec{E} \Leftrightarrow \vec{m}$$
$$\vec{B} \Leftrightarrow n\vec{p}$$
$$\vec{H} \Leftrightarrow \vec{\phi}$$
$$\vec{P} \Leftrightarrow \vec{\omega}^{an}$$
$$\rho \Leftrightarrow \lambda$$
$$\vec{j} \Leftrightarrow \vec{J}$$
$$\vec{M} \Leftrightarrow \frac{1}{n}\left(\vec{J}_I - \vec{J}_L\right)$$
$$\left(\chi^{para} + \chi^{dia}\right)\vec{H} \Leftrightarrow \left(C_I - C_L\right)\vec{\phi}$$
$$\varepsilon_0 \Leftrightarrow \frac{1}{K_2}$$
$$\mu_0 \Leftrightarrow nm$$
$$c = \sqrt{\frac{1}{\varepsilon_0\mu_0}} \Leftrightarrow c_t = \sqrt{\frac{K_2}{mn}}$$

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

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

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

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

Static case:

$$\Delta\left(\tau^{ch}_{statique}\right) = -\frac{2K_2}{4K_2/3+2K_1(1+\tau_0)-K_0}\,\mathrm{div}\,\vec{\lambda}^{ch} = -\frac{2K_2}{4K_2/3+2K_1(1+\tau_0)-K_0}\,\theta^{ch}$$

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

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

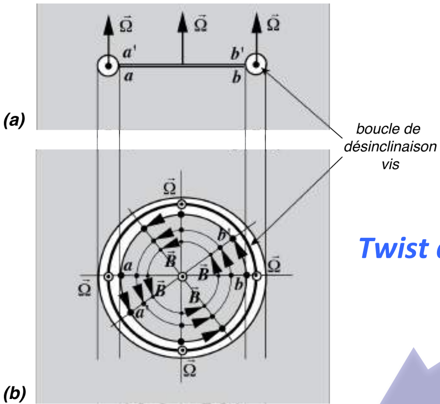
$$nm\frac{d\vec{\phi}^{(p)}}{dt} = \overrightarrow{\mathrm{grad}}\left[\begin{array}{l}\left(4K_2/3+2K_1(1+\tau_0+\tau^{ext}+\tau^{ch})-K_0\right)\tau^{(p)}+K_1\left(\tau^{(p)}\right)^2\\ +\left(K_2\sum_i\left(\vec{\alpha}_i^{ch}\right)^2+2K_3\left(\vec{\omega}^{ch}\right)^2+K_1\left(\tau^{ch}\right)^2\right)\\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

Static case:

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

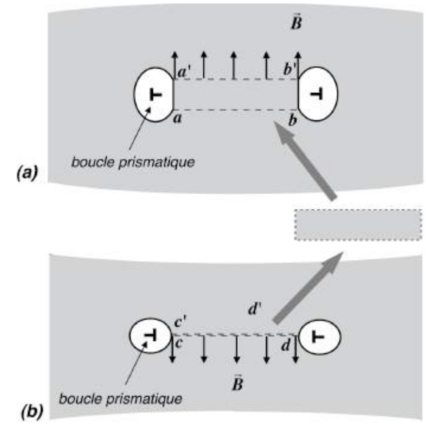
Calculation of the perturbations of the volumic expansion
associated with the topological singularities
(dislocation and disclination loops)

Twist disclination loop and edge dislocation loop



First partial Newton equation

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



Twist disclination loop

Rotation charge *(analogous to electrical charge)*

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

$$\vec{\omega}_{ext}^{BV}=\frac{\boldsymbol{q}_{\lambda\,BV}}{4\pi}\frac{\vec{r}}{r^3}$$

Source of a divergent rotation field *(analogous to an electrical field)*

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

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

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

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

Edge dislocation loop

Flexion charge *(analogous to spatial curvature charge)*

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

$$\vec{\chi}_{ext}^{BC}=\frac{\boldsymbol{q}_{\theta\,BC}}{4\pi}\frac{\vec{r}}{r^3}$$

Source of a divergent flexion field *(analogous to a spatial curvature field)*

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

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

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

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

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)

Conjecture:

$$\begin{cases} K_0 = K_3 > 0, \\ 0 < K_1 << K_0 = K_3 \\ 0 \le K_2 << K_3 = K_0 \end{cases}$$

Same Lorentz transformations for all topological singularities

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

Relativistic energy of the twist disclination loop

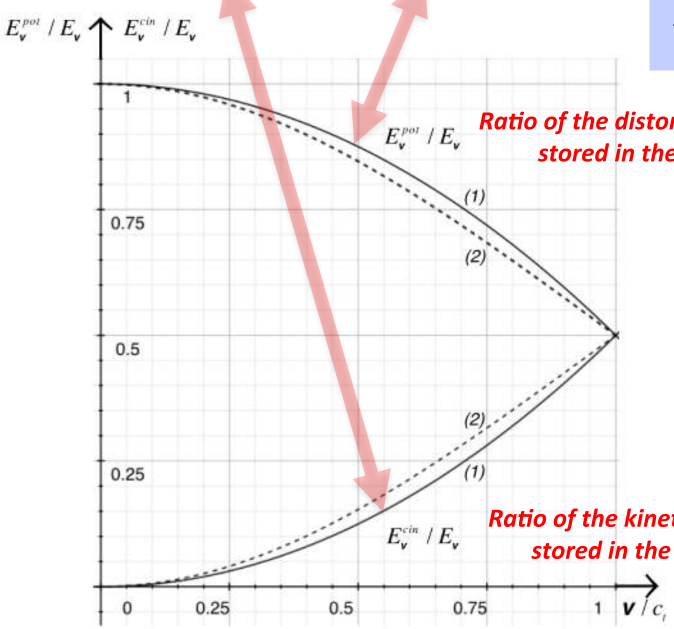
$$E_{\mathbf{v}}^{BV} = \underbrace{\frac{1}{\gamma_t}\left(1 - \frac{\mathbf{v}^2}{2c_t^2}\right)E_{dist}^{BV}}_{E_{\mathbf{v}}^{dist}} + \underbrace{\frac{1}{\gamma_t}\frac{1}{2}M_0^{BV}\mathbf{v}^2}_{E_{\mathbf{v}}^{cin}} = \frac{E_{dist}^{BV}}{\gamma_t} = \frac{M_0^{BV}c_t^2}{\gamma_t}$$

Relativistic dynamics equation for the topological singularities

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

Relativistic energy of the edge dislocation loop

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

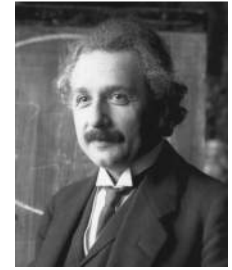


Ratio of the distorsion energy stored in the lattice

Ratio of the kinetic energy stored in the lattice

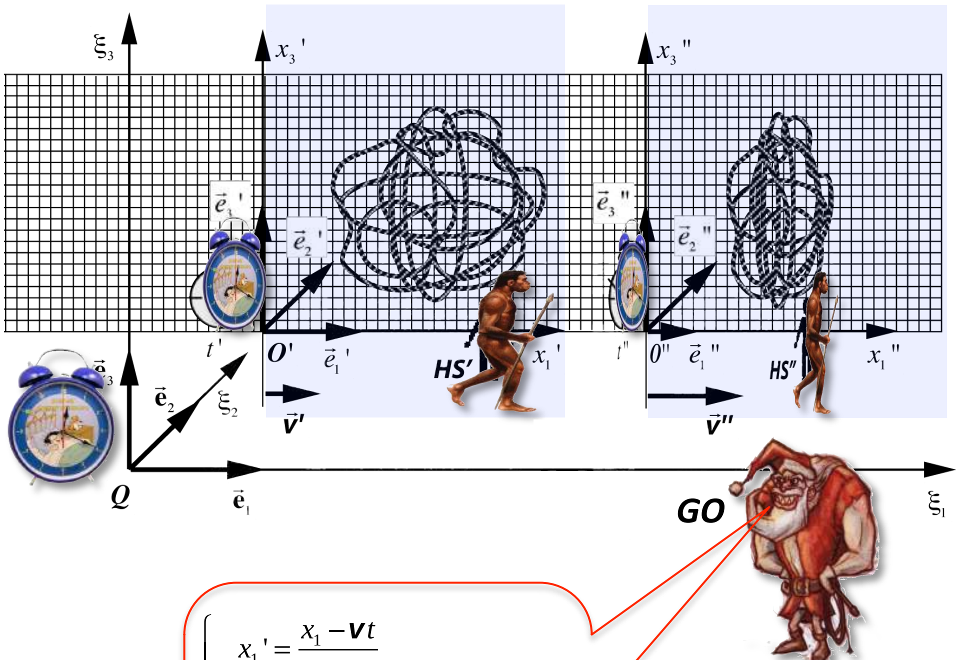
All the topological singularities (of dislocation or disclination types) follow exactly the theory of special relativity

Effects of the Lorentz transformation of the special relativity



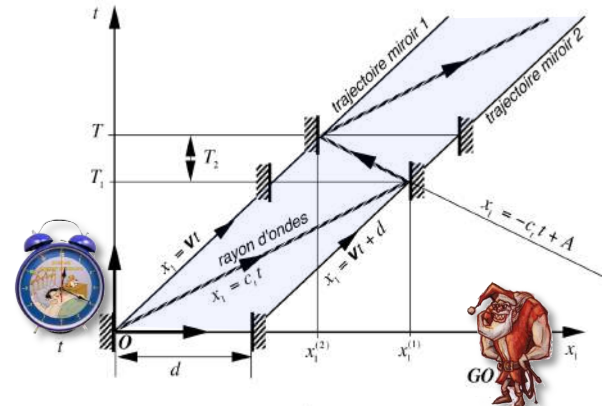
Albert Einstein
(1879-1955)

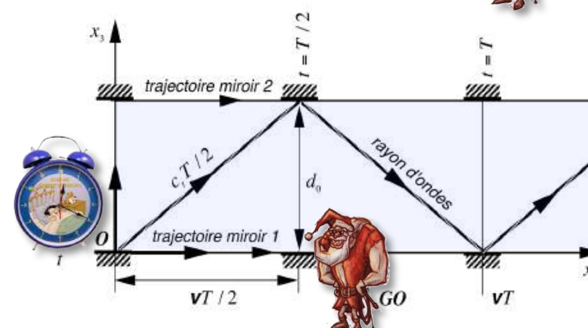
Measuring rods contraction and clock slowing down for the local observers HS



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

Verification of the Michelson-Morley experiments

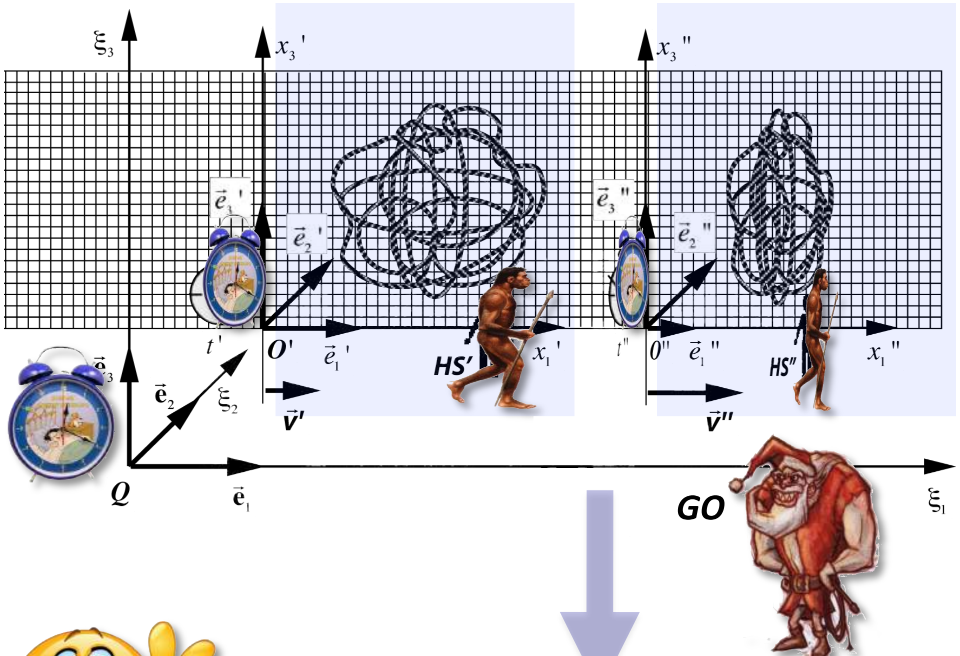




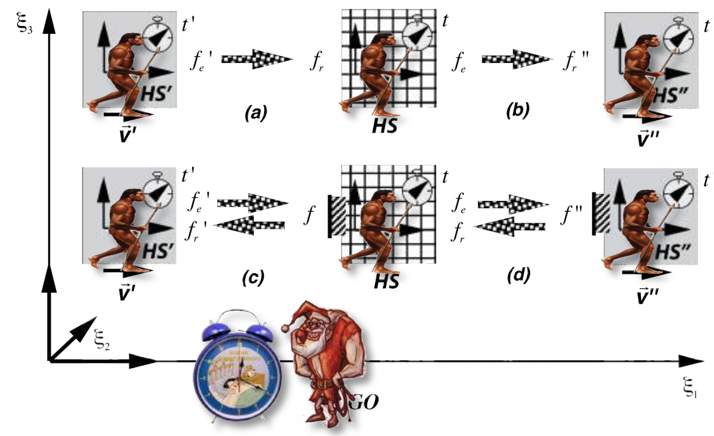
The new « aether » is arrived!

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 exeriment 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

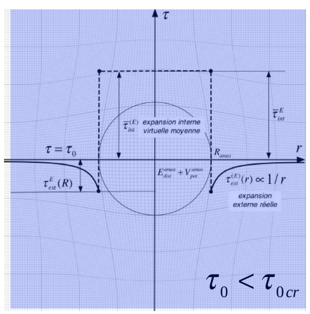
Perturbation of the external expansion field of a topological singularity

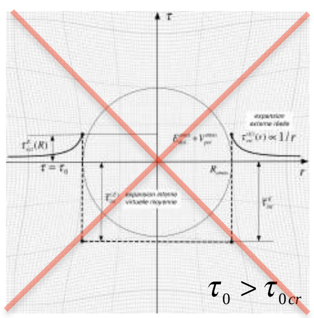
$$K_1\left(\tau^{(p)}(\vec r)\right)^2+\left[4K_2/3+2K_1\left(1+\tau_0+\tau^{ext}(\vec r)+\tau^{ch}(\vec r)\right)-K_0\right]\tau^{(p)}(\vec r)+\left(F^{ch}_{dist}(\vec r)+F^{ch}_{pot}(\vec r)\right)=cste=0$$

Second partial Newton equation
(in the static case)

Effect of the energy of a singularity

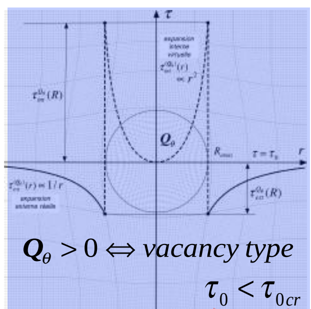
$E^{amas}_{dist}+V^{amas}_{pot}$



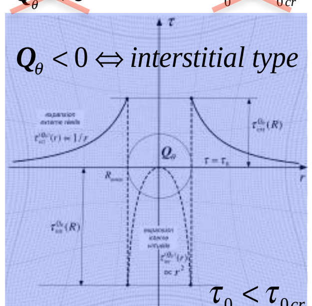


Effect of the flexion charge of a singularity

$\boldsymbol{Q}_\theta$



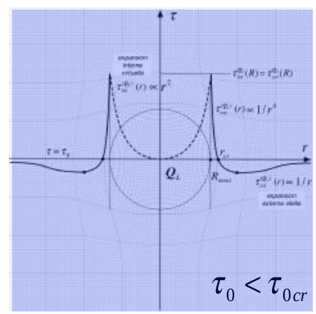
~~$\boldsymbol{Q}_\theta<0$~~ ~~$\tau_0>\tau_{0cr}$~~

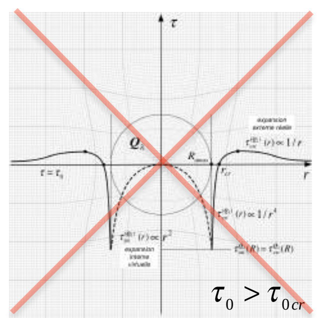


~~$\boldsymbol{Q}_\theta>0$~~ ~~$\tau_0>\tau_{0cr}$~~

Effect of the rotation charge of a singularity

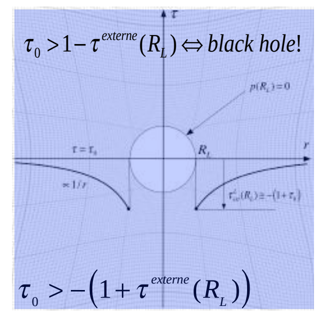
$\boldsymbol{Q}_\lambda$



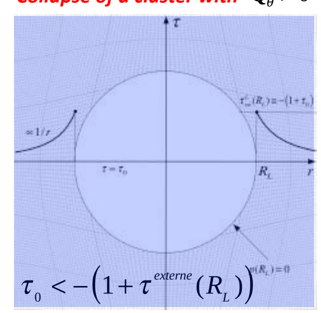


Effect of a macroscopic vacancy singularity

$R_L=\sqrt[3]{\dfrac{3N_L}{4\pi n_0\,\mathrm{e}}}$

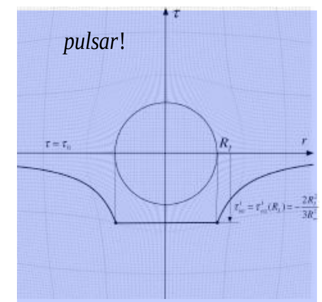


Collapse of a cluster with $\boldsymbol{Q}_\theta>0$



Effect of a macroscopic interstitial singularity

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



Collapse of a cluster with $\boldsymbol{Q}_\theta<0$

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

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

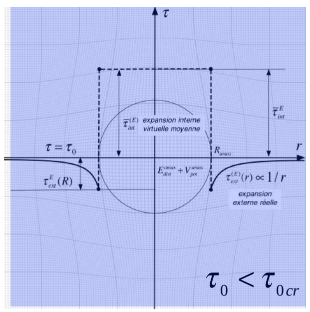
Second partial Newton equation
(in the static case)

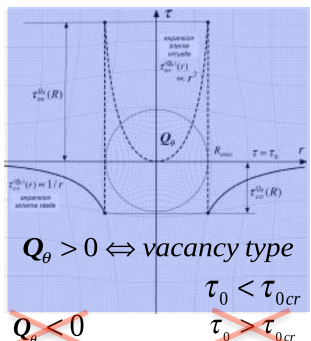
Effect of the energy of the singularity

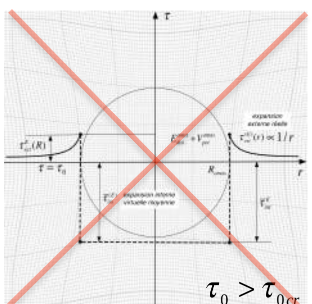
$$E^{amas}_{dist}+V^{amas}_{pot}$$

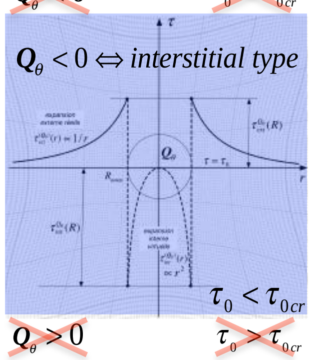
Effect of the flexion charge of the singularity

$$Q_\theta$$









Conjecture:

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

$$\left|\tau^{Q_\theta}_{ext}\right| << \left|\tau^{E}_{ext}\right|$$

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

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

Second partial Newton equation (in the static case)

Conjecture:

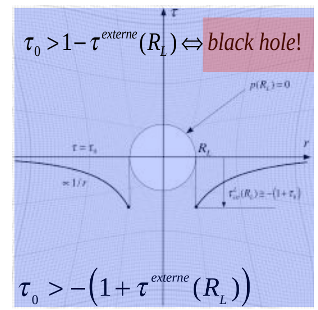
$$\text{flexion charge}: \begin{cases} \mathbf{Q}_\theta>0 \Leftrightarrow \text{vacancy type} \Leftrightarrow \text{analogous to anti-matter} \\ \mathbf{Q}_\theta<0 \Leftrightarrow \text{interstitial type} \Leftrightarrow \text{analogous to matter} \end{cases}$$

Effect of a macroscopic vacancy singularity

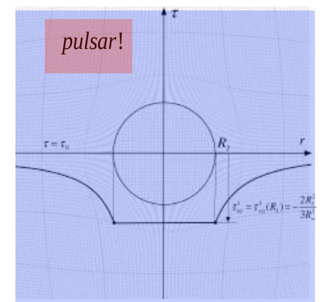
$$R_L=\sqrt[3]{\frac{3N_L}{4\pi n_0\,\mathrm{e}}}$$

Effect of a macroscopic interstitial singularity

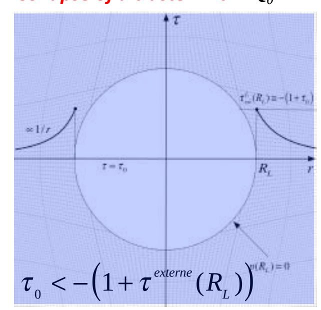
$$R_I\cong\sqrt[3]{\frac{3N_I}{4\pi n_0}}\,\mathrm{e}^{\frac{\tau_0+\tau^{externe}(R_I)}{3}}$$



Collapse of a cluster with $\mathbf{Q}_\theta>0$



Collapse of a cluster with $\mathbf{Q}_\theta<0$



1/ The collapse of a cluster with $\mathbf{Q}_\theta>0$ (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 $\mathbf{Q}_\theta<0$ (matter) leads to a macroscopic interstitial singularity

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

« Gravitational » interaction between elementary topological singularities

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

$$F_{grav}^{BV-BV} \cong \boldsymbol{G}_{grav} \frac{M_{0(1)}^{BV} M_{0(2)}^{BV}}{d^2}$$

Predominant interaction

$$F_{grav}^{BC-BC} \cong (\alpha_{BC} + 2\beta_{BC}) \boldsymbol{G}_{grav} \frac{M_{courbure(1)}^{BC} M_{0(2)}^{BC} + M_{courbure(2)}^{BC} M_{0(1)}^{BC}}{d^2} + 2(\alpha_{BC} + 2\beta_{BC}) \boldsymbol{G}_{grav} \frac{M_{0(1)}^{BC} M_{0(2)}^{BC}}{d^2}$$

$$F_{grav}^{BM-BM} \cong 2(\alpha_{BM} + 2\beta_{BM}) \boldsymbol{G}_{grav} \frac{M_{0(1)}^{BM} M_{0(2)}^{BM}}{d^2}$$

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

$$F_{grav}^{BV-BM} \cong \left(\frac{1}{2} + 4(\alpha_{BM} + 2\beta_{BM})\right) \boldsymbol{G}_{grav} \frac{M_0^{BV} M_0^{BM}}{d^2}$$

$$F_{grav}^{BC-BM} \cong 4(\alpha_{BM} + 2\beta_{BM}) \boldsymbol{G}_{grav} \frac{M_{courbure}^{BC} M_0^{BM}}{d^2} + 4(\alpha_{BC} + 2\beta_{BC} + \alpha_{BM} + 2\beta_{BM}) \boldsymbol{G}_{grav} \frac{M_0^{BC} M_0^{BM}}{d^2}$$

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

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

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

$$F_{grav}^{BM-L} \cong 4\boldsymbol{G}_{grav} \frac{1+(\alpha_{BM} + 2\beta_{BM})(1+\tau_0)}{1+\tau_0} \frac{M_0^{BM} M_{grav}^{(L)}}{d^2} \cong c_t^2 \left[1 + (\alpha_{BM} + 2\beta_{BM})(1+\tau_0)\right] \frac{M_0^{BM} R_L}{d^2}$$

$$F_{grav}^{BV-I} \cong \frac{9}{2} \boldsymbol{G}_{grav} \frac{M_0^{BV} M_{grav}^{(I)}}{d^2} \cong \frac{3c_t^2}{4R_\infty^2} \frac{M_0^{BV} R_I^3}{d^2}$$

$$F_{grav}^{BC-I} \cong 4\boldsymbol{G}_{grav} \frac{M_{courbure}^{BC} M_{grav}^{(I)}}{d^2} + 4\boldsymbol{G}_{grav} (1 + \alpha_{BC} + 2\beta_{BC}) \frac{M_0^{BC} M_{grav}^{(I)}}{d^2}$$

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

$$F_{grav}^{BM-I} \cong 4\boldsymbol{G}_{grav} \left[1 + \alpha_{BM} + 2\beta_{BM}\right] \frac{M_0^{BM} M_{grav}^{(I)}}{d^2} \cong \frac{2c_t^2}{3R_\infty^2} \left[1 + \alpha_{BM} + 2\beta_{BM}\right] \frac{M_0^{BM} R_I^3}{d^2}$$

$$F_{grav}^{L-L} \cong \frac{8\boldsymbol{G}_{grav}}{(1+\tau_0)} \frac{M_{grav(1)}^{(L)} M_{grav(2)}^{(L)}}{d^2} \cong \frac{c_t^4 (1+\tau_0)}{2\boldsymbol{G}_{grav}} \frac{R_{L(1)} R_{L(2)}}{d^2}$$

$$F_{grav}^{I-I} \cong 2\boldsymbol{G}_{grav} \frac{M_{grav(1)}^{(I)} M_{grav(2)}^{(I)}}{d^2} \cong \frac{c_t^4}{18\boldsymbol{G}_{grav} R_\infty^4} \frac{R_{I(1)}^3 R_{I(2)}^3}{d^2}$$

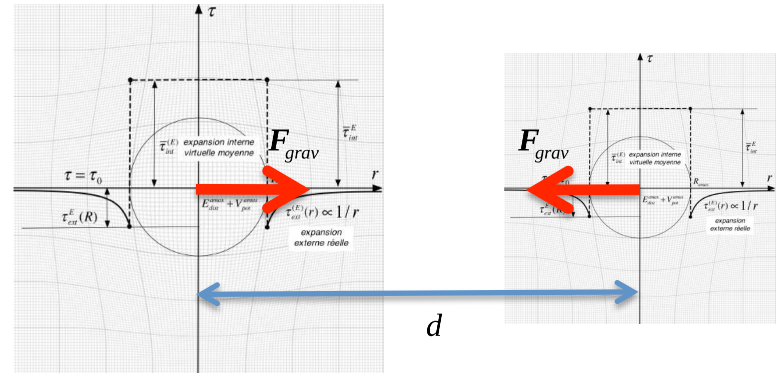
$$F_{grav}^{L-I} \cong 4\boldsymbol{G}_{grav} \frac{2+\tau_0}{1+\tau_0} \frac{M_{grav}^{(L)} M_{grav}^{(I)}}{d^2} \cong \frac{c_t^4}{6R_\infty^2} \frac{2+\tau_0}{\boldsymbol{G}_{grav}} \frac{R_L R_I^3}{d^2}$$

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

L=macroscopic vacancy
I=macorscopic interstitial

Gotlib

Gravitational interaction force between two clusters of elementary singularities



$$\boldsymbol{F}_{grav} \cong \boldsymbol{G}_{grav} \frac{M_{0(1)}^{amas} M_{0(2)}^{amas}}{d^2} \left(1 - \frac{\boldsymbol{G}_{grav}}{4c_t^2} \frac{\left(M_{0(1)}^{amas} + M_{0(2)}^{amas}\right)}{d} + \ldots\right)$$

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

$$\tau_{ext}(r) \cong -\frac{4\boldsymbol{G}_{grav} M_0^{amas}}{c_t^2 r}$$

1/ Analogy with Newton gravitation

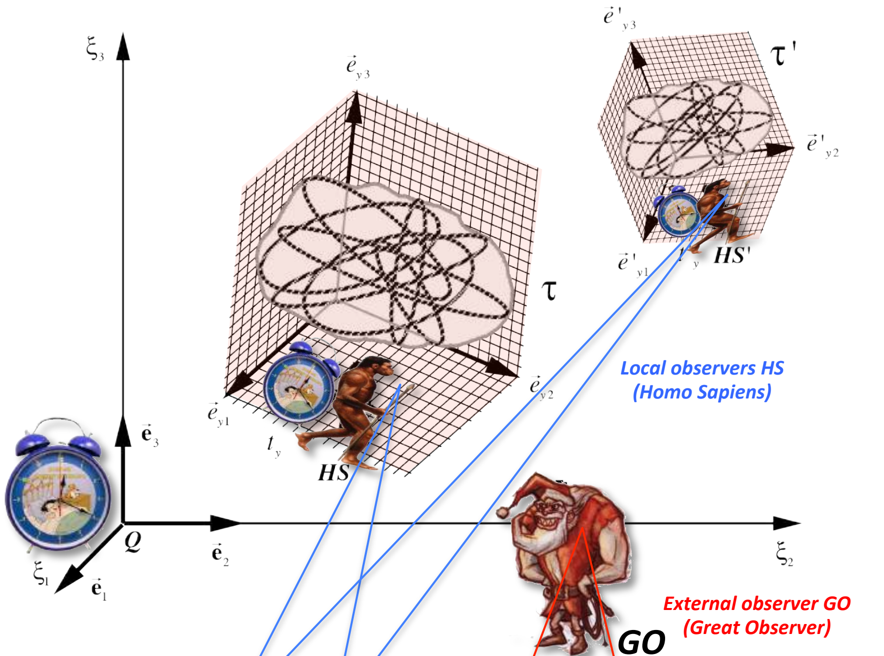
2/ Small corrections at very short distances as in general relativity, but different!

3/ Gravitationnal 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



$$\begin{cases} y_i = \mathrm{e}^{\frac{G_{grav}M_0^{amas}}{c_t^2 r}}\,\xi_i \cong \left(1+\dfrac{G_{grav}M_0^{amas}}{c_t^2 r}\right)\xi_i \\ t_y = \mathrm{e}^{-\frac{G_{grav}M_0^{amas}}{c_t^2 r}}\,t \cong \left(1-\dfrac{G_{grav}M_0^{amas}}{c_t^2 r}\right)t \end{cases}$$

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

Invariant Maxwell equations

$$\begin{cases} -\dfrac{\partial(2\vec{\omega}_{(y)}^{él})}{\partial t_y} + \overrightarrow{\mathrm{rot}}_y\,\vec{\phi}_{(y)}^{rot} \cong (2\vec{J}_{(y)}) \\ \mathrm{div}_y\,(2\vec{\omega}_{(y)}^{él}) = (2\lambda_{(y)}) \end{cases}$$

$$\begin{cases} \dfrac{\partial\left(n_0\vec{p}_{(y)}^{rot}\right)}{\partial t_y} \cong -\overrightarrow{\mathrm{rot}}_y\left(\dfrac{\vec{m}_{(y)}}{2}\right) + 2K_2\vec{\lambda}_{(y)}^{rot} \\ \mathrm{div}_y\left(n_0\vec{p}_{(y)}^{rot}\right) = 0 \end{cases}$$

$$\begin{cases} (2\vec{\omega}_{(y)}^{él}) = \dfrac{1}{(K_2+K_3)}\left(\dfrac{\vec{m}_{(y)}}{2}\right) + (2\vec{\omega}_{(y)}^{an}) \\ \left(n_0\vec{p}_{(y)}^{rot}\right) = (n_0 m)\left[\vec{\phi}_{(y)}^{rot} + \left(C_{I(y)} - C_{L(y)}\right)\vec{\phi}_{(y)}^{rot} + \left(\dfrac{1}{n_0}\left(\vec{J}_{I(y)}^{rot} - \vec{J}_{L(y)}^{rot}\right)\right)\right] \end{cases}$$

$$\left\{ \dfrac{\partial(2\lambda_{(y)})}{\partial t_y} \cong -\mathrm{div}_y(2\vec{J}_{(y)}) \right.$$

$$\left\{ c_{t0} = \sqrt{\dfrac{K_2+K_3}{mn_0}} = cste \right.$$

Maxwell equations depending on the local expansion

$$\begin{cases} -\dfrac{\partial(2\vec{\omega}^{él})}{\partial t} + \overrightarrow{\mathrm{rot}}\,\vec{\phi}^{rot} \cong (2\vec{J}) \\ \mathrm{div}\,(2\vec{\omega}^{él}) = (2\lambda) \end{cases}$$

$$\begin{cases} \dfrac{\partial(n\vec{p}^{rot})}{\partial t} \cong -\overrightarrow{\mathrm{rot}}\left(\dfrac{\vec{m}}{2}\right) + 2K_2\vec{\lambda}^{rot} \\ \mathrm{div}(n\vec{p}^{rot}) = 0 \end{cases}$$

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

$$\left\{ \dfrac{\partial(2\lambda)}{\partial t} \cong -\mathrm{div}(2\vec{J}) \right.$$

$$\left\{ c_t = \sqrt{\dfrac{K_2+K_3}{mn}} = \sqrt{\dfrac{K_2+K_3}{mn_0}}\,\mathrm{e}^{\tau_0} \neq cste \right.$$

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/ Phsics 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 desagreement with the general relativity

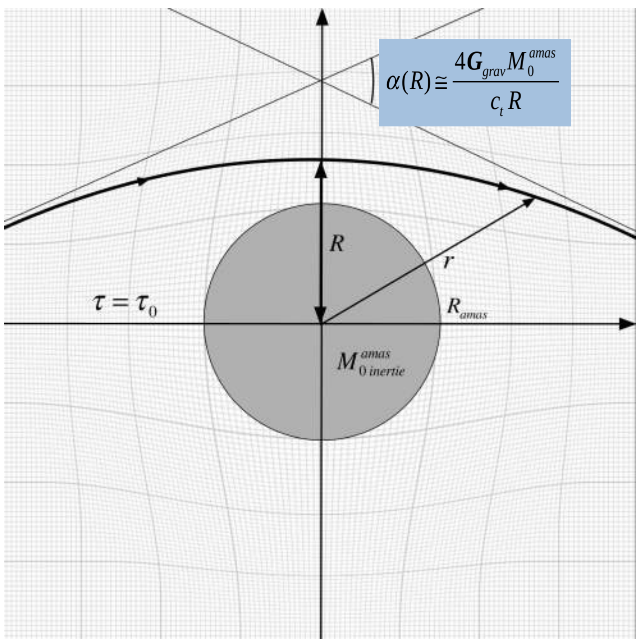
$$\begin{cases} y_i = e^{\frac{G_{grav} M_0^{amas}}{c_t^2 r}} \xi_i \cong \left(1 + \frac{G_{grav} M_0^{amas}}{c_t^2 r}\right) \xi_i \\ t_y = e^{-\frac{G_{grav} M_0^{amas}}{c_t^2 r}} t \cong \left(1 - \frac{G_{grav} M_0^{amas}}{c_t^2 r}\right) t \end{cases}$$

Relations of our theory

Relations of the Schwarzschild metric in general relativity

Karl Schwarzschild (1873-1916)

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

	Our theory	General relativity
Schwarzschild radius	$R_{Schwarzschild} = \frac{2G_{grav} M_0^{amas}}{c_t^2}$	$R_{Schwarzschild} = \frac{2G_{grav} M_0^{amas}}{c_t^2}$
Radius of photon sphere	$R_{photon} = \frac{2G_{grav} M_0^{amas}}{c_t^2}$	$R_{photon} = \frac{3G_{grav} M_0^{amas}}{c_t^2}$
Radius where the time dilatation of falling observers becomes infinite	$R_{time\ dilatation \to \infty} \to 0$	$R_{time\ dilatation \to \infty} \cong \frac{G_{grav} M_0^{amas}}{c_t^2}$

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

$$\boldsymbol{G} = 8\pi \boldsymbol{T}$$

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

$$\vec{\nabla} \bullet \boldsymbol{G} = \vec{\nabla} \bullet \boldsymbol{T} = \vec{\nabla} \bullet \boldsymbol{T}[\quad .... \quad] = 0$$

Motion equation

Curvature tensors

Energy-momentum tensors

Curvature charge

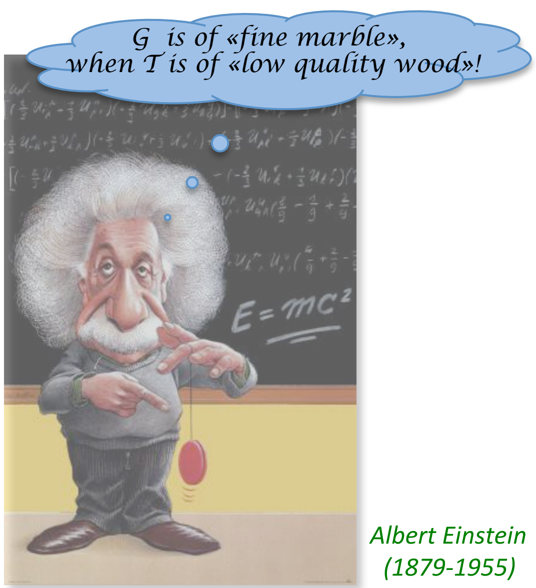
Equations of the 3D space curvature of the lattice as seen by the external observer GO

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

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

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

Newton equation of the lattice!



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

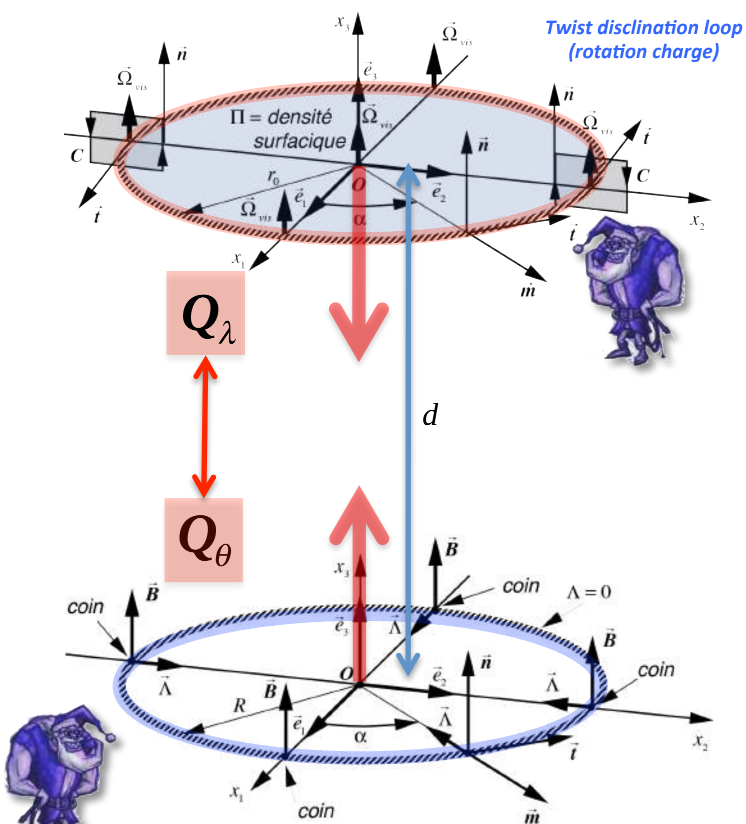
3/ For the local observers HS, who own local clocks, the curvature has to be a space-time curvature

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

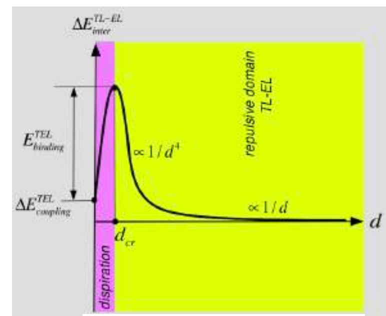
Combination of a twist disclination loop
with an edge dislocation loop
to form a dispiration loop

Twist disclination loop
(rotation charge)

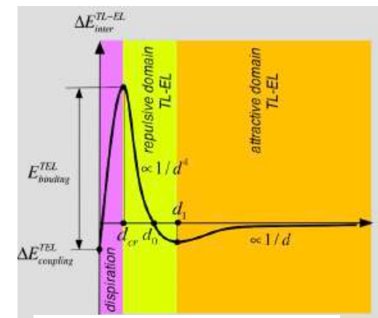


Edge dislocation loop
(flexion charge)

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



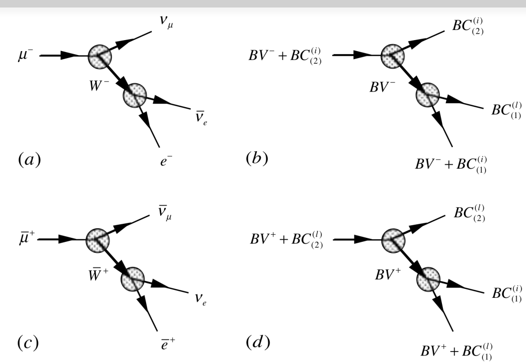
Twist disclination loop
with interstitial type edge dislocation loop



Twist disclination loop
with vacancy type edge dislocation loop

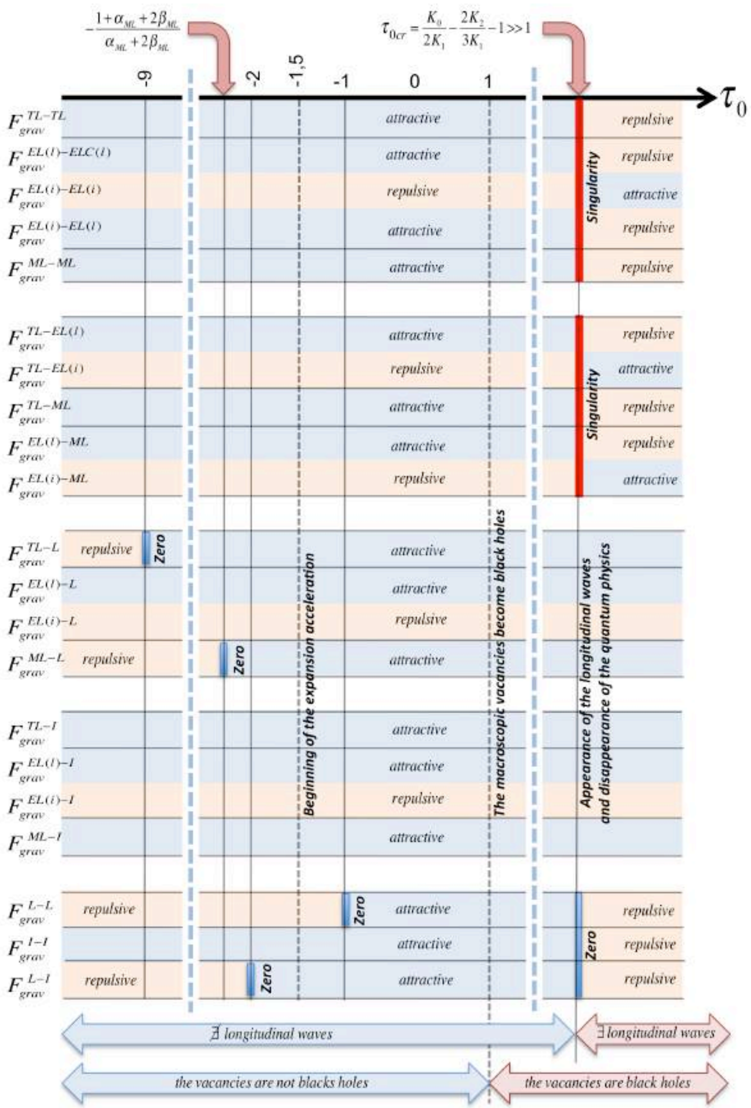
1/ Analogy with the weak interaction force of the standard model of particles

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)

Conjecture:

$$\begin{cases} X \Rightarrow \text{particles (dispirations containing interstitial edge dislocation loop)} \\ \overline{X} \Rightarrow \text{anti-particle (dispirations containing vacancy edge dislocation loop)} \\ \nu^0 \Rightarrow \text{neutrino (pure interstitial edge dislocation loop)} \\ \overline{\nu}^0 \Rightarrow \text{anti-neutrino (pure vacancy edge dislocation loop)} \end{cases}$$

$$\begin{cases} M_0^X = M_0^{\overline{X}} > 0 \\ M_{courbure}^{\overline{X}} > 0 \quad ; \quad M_{courbure}^{X} < 0 \\ \left|M_{courbure}^X\right| = M_{courbure}^{\overline{X}} << M_0^X = M_0^{\overline{X}} \end{cases} \qquad \begin{cases} M_0^{\nu^0} = M_0^{\overline{\nu}^0} > 0 \\ M_{courbure}^{\overline{\nu}^0} > 0 \quad ; \quad M_{courbure}^{\nu^0} < 0 \\ \left|M_{courbure}^{\nu^0}\right| = M_{courbure}^{\overline{\nu}^0} >> M_0^{\nu^0} = M_0^{\overline{\nu}^0} \end{cases}$$

$$\begin{cases} \boldsymbol{F}_{grav}^{X-X} \;\tilde{<}\; \boldsymbol{F}_{grav}^{X-\overline{X}} \;\tilde{<}\; \boldsymbol{F}_{grav}^{\overline{X}-\overline{X}} \\ \boldsymbol{F}_{grav}^{X-Y} \;\tilde{<}\; \boldsymbol{F}_{grav}^{\overline{X}-Y} \cong \boldsymbol{F}_{grav}^{X-\overline{Y}} \;\tilde{<}\; \boldsymbol{F}_{grav}^{\overline{X}-\overline{Y}} \\ \boldsymbol{F}_{grav}^{\nu^0-\nu^0} < 0 \; ; \; \boldsymbol{F}_{grav}^{\overline{\nu}^0-\overline{\nu}^0} > 0 \; ; \; \boldsymbol{F}_{grav}^{\nu^0-\overline{\nu}^0} \cong 0 \; ; \; \boldsymbol{F}_{grav}^{\nu^0-\nu^0} = -\boldsymbol{F}_{grav}^{\overline{\nu}^0-\overline{\nu}^0} \\ \boldsymbol{F}_{grav}^{X-\nu^0} < 0 \; ; \; \boldsymbol{F}_{grav}^{X-\overline{\nu}^0} \cong 0 \; ; \; \boldsymbol{F}_{grav}^{\overline{X}-\nu^0} \cong 0 \; ; \; \boldsymbol{F}_{grav}^{\overline{X}-\overline{\nu}^0} > 0 \end{cases}$$

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

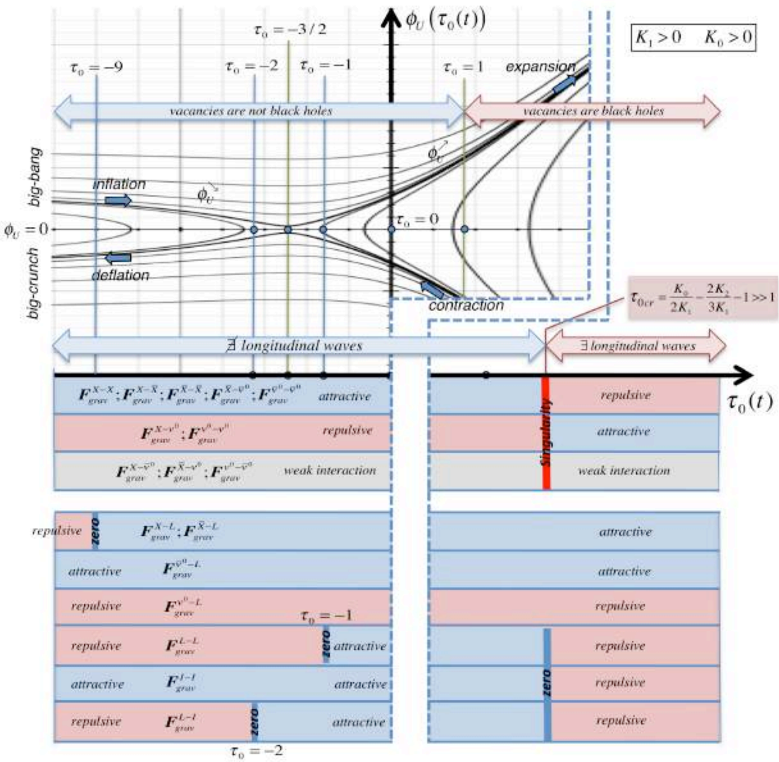
2/ All the other interactions are attractive (or very small)

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

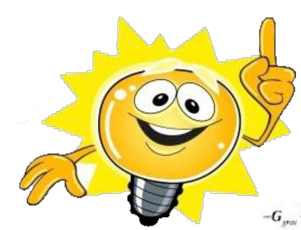
10/ under gravity, collapse of stars of matter to form pulsars (macroscopic interstitial clusters)

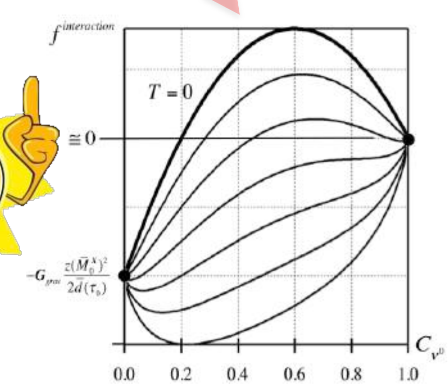
1/ Explains the formation of the galaxies
and of gigantic black holes in the center of the galaxies

2/ Explains the disapearance 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

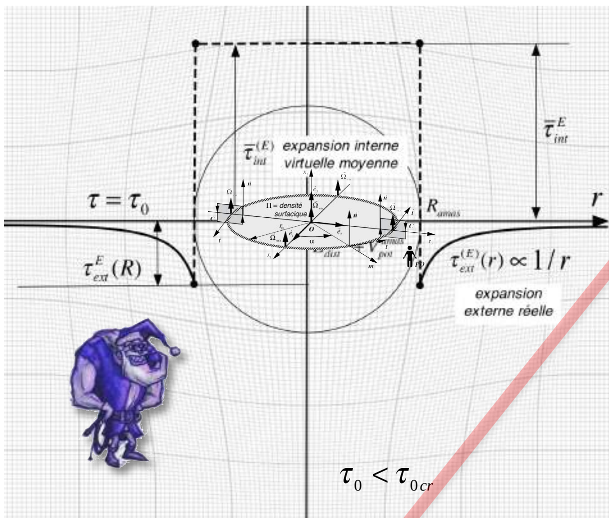




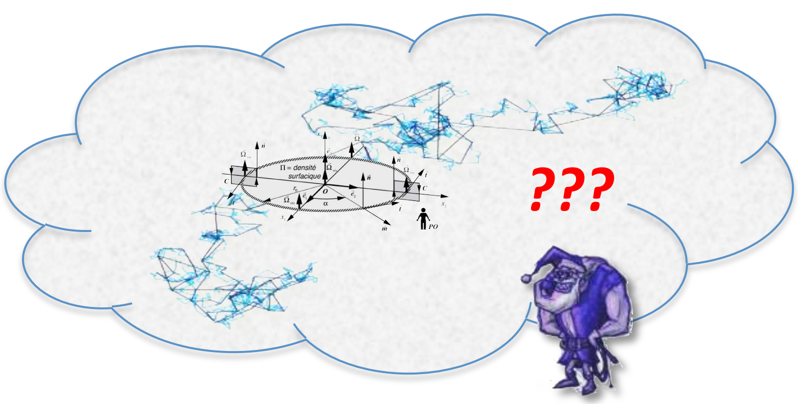
II D - Quantum physics and standard model of particles

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)

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

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

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

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

$$\begin{cases} -\hbar^2 \dfrac{\partial^2}{\partial t^2}\underline{\psi} \rightarrow E_v^2 \underline{\psi} \\ -\hbar^2 \Delta \underline{\psi} \rightarrow \vec{P}_v^{\,2} \underline{\psi} \end{cases}$$

$$\begin{cases} E_v = \dfrac{M_0 c_t^2}{\gamma} = \dfrac{E_0^{dist} + V(\vec{r},t)}{\gamma} \\ M_0 c_t^2 = E_0^{dist} + V(\vec{r},t) \\ \vec{P}_v = \dfrac{M_0}{\gamma}\vec{v} = \dfrac{E_0^{dist} + V(\vec{r},t)}{\gamma c_t^2}\vec{v} \end{cases} \qquad \gamma = \sqrt{1 - \frac{\vec{v}^{\,2}}{c_t^2}}$$

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

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

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

Solution for a relativistic quasi-free singularity

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

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

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

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

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

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

$$\gamma = \sqrt{1-\frac{\vec{\mathbf{v}}^{\,2}}{c_t^2}} \to 1 \quad \& \quad \hbar^2\frac{\partial^2\underline{\psi}}{\partial t^2} = -E_{\mathbf{v}}^2\underline{\psi} \to -\left(E_0^{dist}+V(\vec{r},t)\right)^2\underline{\psi} \quad \Rightarrow$$

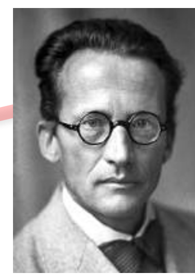
Schrödinger equation

$$i\hbar\frac{\partial\underline{\psi}}{\partial t} \cong -\frac{\hbar^2}{2M_0}\Delta\underline{\psi} + \left(E_0^{dist}+V(\vec{r},t)\right)\underline{\psi}$$

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

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

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: stationnary wave equation, commutators, uncertainty principle of Heisenberg, probabilistic interpretation of the wave function, etc.

Stationary state of two coupled mobile singularities

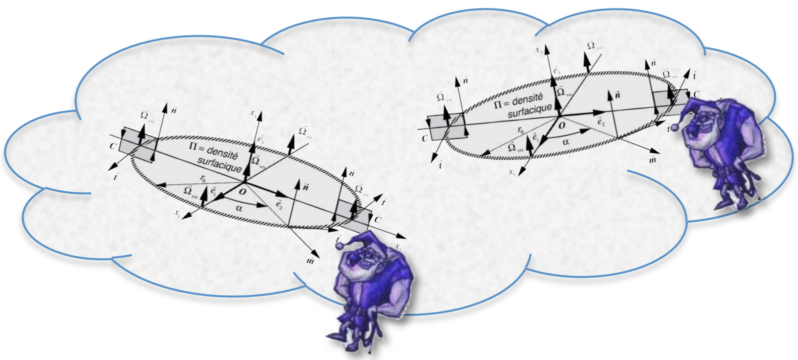
$$\begin{cases} -\dfrac{\hbar^2}{2M_0}\Delta\underline{\psi}_n(\vec{r}_a)+V(\vec{r}_a)\underline{\psi}_n(\vec{r}_a)=E_n\underline{\psi}_n(\vec{r}_a) \\ -\dfrac{\hbar^2}{2M_0}\Delta\underline{\psi}_m(\vec{r}_b)+V(\vec{r}_b)\underline{\psi}_m(\vec{r}_b)=E_m\underline{\psi}_m(\vec{r}_b) \end{cases}$$

Stationary Schrödinger equations

Stationary coupled Schrödinger equation

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

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



Two possible solutions for the gravitational fluctuations with frequency oscillations:

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

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

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

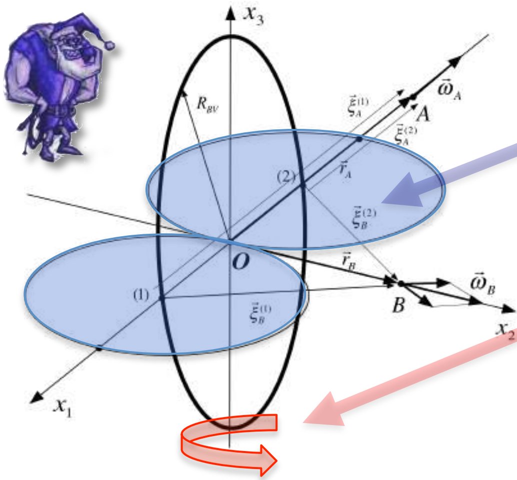
2/ For the fermions solution, superposition of the two singularities is impossible because the gravitational fluctuations will deseappear in this case!
=> Pauli exclusion principle for the fermions solution

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

Dynamic internal gravitationnal field of a singularity: the spin of the singularity

Second partial Newton equation
(in the static case)

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



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

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

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

Solution of the stationary
Schrödinger equation:

$$\begin{cases}\varepsilon_j=\dfrac{\hbar^2}{2I}j(j+1)\\ m_z=j,j-1,...,1-j,-j\end{cases}$$

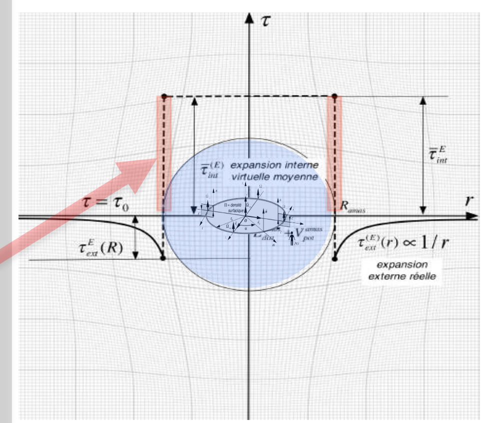
Quantification of the angular momentum
and the magnetic momentum of the loop,
with right value of the Bohr magneton!

$$\begin{cases}E^{cin}_{rotation\,BV}=\hbar^2\,j\,(j+1)/2I_{BV}\\ \left|\vec{L}_{BV}\right|=\sqrt{2I_{BV}E^{cin}_{rotation\,BV}}=\hbar\sqrt{j\,(j+1)}\\ L_z=\hbar m_z\end{cases}\Leftrightarrow\begin{cases}I_{BV}=\delta_1\dfrac{M_0^{BV}R_{BV}^2}{4}\\ \vec{\mu}_{BV\,z}\cong\underbrace{g_{BV}}_{\cong 2}\dfrac{\hbar\boldsymbol{q}_{\lambda BV}}{2M_0^{BV}}m_z\vec{e}_z\end{cases}$$

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, …

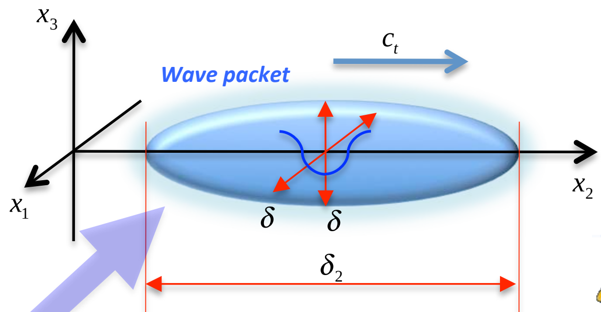
3/ The argument of the pionners of quantum physics against a real rotation of the charge based on the fact that the equatorial velocity of the charge would be higher than the light velocity is wrong if $K_1 < 1{,}8 \bullet 10^9$
due to the enormous static expansion in the vicinity of the loop.



Transversal wave packets: the photons

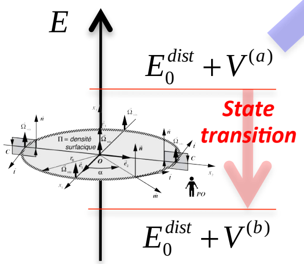
Transversal wave packets needs helicity
to present a constant energy

$$\begin{cases} \underline{\omega}_1(x_2,t) = \omega_{10}\, e^{-\frac{|x_1|}{\delta}}\, e^{-\frac{|x_3|}{\delta}}\, e^{-\frac{|x_2-c_t t|}{\delta_2}}\, e^{i\frac{\omega}{c_t}(x_2-c_t t)} \\ \underline{\omega}_3(x_2,t) = \pm i\omega_{10}\, e^{-\frac{|x_1|}{\delta}}\, e^{-\frac{|x_3|}{\delta}}\, e^{-\frac{|x_2-c_t t|}{\delta_2}}\, e^{i\frac{\omega}{c_t}(x_2-c_t t)} \end{cases} \qquad \begin{cases} \underline{\phi}_3(x_2,t) = -2c_t\omega_{10}\, e^{-\frac{|x_1|}{\delta}}\, e^{-\frac{|x_3|}{\delta}}\, e^{-\frac{|x_2-c_t t|}{\delta_2}}\, e^{i\frac{\omega}{c_t}(x_2-c_t t)} \\ \underline{\phi}_1(x_2,t) = \pm i2c_t\omega_{10}\, e^{-\frac{|x_1|}{\delta}}\, e^{-\frac{|x_3|}{\delta}}\, e^{-\frac{|x_2-c_t t|}{\delta_2}}\, e^{i\frac{\omega}{c_t}(x_2-c_t t)} \end{cases}$$



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

Constant energy of the wave packet with helicity



$$\Delta E_{perdue} = E_0^{dist} + V^{(a)} - \left(E_0^{dist} + V^{(b)}\right) = V^{(a)} - V^{(b)} = \hbar\underline{\omega}_f^{(a)} - \hbar\underline{\omega}_f^{(b)} = \hbar\left(\underline{\omega}_f^{(a)} - \underline{\omega}_f^{(b)}\right)$$

Energy of formation

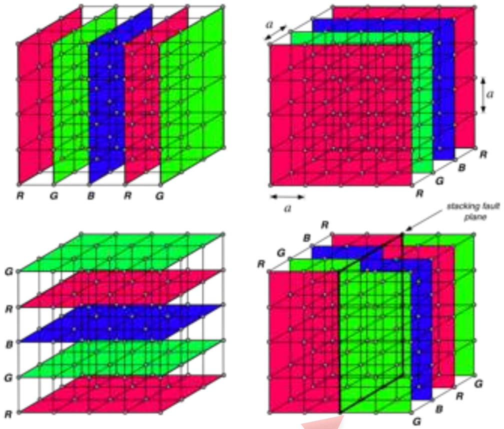
$$E^{\,fluctuation} = 4K_3\omega_{10}^2\delta^2\delta_2 = \hbar\left(\underline{\omega}_f^{(a)} - \underline{\omega}_f^{(b)}\right) = \hbar\underline{\omega}_{\,fluctuation}$$

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



Stacking fault energy

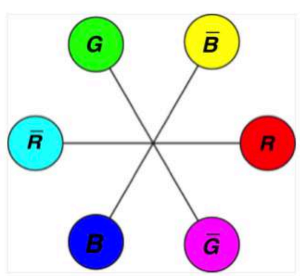
1/ Introduce a « coloured » cubic lattice with three simple rules concerning the alternance and the rotation of the coloured planes

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),

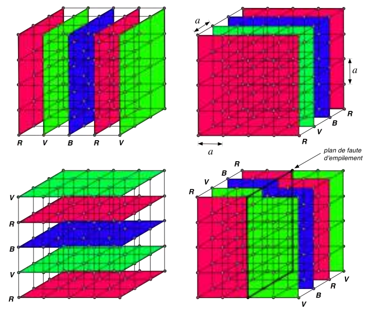
Rule 2: in a given direction of space, there may appear a stacking fault corresponding to a shift in the alternation of planes R, G, B , which possesses a surface stacking fault energy which is not null .

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.

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

Steven Weinberg, Abdus Salam and Sheldon Glashow

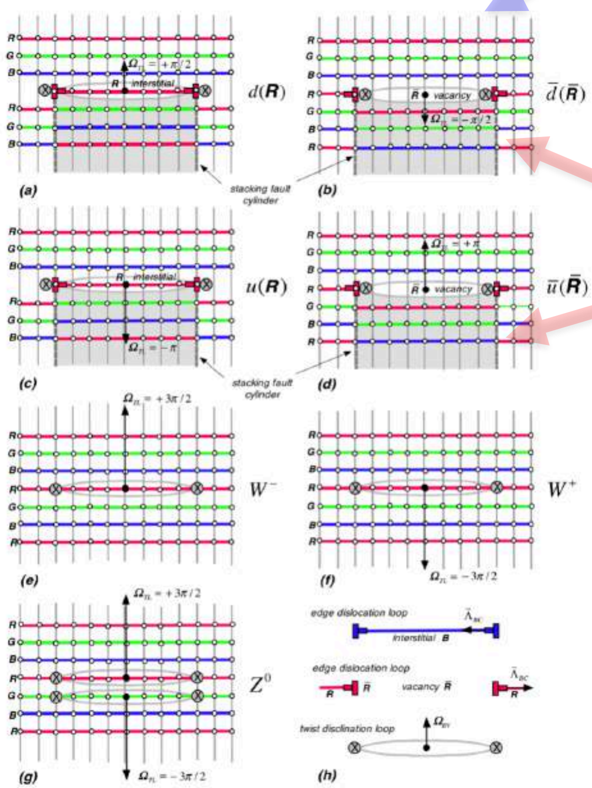
Standard model of elementary particles: quarks and leptons



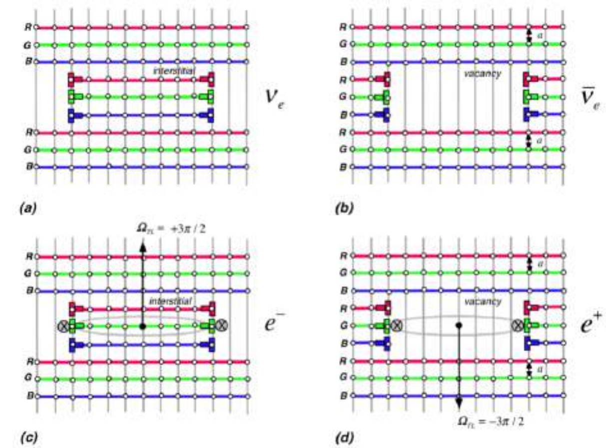
2/ Combine edge dislocation loops and screw disclination loops

quarks
gauge bosons

leptons



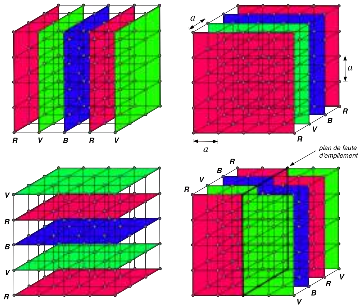
Stacking fault energy



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

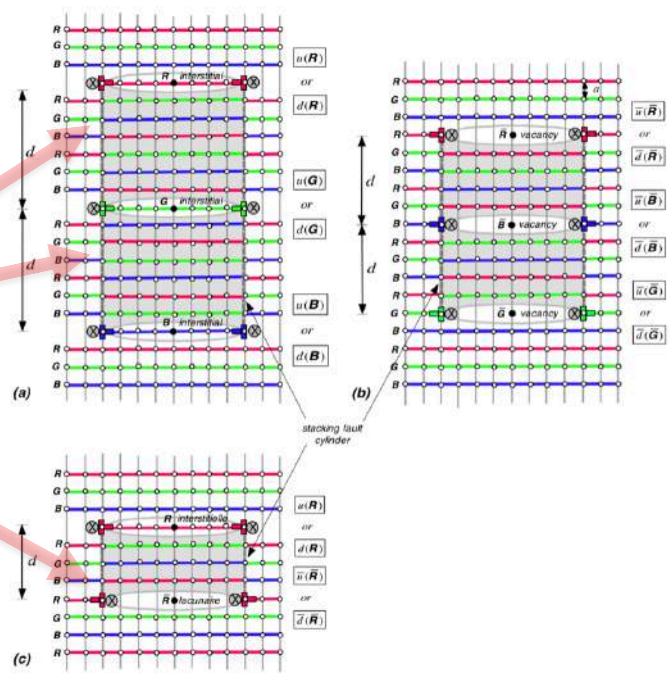
symbol	Ω_{TL}	$q_{\lambda TL}$	edge loop	$q_{\theta EL}$
ν_e	$+3\pi/2$	0	interstitial	$-6\pi a$
e^-	0	$-3\pi^2 R_{TL}^2/2$	interstitial	$-6\pi a$
$\bar{\nu}_e$	$-3\pi/2$	0	vacancy	$6\pi a$
e^+	-3π	$+3\pi^2 R_{TL}^2/2$	vacancy	$6\pi a$
W^-	$+3\pi/2$	$-3\pi^2 R_{TL}^2/2$	-	0
W^+	$-3\pi/2$	$+3\pi^2 R_{TL}^2/2$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

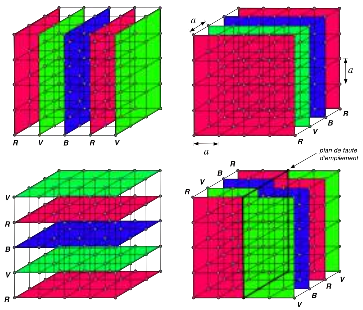


Stacking fault energy
=> strong interaction

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

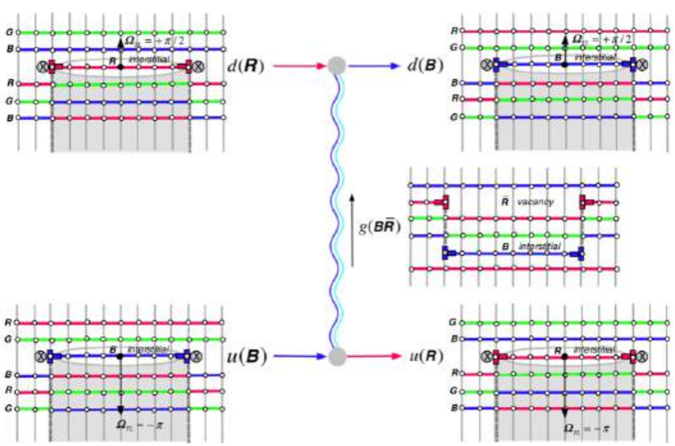
Standard model of elementary particles: gluons, strong and weak interactions

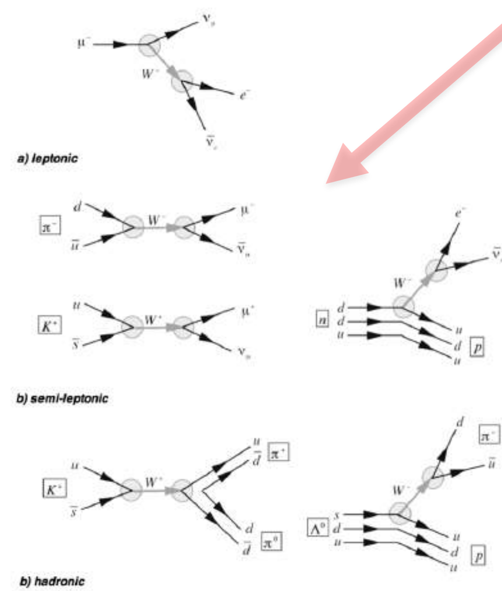


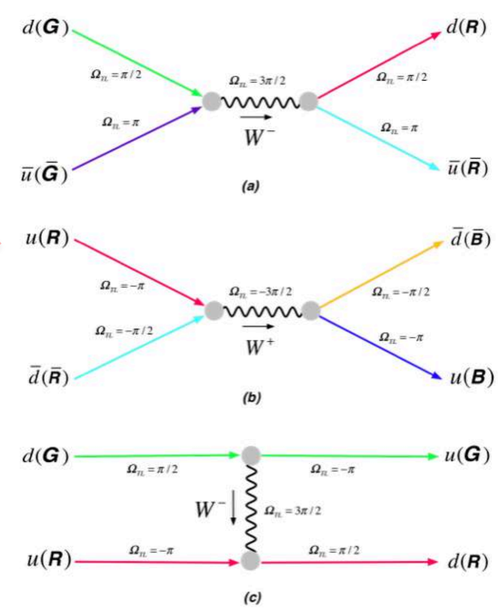
4/ Exchange edge dislocation loops or twist disclination loops

gluons
strong interactions

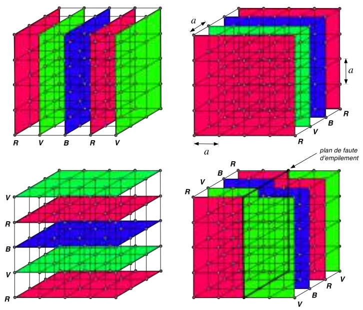
gauge bosons
weak interactions



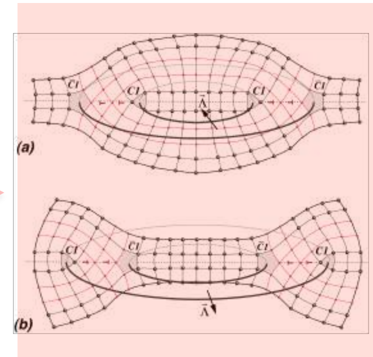




Standard model of elementary particles: the three families of particles

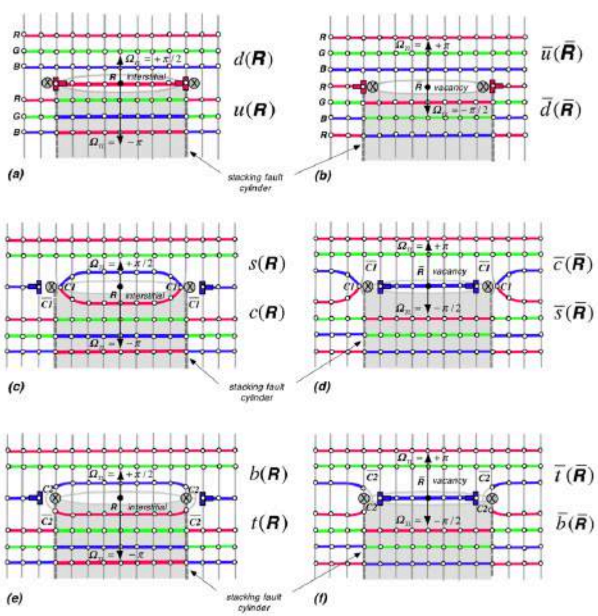


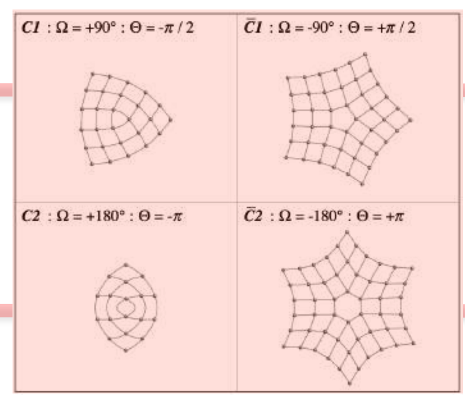
5/ Replace edge dislocation loops
by wedge disclination loops

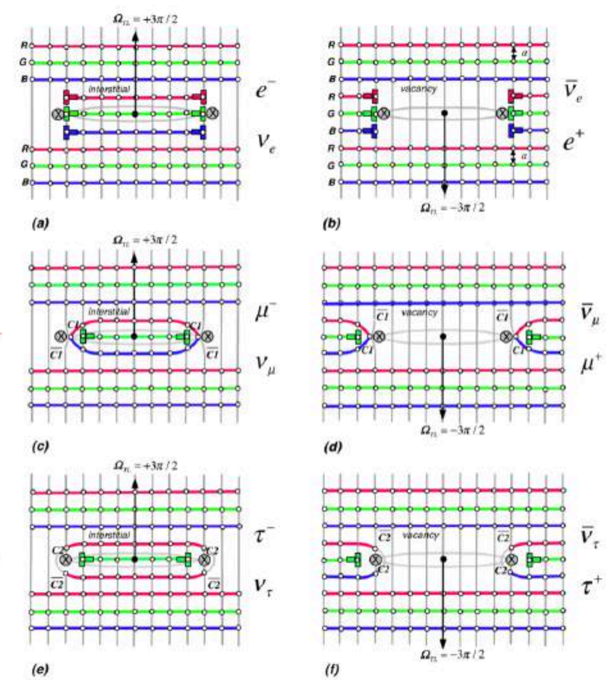


three families
of quarks

three families
of leptons

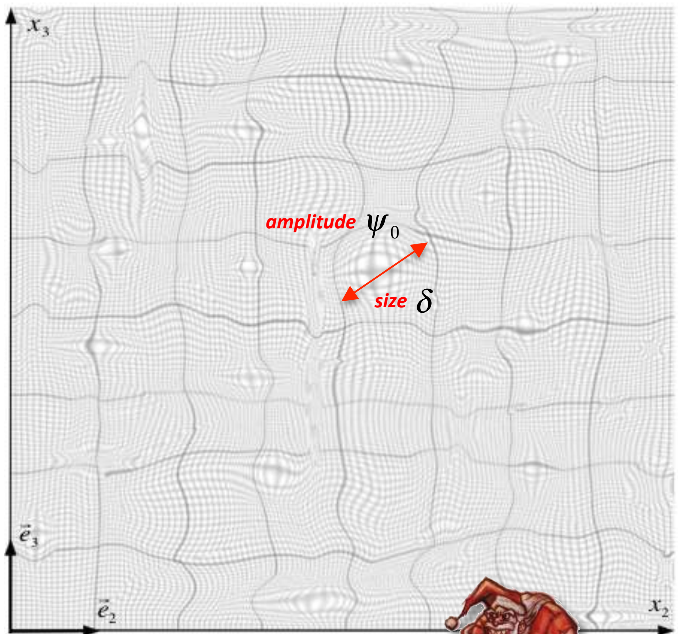






II E - Some other hypothetical consequences of the cosmic lattice

Gravitational fluctuations of the expansion: quantum vacuum state



Distortion energy of each fluctuation

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

Superposition of numerous fluctuations

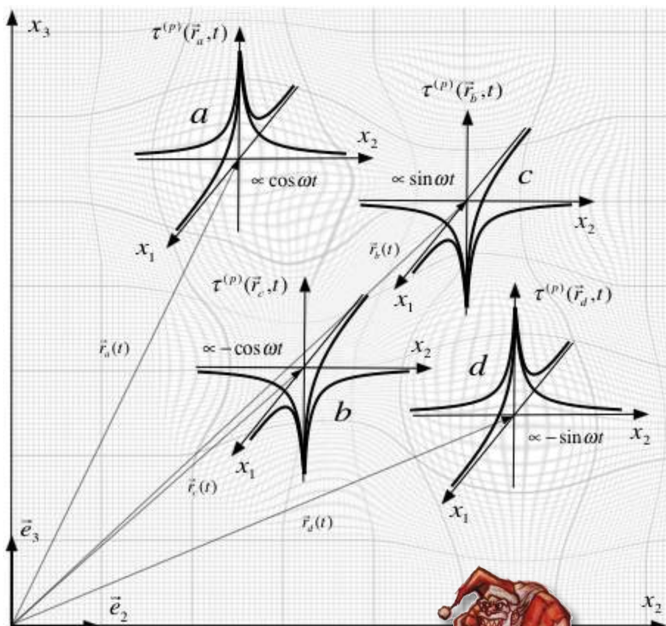
$$\tau^{(p)}(\vec{r},t) = \sum_k \psi_{0k}\, e^{-\frac{|x_1-x_{1k}|}{\delta_{1k}}}\, e^{-\frac{|x_2-x_{2k}|}{\delta_{2k}}}\, e^{-\frac{|x_3-x_{3k}|}{\delta_{3k}}}\, e^{-i(\omega_k t+\varphi_k)}$$

Zero average energy of all fluctuations

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

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

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

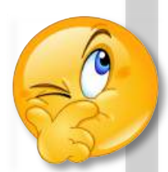
Conditions for stable gravitational fluctuations with a constant energy

$$\psi_{a0} = \psi_{b0} = \psi_{c0} = \psi_{d0} = \psi_0$$

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

Constant kinetic energy of the four fluctuations

$$\begin{cases} E^{fluctuation} \cong E^{cin} \cong \frac{K_0}{9}\psi_0^2 ABC\left(A^2+B^2+C^2\right)\left(\frac{1}{A^2}+\frac{1}{B^2}+\frac{1}{C^2}\right) \\ \omega \cong c_t\sqrt{\frac{1}{A^2}+\frac{1}{B^2}+\frac{1}{C^2}} \end{cases}$$



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

curvature of wave rays

pure transversal waves
coupled with longitudinal wavelets

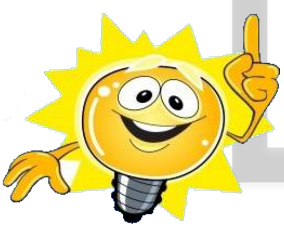
special relativity

general relativity

spatial curvature of the lattice
for the observer GO

Maxwell equations

spatiotemporal curvature of space
for the observers HS



Newton equation
of cosmological lattice

$$n\frac{d\vec{p}}{dt} = -2\left(K_2 + K_3\right)\overrightarrow{\text{rot}}\,\vec{\omega}^{\,él} + \left(\frac{4}{3}K_2 + 2K_1\right)\overrightarrow{\text{grad}}\,\tau + 2K_2\,\vec{\lambda} + nm\vec{\phi}_I\,\frac{dC_I}{dt} - nm\vec{\phi}_L\,\frac{dC_L}{dt}$$
$$+\,\overrightarrow{\text{grad}}\underbrace{\left(K_2\sum_i(\vec{\alpha}_i^{\,él})^2 + K_1^{an}\sum_i(\vec{\alpha}_i^{\,an})^2 + 2K_3(\vec{\omega}^{\,él})^2 + 2K_2^{an}(\vec{\omega}^{\,an})^2 + K_1\tau^2 - K_0\tau\right)}_{F^{déf}}$$

+ 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