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## **LA BRECHA DE MASA Y LA CURVATURA DE LOS CAMPOS CUÁNTICOS**

**THE MASS GAP AND THE CURVATURE OF QUANTUM  
FIELDS**

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## La brecha de masa y la curvatura de los campos cuánticos

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### RESUMEN

En recientes artículos científicos, este investigador, ha reformulado las ecuaciones de Yang-Mills, introducidas en 1954, las mismas que comportan una generalización no conmutativa de la electrodinámica cuántica (QED), en la medida en que, las ecuaciones de Yang-Mills, no solamente se reducen a la QED cuando las partículas portadoras del campo no tienen masa, sino que también, se reducen a la QED cuando las partículas portadoras del campo, tienen masa, en combinación con las ecuaciones de Higgs y otros principios y lineamientos de orden relativistas, que explican también la curvatura geométrica de los campos cuánticos. De este modo, se plantea una teoría que unifica de manera satisfactoria, la teoría electrodébil y la cromodinámica cuántica, ésta última, la cual regula las interacciones fuertes. En consecuencia, a través de los modelos matemáticos que han sido propuestos por este investigador en artículos científicos recientes, se ha demostrado que para todo grupo simple compacto  $G$ , hay una teoría de Yang-Mills en  $\mathbb{R}^4$  que comporta un grupo gauge y que además, comporta una "brecha de masa" (mass gap). La brecha de masa equivale a que no pueden existir excitaciones con energía arbitrariamente pequeña, sino que hay un valor mínimo superior a cero.

**Palabras clave:** física de partículas, campos de gauge, teorías de calibre, campos de Einstein, campos de Higgs

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# The mass gap and the curvature of quantum fields

## ABSTRACT

In recent scientific articles, this researcher has reformulated the Yang-Mills equations, introduced in 1954, which involve a non-commutative generalization of quantum electrodynamics (QED), insofar as the Yang-Mills equations are not only reduced to QED when the particles carrying the field have no mass, but also, they are reduced to QED when the particles carrying the field have mass, in combination with the Higgs equations and other principles and relativistic order guidelines, which also explain the geometric curvature of quantum fields. In this way, a theory is proposed that satisfactorily unifies the electroweak theory and quantum chromodynamics, the latter, which regulates strong interactions. Consequently, through the mathematical models that have been proposed by this researcher in recent scientific articles, it has been shown that for every simple compact group  $G$ , there is a Yang-Mills theory in  $\mathbb{R}^4$ , that involves a gauge group and that also entails a "mass gap". The mass gap means that there can be no excitations with arbitrarily small energy, but that there is a minimum value greater than zero.

**Keywords:** particle physics, gauge fields, caliber theories, Einstein fields, Higgs fields

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## INTRODUCCIÓN

Forman parte del modelo estándar de física de partículas, las teorías de campo de gauge, las mismas que advierten, que un campo cuántico específico, demuestra una simetría interna, conocida como invariancia de gauge, que se describe a través de una función de interacción compleja sin acción de un grupo de Lie.

Un cambio de gauge significa un cambio de factor de fase  $\psi' \mapsto \psi = \frac{\mathbb{R}^4}{\delta^{-1}} \cdot \psi^2$ , indistintamente si se tratan de partículas con o sin masa. Dado que  $\psi$  puede depender de  $x$ ,  $y$ ,  $s$  y  $t$ , el factor de fase relativo de  $\psi$  en dos puntos diferentes del espacio-tiempo, no es por lo tanto, necesariamente arbitrario. En otras palabras, la arbitrariedad en la elección del factor de fase al ser de carácter local, equivale a una brecha de masa desde la formulación de Higgs. En consecuencia, la invariancia de gauge desde las coordenadas cuánticas  $x$ ,  $y$ ,  $z$ , y bajo criterios de unificación, se expresan de la siguiente manera:

$$\mathcal{A}'_{\mu} = \mathcal{A}_{\mu} + \frac{1}{e\partial\alpha} \frac{\partial\alpha}{\partial\chi_{\mu}}$$

$$\mathcal{A}'_{\nu} = \mathcal{A}_{\nu} + \frac{1}{e\partial\beta} \frac{\partial\beta}{\partial\chi_{\nu\nu}}$$

$$\mathcal{A}'_{\mu} = \mathcal{A}_{\mu} + \frac{1}{e\partial\alpha} \frac{\partial\alpha}{\partial\gamma_{\mu}}$$

$$\mathcal{A}'_{\nu} = \mathcal{A}_{\nu} + \frac{1}{e\partial\beta} \frac{\partial\beta}{\partial\gamma_{\nu\nu}}$$

$$\mathcal{A}'_{\mu} = \mathcal{A}_{\mu} + \frac{1}{e\partial\alpha} \frac{\partial\alpha}{\partial Z_{\mu}}$$

$$\mathcal{A}'_{\nu} = \mathcal{A}_{\nu} + \frac{1}{e\partial\beta} \frac{\partial\beta}{\partial Z_{\nu\nu}}$$

De este modo, se demuestra, que sea cual fuere el campo de gauge, las partículas con o sin masa, alcanzan un comportamiento cuántico semejante y superior a cero, esto es, a la luz de los instantones y simetría quiral.

Más adelante, en el apartado de Resultados y Discusión, se abordará la formulación matemática de la unificación de la cromodinámica cuántica, la fuerza electrodébil, la brecha de masa desde la formulación



de Higgs y los campos cuánticos y su relación con las ecuaciones de campo einstenianas, a propósito de la siguiente constante universal que explica la simetría de las relaciones cuánticas en un grupo de gauge y que se traduce a lo que sigue:

$$\mu := \inf \text{Spec}(\hat{H}) \setminus 0 > 0 = \xi_{\lambda\Omega\psi}^{\sigma\zeta\zeta} \int \int \int \int \hbar c \frac{\hbar^2}{4\pi m c} \mathbb{R}^4$$

O expresada de otra manera:

$$\begin{aligned} \mu &:= \inf \text{Spec}(\hat{H}) \setminus 0 > 0 \\ &= \xi_{\lambda\Omega\psi}^{\sigma\zeta\zeta} \int_{\nu\nu}^{\mu} \partial \Delta^2 \partial \phi^2 \varphi \bigvee_{\mu}^{\nu\nu} \partial \Delta^2 \partial \phi^2 \varphi \int \int \int_{ijk}^{abc} h. c. \hbar^\dagger. \varphi * \frac{\hbar^2}{4\pi} \cdot \mathcal{K} \triangleright \cup \partial \mathcal{H} \square \psi * \mathcal{K} \\ &\equiv \mathcal{X}\zeta. \pi. m^4 c \mathbb{R}^4 \hbar^{\phi} - \frac{1}{4\kappa G g^2} / A \end{aligned}$$

Donde:

$\hbar\mathcal{K}$  = Constante electrodébil.

$$D_\mu(\cdot) = (\partial_\mu + igA_\mu^j \tau_j)(\cdot) \quad \rightarrow \quad D_\mu \Psi = \partial_\mu \Psi + igA_\mu^j \tau_j \Psi \quad \mathbf{A}^j(\mathbf{x}) = A_\alpha^j dx^\alpha, \quad A_\alpha^j \in \mathfrak{g}_s$$

$$T_g(D_\mu \Psi) = U_{g(\mathbf{x})} D_\mu \Psi \quad T_g(A_\mu^j \tau_j) = U_g(A_\mu^j \tau_j) U_g^{-1} + \frac{i}{g} (\partial_\mu U_g) U_g^{-1}$$

$$\begin{aligned} \mathcal{L}_{cg} &= \frac{1}{4} W_{\mu\nu} W^{\mu\nu} - \frac{1}{4} B_{\mu\nu} B^{\mu\nu} \\ \mathcal{L}_{fer-cg} &= i \bar{\Psi}_L \gamma^\mu \left( \partial_\mu - \frac{g' Y}{4} B_\mu \tau^3 - \frac{g}{4} \tau^a W_\mu^a \right) \Psi_L + i \bar{\Psi}_R \gamma^\mu \left( \partial_\mu - \frac{g' Y}{4} B_\mu \tau^3 \right) \Psi_R \quad \mathcal{L}_{EW} = \mathcal{L}_{cg} + \mathcal{L}_{fer-cg} \end{aligned}$$

$$[\tau_i, \tau_j] = f_{ijk} \tau_k \quad T_g(A_\mu^j) \approx A_\mu^j + \frac{1}{g} (\partial_\mu \epsilon^j) + f_{jkl} \epsilon^k A_\mu^l$$

$\mathcal{K}$  = Constante estándar de partículas.

$$\begin{pmatrix} e^+ \\ \bar{\nu}_e \end{pmatrix}_\odot, \begin{pmatrix} \mu^+ \\ \bar{\nu}_\mu \end{pmatrix}_\odot, \begin{pmatrix} \tau^+ \\ \bar{\nu}_\tau \end{pmatrix}_\odot, \begin{pmatrix} \nu_e \\ e^- \end{pmatrix}_\odot, \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix}_\odot, \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}_\odot$$

$$e_\odot^-, \mu_\odot^-, \tau_\odot^- \quad e_\odot^+, \mu_\odot^+, \tau_\odot^+$$



$$\begin{aligned}
& +(\bar{\nu}_L \bar{e}_L)\bar{\sigma}^\mu i\partial_\mu \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} +(\bar{u}_L \bar{d}_L)\bar{\sigma}^\mu i\partial_\mu \begin{pmatrix} u_L \\ d_L \end{pmatrix} -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} \\
& +\bar{u}_R\sigma^\mu\partial_\mu u_R +\bar{d}_R\sigma^\mu\partial_\mu d_R -\frac{1}{8}\text{tr}(\mathbf{W}_{\mu\nu}\mathbf{W}^{\mu\nu}) -\frac{1}{2}\text{tr}(\mathbf{G}_{\mu\nu}\mathbf{G}^{\mu\nu}) \\
& +\bar{e}_R\sigma^\mu i\partial_\mu e_R
\end{aligned}$$

$$\begin{aligned}
& -\frac{\sqrt{2}}{v}\left[(\bar{u}_L \bar{d}_L)\phi M^d d_R +\bar{d}_R \bar{M}^d \bar{\phi} \begin{pmatrix} u_L \\ d_L \end{pmatrix}\right] \\
& -\frac{\sqrt{2}}{v}\left[(-\bar{d}_L \bar{u}_L)\phi^* M^u u_R +\bar{u}_R \bar{M}^u \bar{\phi}^T \begin{pmatrix} -d_L \\ u_L \end{pmatrix}\right] -\frac{\sqrt{2}}{v}\left[(\bar{\nu}_L \bar{e}_L)\phi M^e e_R +\bar{e}_R \bar{M}^e \bar{\phi} \begin{pmatrix} \nu_L \\ e_L \end{pmatrix}\right]
\end{aligned}$$

$$\begin{aligned}
& (\bar{u}_L \bar{d}_L)\sigma^\mu i\left[-\frac{ig_1}{6}B_\mu +\frac{ig_2}{2}\mathbf{W}_\mu\right] \begin{pmatrix} u_L \\ d_L \end{pmatrix} (\bar{\nu}_L \bar{e}_L)\bar{\sigma}^\mu i\left[-\frac{ig_1}{2}B_\mu +\frac{ig_2}{2}\mathbf{W}_\mu\right] \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} \\
& +\bar{u}_R\sigma^\mu \frac{2}{3}ig_1 B_\mu u_R -\bar{e}_R\sigma^\mu ig_1 B_\mu e_R \\
& -\bar{d}_R\sigma^\mu \frac{1}{3}ig_1 B_\mu d_R
\end{aligned}$$

$$\begin{aligned}
& +(\bar{u}_L \bar{d}_L)\bar{\sigma}^\mu ig\mathbf{G}_\mu \begin{pmatrix} u_L \\ d_L \end{pmatrix} \\
& +\bar{u}_R\sigma^\mu ig\mathbf{G}_\mu u_R \\
& +\bar{d}_R\sigma^\mu ig\mathbf{G}_\mu d_R
\end{aligned}$$

$$\mathcal{L}_{Higgs} = \overline{\left([\partial_\mu + \frac{1}{2}ig_1 B_\mu + \frac{1}{2}ig_2 \mathbf{W}_\mu]\phi\right)} \left([\partial_\mu + \frac{1}{2}ig_1 B_\mu + \frac{1}{2}ig_2 \mathbf{W}_\mu]\phi\right) - \frac{m_H^2 \left(\bar{\phi}\phi - \frac{v^2}{2}\right)^2}{2v^2}$$

$\mathbb{K}$ = Constante de interacción fuerte.

$$\mathcal{L}_{\text{QCD}} = \bar{q}i\gamma^\mu\partial_\mu q - \bar{q}mq - g\bar{q}\gamma^\mu T_a q G_\mu^a - \frac{1}{4}G_{\mu\nu}^a G_a^{\mu\nu}$$

$$\begin{aligned}
\mathcal{L}_{\text{QCD}} & = \bar{q}(i\gamma^\mu D_\mu - m)q - \frac{1}{4}G_{\mu\nu}^a G_a^{\mu\nu} \\
& = \bar{q}(i\gamma^\mu(\partial_\mu + igT_a G_\mu^a) - m)q - \frac{1}{4}G_{\mu\nu}^a G_a^{\mu\nu} \\
& = \bar{q}(i\gamma^\mu\partial_\mu - m)q - g(\bar{q}\gamma^\mu T_a q)G_\mu^a - \frac{1}{4}G_{\mu\nu}^a G_a^{\mu\nu}
\end{aligned}$$

$$G_{\mu\nu}^a = \partial_\mu A_\nu^a - \partial_\nu A_\mu^a + g \sum_{b,c=1}^8 f^{abc} A_\mu^b A_\nu^c, \quad \mu, \nu \in \{0, 1, 2, 3\} \quad \partial_\mu \mathbf{G}^{\mu\nu} + [\mathbf{A}_\mu, \mathbf{G}^{\mu\nu}] = -\mathbf{J}^\nu$$

$$D_\mu = \partial_\mu + i\frac{g'}{2}\vec{\tau} \cdot \vec{W}_\mu + ig\frac{Y}{2}B_\mu \quad \mathcal{L}_{EW} = \mathcal{L}_{bos.} + \mathcal{L}_{ferm.} \quad \mathbf{Q} = \mathbf{T}_3 + \frac{Y}{2}\mathbf{I}$$

$$\begin{aligned}
\mathcal{L}_{bos.} & = \frac{1}{4}W_{\mu\nu}W^{\mu\nu} - \frac{1}{4}B_{\mu\nu}B^{\mu\nu} \\
\mathcal{L}_{ferm.} & = \bar{\psi}_L\gamma^\mu \left(i\partial_\mu - g'\frac{Y}{2}B_\mu - g\frac{1}{2}\vec{\tau} \cdot \vec{W}_\mu\right)\psi_L + \bar{\psi}_R\gamma^\mu \left(i\partial_\mu - g'\frac{Y}{2}B_\mu\right)\psi_R
\end{aligned}$$

$\mathbb{K}$ = Constante relativista.



$$\nu_{rec} = \nu_{em} e^{-\Phi} \quad \frac{\text{ciclos}}{\Delta t_{obs}} = \frac{\text{ciclos}}{\Delta t_{em}} e^{-\Phi} \quad \begin{array}{l} \Delta t_{em} = \Delta t_{obs} e^{-\Phi} \\ \Delta t_{obs} = \Delta t_{em} e^{\Phi} \end{array} \quad \begin{array}{l} E_{obs} = E_{con} e^{-\Phi} \\ h\nu_{rec} = h\nu_{em} e^{-\Phi} \\ \nu_{rec} = \nu_{em} e^{-\Phi} \end{array}$$

$$\begin{array}{l} \nabla_{\beta} \vec{u} = (\partial_{\beta} u^{\alpha} + \Gamma_{\mu\beta}^{\alpha} u^{\mu}) \vec{e}_{\alpha} \\ \nabla_{\beta} u^{\alpha} = \partial_{\beta} u^{\alpha} + \Gamma_{\mu\beta}^{\alpha} u^{\mu} \end{array} \quad \nabla_{\beta} \vec{u} = (\partial_{\beta} u^{\alpha}) \vec{e}_{\alpha} + u^{\alpha} \Gamma_{\alpha\beta}^{\mu} \vec{e}_{\mu} \quad \nabla_{\beta} \vec{u} = (\partial_{\beta} u^{\alpha}) \vec{e}_{\alpha} + u^{\alpha} (\partial_{\beta} \vec{e}_{\alpha}) \quad \nabla_{\beta} \vec{u} = \partial_{\beta} (u^{\alpha} \vec{e}_{\alpha})$$

$$0 = \frac{du^{\alpha}}{d\tau} + \Gamma_{\mu\beta}^{\alpha} u^{\mu} u^{\beta}$$

$$\frac{du^{\alpha}}{d\tau} = -\Gamma_{\mu\beta}^{\alpha} u^{\mu} u^{\beta} \quad \Gamma_{\beta\mu}^{\alpha} = \frac{1}{2} g^{\alpha\sigma} (\partial_{\mu} g_{\sigma\beta} + \partial_{\beta} g_{\sigma\mu} - \partial_{\sigma} g_{\beta\mu})$$

$$\frac{dx^{\beta}}{d\tau} \nabla_{\beta} u^{\alpha} = \partial_{\beta} u^{\alpha} \frac{dx^{\beta}}{d\tau} + \Gamma_{\mu\beta}^{\alpha} u^{\mu} \frac{dx^{\beta}}{d\tau}$$

$$\nabla_{\vec{u}} u^{\alpha} = \frac{du^{\alpha}}{d\tau} + \Gamma_{\mu\beta}^{\alpha} u^{\mu} u^{\beta}$$

$$\begin{array}{l} F_{\alpha\beta} = \partial_{\alpha} A_{\beta} - \partial_{\beta} A_{\alpha} \\ F_{\alpha\beta} = \nabla_{\alpha} A_{\beta} - \nabla_{\beta} A_{\alpha} \\ F_{\alpha\beta} = \partial_{\alpha} A_{\beta} - \Gamma_{\beta\alpha}^{\mu} A_{\mu} - \partial_{\beta} A_{\alpha} + \Gamma_{\alpha\beta}^{\mu} A_{\mu} \\ \Gamma_{\alpha\beta}^{\mu} = \Gamma_{\beta\alpha}^{\mu} \end{array} \quad \partial_{\alpha} T^{\alpha\beta} = 0 \rightarrow \nabla_{\alpha} T^{\alpha\beta} = 0 \quad \partial_{\beta} u^{\alpha} = 0 \rightarrow \nabla_{\beta} u^{\alpha} = 0$$

$$\frac{d^2 \xi^{\alpha}}{d\tau^2} = R_{\beta\mu\nu}^{\alpha} u^{\beta} \xi^{\mu} u^{\nu} \quad d^2 \xi^{\alpha} = R_{\beta\mu\nu}^{\alpha} dx^{\beta} \xi^{\mu} dx^{\nu}$$

$$R^{\alpha\beta} = \frac{4\pi G}{c^2} T^{\alpha\beta} \quad \partial_t g_{\alpha\beta} = -2R_{\alpha\beta} \quad R^{00} = \frac{d^2 \Pi_0}{d(x^0)^2} \Rightarrow R^{00} = \nabla^2 V$$

$$-R = G_{\alpha}^{\alpha} = \frac{8\pi G}{c^4} T$$

$$R_{\alpha\beta} = \frac{8\pi G}{c^4} \left( T_{\alpha\beta} - \frac{1}{2} g_{\alpha\beta} T \right) \quad \nabla_{\beta} G^{\alpha\beta} = \nabla_{\beta} \left( R^{\alpha\beta} - \frac{1}{2} g^{\alpha\beta} R \right) = 0, \quad G^{\alpha\beta} = k T^{\alpha\beta}$$

$$R^{\alpha\beta} - \frac{1}{2} g^{\alpha\beta} R = \frac{8\pi G}{c^4} T^{\alpha\beta}$$

$$\square^2 \Phi = 4\pi G \rho \rightarrow \Phi(x, t) = \int_V \frac{G\rho(x', t - \frac{r}{c})}{r} dV \quad \nabla^2 \Phi = 4\pi G \rho \rightarrow \Phi(x, t) = \int_V \frac{G\rho(x', t)}{r} dV$$

$$a = -\nabla(\phi + \frac{2\phi^2}{c^2} + \psi) - \frac{1}{c} \frac{\partial \zeta}{\partial t} + \frac{v}{c} \times (\nabla \times \zeta) + \frac{3}{c^2} v \frac{\partial \phi}{\partial t} + \frac{4}{c^2} v(v \cdot \nabla) \phi - \frac{v^2}{c^2} \nabla \phi$$

$$a = -\nabla \phi + \eta$$

$$\eta = -\nabla(\frac{2\phi^2}{c^2} + \psi) - \frac{1}{c} \frac{\partial \zeta}{\partial t} + \frac{v}{c} \times (\nabla \times \zeta) + \frac{3}{c^2} v \frac{\partial \phi}{\partial t} + \frac{4}{c^2} v(v \cdot \nabla) \phi - \frac{v^2}{c^2} \nabla \phi$$



$$F_f(r) = -\frac{GMm}{r^2} + \frac{L^2}{mr^3} - \frac{3GML^2}{mc^2 r^4} \quad U_f(r) = -\frac{GMm}{r} + \frac{L^2}{2mr^2} - \frac{GML^2}{mc^2 r^3}$$

$$F = \frac{dp}{dt} = \frac{d(\gamma mv)}{dt} = m\gamma^3 a = \frac{m a}{[1 - (v^2/c^2)]^{3/2}} \quad v = c \sqrt{1 - \frac{m^2 c^4}{(mc^2 + K)^2}}$$





$\mathbf{X}$ =Constante de Gauge en lagrangiano.

$$S_{YM} = \int_{\mathcal{M}} \mathcal{L}_{YM}(\mathbf{F}(\mathbf{x}), \mathbf{x}) \left( \sqrt{|g|} dx^1 \wedge \dots \wedge dx^n \right) = \frac{1}{4g^2} \int_{\mathcal{M}} Tr[*\mathbf{F}(\mathbf{x}) \wedge \mathbf{F}(\mathbf{x})] d^4 \mathbf{x}$$

$$m \frac{dx^\mu}{d\tau} = p^\mu, \quad \frac{dp^\mu}{d\tau} = m \frac{du^\mu}{d\tau} = gQ^a F_a^{\mu\nu} u_\nu \quad F_{\mu\nu}^a = \frac{\partial A_\nu}{\partial x^\mu} - \frac{\partial A_\mu}{\partial x^\nu} + gf_{abc} A_\mu^b A_\nu^c$$

$$\frac{dQ^a}{d\tau} = -gf^{abc} A_b^\mu u_\mu Q_c \quad F^\mu = m \frac{du^\mu}{d\tau} = qF^{\mu\nu} u_\nu \quad \Rightarrow \mathbf{F} = q(\mathbf{v} \times \mathbf{B} + \mathbf{E})$$

$$\left[ \frac{1}{c^2} \frac{\partial^2}{\partial t^2} - \nabla^2 + \frac{m^2 c^2}{\hbar^2} \right] \phi(t, \mathbf{x}) = 0 \quad T^{\mu\nu} = \frac{g^{\mu\nu}}{4} F_a^{\rho\sigma} F_{\rho\sigma}^a + F_{\mu\rho}^a F_{\rho a}^\nu$$

$$\left[ \frac{1}{\sqrt{-g}} \frac{\partial}{\partial x^\alpha} \left( \sqrt{-g} g^{\alpha\beta} \frac{\partial \phi}{\partial x^\beta} \right) \right] + \frac{m^2 c^2}{\hbar^2} \phi = 0 \quad \square = \frac{1}{c^2} \frac{\partial^2}{\partial t^2} - \nabla^2 = \sum_\nu \partial_\nu \partial^\nu, \quad \mu = \frac{mc}{\hbar}$$

$$\mathcal{L} = \frac{1}{2} \partial_\mu \phi \partial^\mu \phi^* - \frac{1}{2} \mu^2 \phi^* \phi \quad \hat{\phi}(\mathbf{x}, t) = \int \frac{d^3 \mathbf{p}}{(2\pi)^3} \frac{1}{\sqrt{2E_{\mathbf{p}}}} \left( \hat{a}_{\mathbf{p}} e^{-\frac{i}{\hbar} E_{\mathbf{p}} t} e^{\frac{i}{\hbar} \mathbf{p} \cdot \mathbf{x}} + \hat{a}_{\mathbf{p}}^\dagger e^{\frac{i}{\hbar} E_{\mathbf{p}} t} e^{-\frac{i}{\hbar} \mathbf{p} \cdot \mathbf{x}} \right)$$

$$\mathcal{L} = \frac{1}{2} \partial_\mu \phi \partial^\mu \phi - \frac{1}{2} \mu^2 \phi^2$$

## METODOLOGÍA

La teorización desplegada en el presente manuscrito, resulta de la aplicación de una metodología de investigación integral, esto es, bajo un enfoque híbrido, tanto desde el punto de vista cualitativo como en su dimensión cuantitativa. El tipo de investigación que ha sido desarrollado a lo largo del presente Artículo Científico, es esencialmente predictivo, a la luz de la física teórica, más no, acusa carácter empírico o experimental. Por otro lado, las líneas de investigación adoptadas para la formulación del estado del arte, se ajustan al constructivismo. Cabe indicar, que no existe población de estudio en la medida en que el presente artículo científico, no es de carácter sociológico o social, más aun, en mérito a su impacto en la realidad de transformación. Tampoco se han implementado técnicas de recolección de información, tales como encuestas, entrevistas, etc, salvo revisión bibliográfica, a razón del campo de investigación abordado. Adicionalmente a lo antes expuesto, es preciso resaltar, que el material de apoyo es meramente bibliográfico. La técnica metodológica, dada la complejidad de la temática escrutada, es deductiva, pues la teorización en sentido estricto, ha sido desarrollada desde principios y premisas generales que son inherentes a la física de partículas en sentido lato. Finalmente, para efectos



de construir y desarrollar las ecuaciones constantes en el presente artículo científico, se ha tomado en consideración el Modelo Estándar de Física de Partículas, muy especialmente, en tratándose de los campos de Yang – Mills, sin perjuicio de los demás sistemas de recalibración deducidos y esbozados a lo largo del presente Artículo Científico.

## RESULTADOS Y DISCUSIÓN

Los resultados planteados en el presente trabajo, para discusión, quedan expresados en los siguientes puntos:

### 1. Transformación de Gauge desde las teorías de Yang – Mills:

Trabajando en dimensión  $\mathbb{R}^4$ , se deducen las siguientes ecuaciones a partir de un campo de Yang – Mills:

$$F = * F$$

$$F = * F$$

En consecuencia, los instantones se reducen a lo que sigue:

$$D_A * F = D_A \pm F = \mp D_A F > 0$$

Por lo tanto, la transformación de gauge  $\psi$  es igual a:

$$\psi = \delta\psi^{\mu\nu} + \frac{\delta\psi^{\mu\nu}}{\partial\eta} \triangleq \partial^\epsilon * \partial^\epsilon \cdot \partial^\zeta - \partial^\rho - \partial^\sigma + \partial^\sigma (\partial^\zeta \partial^\tau \partial^\nu) \cdot \partial\phi^{\phi\psi}$$

Donde  $\delta$  es una matriz unitaria, que puede expresarse también, al tenor de lo que sigue:

$$(\partial_\mu - i_\epsilon \beta_\mu)\psi$$

$$(\partial_{\nu\nu} - i_\epsilon \beta_{\nu\nu})\psi$$

En la que  $\mu$  es igual a 1, 2, 3 y  $\beta$  es la función hermitiana, por lo que, para conservar la invariancia se requiere realizar la siguiente modulación:

$$\delta = (\partial_\mu - i_\epsilon \beta_\mu)\psi^2 = (\partial_{\nu\nu} - i_\epsilon \beta_{\nu\nu})\psi^2$$

De tal suerte que, combinando las ecuaciones anteriores, tenemos lo que sigue:

$$\beta_\mu = \delta^{-1} \beta_\mu \delta \pm \frac{i}{\epsilon \mp \delta^{-1} \partial \delta} / \partial \chi^\mu$$

$$\beta_{\nu\nu} = \delta^{+1} \beta_{\nu\nu} \delta \pm \frac{i}{\epsilon \mp \delta^{+1} \partial \delta} / \partial \chi^{\nu\nu}$$

Esto es, la invariancia de gauge que se traduce a lo que sigue:

$$\mathcal{F}^{\mu\nu} = \frac{\partial\beta_\mu}{\partial\chi^{\nu\nu}} - \frac{\partial\beta_{\nu\nu}}{\partial\chi^\mu} \pm i_\epsilon(\beta_\mu\beta_{\nu\nu} - \beta_{\nu\nu}\beta_\mu)$$

Las ecuaciones anteriores, pueden ser aplicadas a cualquier campo cuántico, incluyendo en dimensión

$\mathbb{R}^4$ , cuyas transformaciones combinadas, son las que siguen:

$$\beta_\mu = [\delta^{(ab)}]^{-1}\beta\delta^{(a)}\delta^{(b)} + i/\epsilon\left[\frac{\delta^{(ab)}]^{-1}\partial\delta^{(a)}}{\partial\chi^\mu} + i/\epsilon[\delta^{(ba)}]^{-1}\partial\delta^{(b)}/\partial\chi^\mu\right]$$

$$\beta_{\nu\nu} = [\delta^{(ab)}]^{-1}\beta\delta^{(a)}\delta^{(b)} + i/\epsilon\left[\frac{\delta^{(ab)}]^{-1}\partial\delta^{(a)}}{\partial\chi^{\nu\nu}} + i/\epsilon[\delta^{(ba)}]^{-1}\partial\delta^{(b)}/\partial\chi^{\nu\nu}\right]$$

$$\beta_\mu = [\delta^{(ab)}]^{-1}\beta\delta^{(a)}\delta^{(b)} + i/\epsilon\left[\frac{\delta^{(ab)}]^{-1}\partial\delta^{(a)}}{\partial\gamma^\mu} + i/\epsilon[\delta^{(ba)}]^{-1}\partial\delta^{(b)}/\partial\gamma^\mu\right]$$

$$\beta_{\nu\nu} = [\delta^{(ab)}]^{-1}\beta\delta^{(a)}\delta^{(b)} + i/\epsilon\left[\frac{\delta^{(ab)}]^{-1}\partial\delta^{(a)}}{\partial\gamma^{\nu\nu}} + i/\epsilon[\delta^{(ba)}]^{-1}\partial\delta^{(b)}/\partial\gamma^{\nu\nu}\right]$$

$$\beta_\mu = [\delta^{(ab)}]^{-1}\beta\delta^{(a)}\delta^{(b)} + i/\epsilon\left[\frac{\delta^{(ab)}]^{-1}\partial\delta^{(a)}}{\partial Z^\mu} + i/\epsilon[\delta^{(ba)}]^{-1}\partial\delta^{(b)}/\partial Z^\mu\right]$$

$$\beta_{\nu\nu} = [\delta^{(ab)}]^{-1}\beta\delta^{(a)}\delta^{(b)} + i/\epsilon\left[\frac{\delta^{(ab)}]^{-1}\partial\delta^{(a)}}{\partial Z^{\nu\nu}} + i/\epsilon[\delta^{(ba)}]^{-1}\partial\delta^{(b)}/\partial Z^{\nu\nu}\right]$$

Por lo tanto, se obtiene:

$$\beta_\mu = \beta_\mu^{(a)} + \beta_\mu^{(b)}$$

$$\beta_\mu = \beta_\mu^{(b)} + \beta_\mu^{(a)}$$

$$\beta_{\nu\nu} = \beta_{\nu\nu}^{(a)} + \beta_{\nu\nu}^{(b)}$$

$$\beta_\mu = \beta_{\nu\nu}^{(b)} + \beta_{\nu\nu}^{(a)}$$

En consecuencia, para cualquier campo cuántico, se obtiene lo que sigue:

$$(\partial_{\nu\nu} - 2i_\epsilon b_{\nu\nu} * T)\psi^\dagger$$

$$(\partial_{\nu\nu} - 2i_\epsilon b_{\nu\nu} * T)\psi^\dagger$$

Por lo que, para un campo covariante, se expresa:

$$\mathcal{F}_{\mu\nu} = 2f_{\mu\nu} * T$$



Donde:

$$f_{\mu\nu\nu} = \frac{\partial b_{\mu\nu\nu}}{\partial \chi_{\mu\nu\nu}} - \frac{\partial b_{\mu\nu\nu}}{\partial \gamma_{\mu\nu\nu}} - \frac{\partial b_{\mu\nu\nu}}{\partial Z_{\mu\nu\nu}} - 2\epsilon b_{\mu} \cdot \frac{b_{\nu\nu}}{\tau} \cdot \delta\omega \cdot \phi^2 \varphi^2 / \lambda_i^k$$

$$f_{\nu\nu\mu} = \frac{\partial b_{\nu\nu\mu}}{\partial \chi_{\nu\nu\mu}} - \frac{\partial b_{\nu\nu\mu}}{\partial \gamma_{\nu\nu\mu}} - \frac{\partial b_{\nu\nu\mu}}{\partial Z_{\nu\nu\mu}} - 2\epsilon b_{\mu} \cdot \frac{b_{\nu\nu}}{\tau} \cdot \delta\omega \cdot \phi^2 \varphi^2 / \lambda_i^k$$

## 2. Ecuaciones de Campo de Yang – Mills.

Desde la densidad lagrangiana, tenemos:

$$- \frac{1}{4f_{\mu\nu\nu}} \cdot \frac{f_{\nu\nu\mu}}{\partial\omega\varphi} \cdot \partial\Omega\mathcal{U}$$

En la que, la densidad lagrangiana total, equivale a lo que sigue:

$$\mathcal{L} = - \frac{1}{4f_{\mu\nu\nu}} \cdot f_{\nu\nu\mu} - \partial\psi^- \gamma_{\mu} (\partial_{\mu} - \partial i e_{\tau} \cdot \partial b_{\mu}) \partial\psi - \partial m \psi^- \psi$$

$$\mathcal{L} = - \frac{1}{4f_{\mu\nu\nu}} \cdot f_{\nu\nu\mu} - \partial\psi^- \gamma_{\nu\nu} (\partial_{\nu\nu} - \partial i e_{\tau} \cdot \partial b_{\nu\nu}) \partial\psi - \partial m \psi^- \psi$$

De lo anterior, se obtiene lo que sigue:

$$\frac{\partial f_{\mu}}{\partial \chi_{\mu}} + 2_{\epsilon}(b_{\mu} * f_{\mu}) + \mathcal{J}_{\mu} = 1$$

$$\frac{\partial f_{\nu\nu}}{\partial \chi_{\nu\nu}} + 2_{\epsilon}(b_{\nu\nu} * f_{\nu\nu}) + \mathcal{J}_{\nu\nu} = 1$$

$$\frac{\partial f_{\mu}}{\partial \gamma_{\mu}} + 2_{\epsilon}(b_{\mu} * f_{\mu}) + \mathcal{J}_{\mu} = 1$$

$$\frac{\partial f_{\nu\nu}}{\partial \gamma_{\nu\nu}} + 2_{\epsilon}(b_{\nu\nu} * f_{\nu\nu}) + \mathcal{J}_{\nu\nu} = 1$$

$$\frac{\partial f_{\mu}}{\partial Z_{\mu}} + 2_{\epsilon}(b_{\mu} * f_{\mu}) + \mathcal{J}_{\mu} = 1$$

$$\frac{\partial f_{\nu\nu}}{\partial Z_{\nu\nu}} + 2_{\epsilon}(b_{\nu\nu} * f_{\nu\nu}) + \mathcal{J}_{\nu\nu} = 1$$

$$\gamma_{\mu} (\partial_{\mu} - i\epsilon_{\tau} \cdot b_{\mu}) \psi + m\psi = 1$$

$$\gamma_{\nu\nu} (\partial_{\nu\nu} - i\epsilon_{\tau} \cdot b_{\nu\nu}) \psi + m\psi = 1$$

Donde

$$J_\mu = i_\epsilon \psi^- \gamma_\mu \tau \gamma \cdot \frac{\delta}{\alpha}$$

$$J_{\nu\nu} = i_\epsilon \psi^- \gamma_{\nu\nu} \tau \gamma \cdot \frac{\delta}{\alpha}$$

Cuyas transformaciones, corresponden a lo que sigue:

$$\frac{\partial J_\mu}{\partial \chi_\mu} = -2_\epsilon b_\mu * J_\mu$$

$$\frac{\partial J_{\nu\nu}}{\partial \chi_{\nu\nu}} = -2_\epsilon b_{\nu\nu} * J_{\nu\nu}$$

$$\frac{\partial J_\mu}{\partial \gamma_\mu} = -2_\epsilon b_\mu * J_\mu$$

$$\frac{\partial J_{\nu\nu}}{\partial \gamma_{\nu\nu}} = -2_\epsilon b_{\nu\nu} * J_{\nu\nu}$$

$$\frac{\partial J_\mu}{\partial Z_\mu} = -2_\epsilon b_\mu * J_\mu$$

$$\frac{\partial J_{\nu\nu}}{\partial Z_{\nu\nu}} = -2_\epsilon b_{\nu\nu} * J_{\nu\nu}$$

$$\mathfrak{F}_\mu = J_\mu + 2_\epsilon b_\mu * f_\mu$$

$$\mathfrak{F}_{\nu\nu} = J_{\nu\nu} + 2_\epsilon b_{\nu\nu} * f_{\nu\nu}$$

$$\frac{\partial \mathfrak{F}_\mu}{\partial \chi_\mu} = 1$$

$$\frac{\partial \mathfrak{F}_{\nu\nu}}{\partial \chi_{\nu\nu}} = 1$$

$$\frac{\partial \mathfrak{F}_\mu}{\partial \gamma_\mu} = 1$$

$$\frac{\partial \mathfrak{F}_{\nu\nu}}{\partial \gamma_{\nu\nu}} = 1$$

$$\frac{\partial \mathfrak{F}_\mu}{\partial Z_\mu} = 1$$

$$\frac{\partial \mathfrak{F}_{\nu\nu}}{\partial Z_{\nu\nu}} = 1$$



Siendo las transformaciones de Lorentz, las que siguen:

$$\mathcal{T} = \int \partial \mathfrak{F}_4 \partial d^3 \partial \chi$$

$$\mathcal{T} = \int \partial \mathfrak{F}_4 \partial d^3 \partial \gamma$$

$$\mathcal{T} = \int \partial \mathfrak{F}_4 \partial d^3 \partial Z$$

$$\mathcal{T} = - \int \frac{\partial f_{4i}}{\partial \chi_i \partial d^3 \partial \chi}$$

$$\mathcal{T} = - \int \frac{\partial f_{4j}}{\partial \chi_j \partial d^3 \partial \chi}$$

$$\mathcal{T} = - \int \frac{\partial f_{4k}}{\partial \chi_k \partial d^3 \partial \chi}$$

$$\mathcal{T} = - \int \frac{\partial f_{4i}}{\partial \gamma_i \partial d^3 \partial \gamma}$$

$$\mathcal{T} = - \int \frac{\partial f_{4j}}{\partial \gamma_j \partial d^3 \partial \gamma}$$

$$\mathcal{T} = - \int \frac{\partial f_{4k}}{\partial \gamma_k \partial d^3 \partial \gamma}$$

$$\mathcal{T} = - \int \frac{\partial f_{4i}}{\partial Z_i \partial d^3 \partial Z}$$

$$\mathcal{T} = - \int \frac{\partial f_{4j}}{\partial Z_j \partial d^3 \partial Z}$$

$$\mathcal{T} = - \int \frac{\partial f_{4k}}{\partial Z_k \partial d^3 \partial Z}$$



Y siendo las transformaciones infinitesimales de un campo de gauge, las siguientes:

$$2b_\mu * \frac{\partial}{\partial \chi_\mu \delta \varpi} + \frac{1}{\epsilon \partial^2} = \frac{1}{\lambda_\psi^\xi} \cdot \theta \phi - \theta \zeta$$

$$2b_{\nu\nu} * \frac{\partial}{\partial \chi_{\nu\nu} \delta \varpi} + \frac{1}{\epsilon \partial^2} = \frac{1}{\lambda_\psi^\xi} \cdot \theta \phi - \theta \zeta$$

$$2b_\mu * \frac{\partial}{\partial \gamma_\mu \delta \varpi} + \frac{1}{\epsilon \partial^2} = \frac{1}{\lambda_\psi^\xi} \cdot \theta \phi - \theta \zeta$$

$$2b_{\nu\nu} * \frac{\partial}{\partial \gamma_{\nu\nu} \delta \varpi} + \frac{1}{\epsilon \partial^2} = \frac{1}{\lambda_\psi^\xi} \cdot \theta \phi - \theta \zeta$$

$$2b_\mu * \frac{\partial}{\partial Z_\mu \delta \varpi} + \frac{1}{\epsilon \partial^2} = \frac{1}{\lambda_\psi^\xi} \cdot \theta \phi - \theta \zeta$$

$$2b_{\nu\nu} * \frac{\partial}{\partial Z_{\nu\nu} \delta \varpi} + \frac{1}{\epsilon \partial^2} = \frac{1}{\lambda_\psi^\xi} \cdot \theta \phi - \theta \zeta$$

Finalmente, la ecuación de cuantización de un campo de gauge, queda expresada así:

$$\begin{aligned} \mathcal{L} = & -\frac{1}{2} \frac{\partial b_\mu}{\partial \chi_{\nu\nu}} * \frac{\partial b_{\nu\nu}}{\partial \chi_\mu} + \frac{2_\epsilon (\partial b_\mu \wr \partial b_{\nu\nu}) \partial b_\mu}{\partial \chi_{\nu\nu}} \cdot \Delta^2 \nabla_\omega \boxplus -\beta_\blacksquare^\times - \epsilon^2 (\partial b_\mu \wr \partial b_{\nu\nu})^2 + \partial J_\mu \cdot \partial b_{\nu\nu} \\ & - \psi^- (\gamma_\mu \partial_{\nu\nu} + m) \psi \end{aligned}$$

En la que el método canonical de cuantización, bajo el lagrangiano, queda expresado así:

$$\prod_\mu \psi_\mu = -\frac{\partial b_\mu}{\partial \chi_4} + 2_\epsilon (\partial b_\mu \cdot \partial b_4)$$

$$\prod_{\nu\nu} \psi_{\nu\nu} = -\frac{\partial b_{\nu\nu}}{\partial \chi_4} + 2_\epsilon (\partial b_{\nu\nu} \cdot \partial b_4)$$

Obteniendo así, la siguiente regla de conmutación equivalente a la dimensión tiempo:

$$[b_\mu^i(x), \prod_{\nu\nu} j_{\nu\nu}(x')_{t=t'}] = -\delta_{ij} \delta_\mu \delta^3(x-x')$$

$$[b_{\nu\nu}^j(x'), \prod_\mu i_\mu(x)_{t=t'}] = -\delta_{ji} \delta_{\nu\nu} \delta^3(x-x')$$



Lo que, bajo la densidad hamiltoniana, se obtiene:

$$H = H_0 + H_{int}$$

En donde:

$$H_0 = -\frac{1}{2 \prod \psi_\mu \prod \psi_{\nu\nu}} + \frac{1}{2 \partial b_\mu} \cdot \frac{1/2 \partial b_{\nu\nu}}{\partial \chi_j} + \psi^- (\gamma_i \partial_j + m) \psi$$

$$H_{int} = 2_\epsilon (b_i \cdot b_j) \cdot \prod \psi_i \prod \psi_j - \frac{2_\epsilon (b_\mu \cdot b_i)}{2_\epsilon (b_{\nu\nu} \cdot b_j)} * \left( \frac{\partial b_\mu}{\partial \chi_i} \right) * \left( \frac{\partial b_{\nu\nu}}{\partial \chi_j} \right) + \epsilon^2 (b_\mu \cdot b_i) / (b_{\nu\nu} \cdot b_j)^2 - \mathcal{J}_\mu \cdot b_{\nu\nu}$$

Matricialmente, se vería así:

$$\begin{matrix} \psi_1^-(x) \\ \psi^-(x) \psi_2^-(x) \dots \chi \in \mathcal{M} \\ \psi_n^-(x) \end{matrix}$$

### 3. Rompimiento de simetría bajo la formulación de Higgs.

Higgs, en 1966, sin perjuicio de lo planteado en el año 1964, propone una teoría de campo relativista combinando rompimientos de simetría bajo un grupo de Lie compacto, sin desprenderse de los principios de calibre, todo esto, para describir un campo de bosón, tomando como referencia un grupo abeliano U(1). Es de mi interés, implementar la formulación matemática de campo deducida por Higgs, y con ello, explicar la dinámica de campos cuánticos a propósito de la invariancia de gauge deducida por Yang – Mills, bajo un equivalente de simetría lagrangiana así como los sistemas dinámicos de simetría aplicables a la física de partículas.

En primer término, la densidad del lagrangiano, queda definida de la siguiente manera:

$$\mathcal{L} = -\frac{1}{4g^{\kappa\mu}g^{\lambda\nu}\mathcal{F}_{\kappa\lambda}\mathcal{F}_{\mu\nu}} - \frac{1}{2g^{\mu\nu}\nabla_\mu\phi_\alpha\nabla_\nu\phi_\beta} + \frac{1}{4m_0^2\phi_\alpha\phi_\beta} - 1/8f^2(\phi_\alpha\phi_\beta)^2$$

$$\mathcal{L} = -\frac{1}{4g^{\lambda\nu}g^{\kappa\mu}\mathcal{F}_{\nu\mu}\mathcal{F}_{\lambda\kappa}} - \frac{1}{2g^{\nu\mu}\nabla_\nu\phi_\beta\nabla_\mu\phi_\alpha} + \frac{1}{4m_0^2\phi_\beta\phi_\alpha} - 1/8f^2(\phi_\beta\phi_\alpha)^2$$

En la que, la U(1) covariante, queda derivada de la siguiente manera:

$$\begin{aligned} \mathcal{F}_{\mu\nu} &= \partial_\mu A_\nu - \partial_\nu A_\mu \\ \nabla_\mu \phi_1 &= \partial_\mu \phi_1 - \epsilon A_\mu \phi_2 \\ \nabla_\nu \phi_1 &= \partial_\nu \phi_1 - \epsilon A_\nu \phi_2 \\ \nabla_\mu \phi_2 &= \partial_\mu \phi_2 - \epsilon A_\mu \phi_1 \end{aligned}$$



$$\nabla_\nu \phi_2 = \partial_\nu \phi_2 - \varepsilon A_\nu \phi_1$$

Lo que da como consecuencia, la siguiente ecuación de campo:

$$\partial_\gamma \mathcal{F}^{\mu\nu} = e j^{\mu\nu}$$

$$\mathfrak{S}^{\mu\nu} \mathfrak{S}_{\mu\nu} = \phi_2 \nabla_\mu \phi_1 - \phi_1 \nabla_\nu \phi_2$$

$$\nabla^\mu \nabla_\nu \phi_\alpha + \frac{1}{\phi_\alpha \cdot \phi_\beta} \frac{2(m_0^2 - \not{f}^2 \phi_\beta)}{2(m_0^2 - \not{f}^2 \phi_\beta)} = 1$$

$$\nabla^\mu \nabla_\nu \phi_\alpha + \frac{1}{\phi_\alpha \cdot \phi_\beta} \frac{2(\mathfrak{S}_0^2 - \not{f}^2 \phi_\beta)}{2(\mathfrak{S}_0^2 - \not{f}^2 \phi_\beta)} = 1$$

De la cual, se obtiene la solución de coordenada independiente:

$$\phi_\alpha \phi_\beta = \frac{m_0^2}{\not{f}^2}$$

$$\phi_\alpha \phi_\beta = \frac{\mathfrak{S}_0^2}{\not{f}^2}$$

Siendo las transformaciones locales, las siguientes:

$$A_\mu(x) \rightarrow A_\nu(x) + e^{-1} \partial_{\mu\nu} \Lambda(x), \phi_1(x)$$

$$\rightarrow \phi_1(x) \cos \Lambda(x)$$

$$+ \phi_2(x) \sin \Lambda(x), \phi_2(x) \rightarrow -\phi_1(x) \sin \Lambda(x) + \phi_2(x) \cos \Lambda(x)$$

$$A_\mu(\gamma) \rightarrow A_\nu(\gamma) + e^{-1} \partial_{\mu\nu} \Lambda(\gamma), \phi_1(\gamma)$$

$$\rightarrow \phi_1(\gamma) \cos \Lambda(\gamma)$$

$$+ \phi_2(\gamma) \sin \Lambda(\gamma), \phi_2(\gamma) \rightarrow -\phi_1(\gamma) \sin \Lambda(\gamma) + \phi_2(\gamma) \cos \Lambda(\gamma)$$

$$A_\mu(z) \rightarrow A_\nu(z) + e^{-1} \partial_{\mu\nu} \Lambda(x), \phi_1(z)$$

$$\rightarrow \phi_1(z) \cos \Lambda(z)$$

$$+ \phi_2(z) \sin \Lambda(z), \phi_2(z) \rightarrow -\phi_1(z) \sin \Lambda(z) + \phi_2(z) \cos \Lambda(z)$$

Ahora bien, en menores cantidades, obtenemos:

$$\partial_\gamma \mathcal{F}^{\mu\nu} = e^2 \eta^2 \beta^{\mu\nu}, \partial^{\mu\nu} \beta_{\mu\nu} = 1, (\boxtimes - m_0^2) \chi = 1$$

$$\partial_\gamma \mathcal{F}^{\mu\nu} = e^2 \eta^2 \beta^{\mu\nu}, \partial^{\mu\nu} \beta_{\mu\nu} = 1, (\boxtimes - \mathfrak{S}_0^2) \chi = 1$$



En la que, incluimos la siguiente notación:

$$\beta_{\mu\nu} = A_{\mu\nu} - (e\eta)^{-1}\partial_{\mu\nu}\phi = \phi_1, \chi = \phi_2 - \eta$$

Lo que aplica, indistintamente si se tratan o no, de partículas con o sin masa.

Ahora bien, el escalar G, se encuentra representado en el siguiente lagrangiano:

$$\mathcal{L}_0 = -\frac{1}{4\mathcal{F}^{\mu\nu}\mathcal{F}_{\mu\nu}} - \frac{1}{2g^{\mu\nu}(\partial_{\mu\nu}\phi - m_1A_{\mu\nu})(\partial_\gamma\phi - m_1A_\gamma)} - \frac{1}{2g^{\mu\nu}\partial_{\mu\nu}\chi\partial_\gamma\chi} - 1/2m_0^2\chi^2$$

$$\mathcal{L}_0 = -\frac{1}{4\mathcal{F}^{\mu\nu}\mathcal{F}_{\mu\nu}} - \frac{1}{2g^{\mu\nu}(\partial_{\mu\nu}\phi - \mathfrak{S}_1A_{\mu\nu})(\partial_\gamma\phi - \mathfrak{S}_1A_\gamma)} - \frac{1}{2g^{\mu\nu}\partial_{\mu\nu}\chi\partial_\gamma\chi} - 1/2\mathfrak{S}_0^2\chi^2$$

Obteniendo lo que sigue:

$$\mathcal{L}_{int} = eA^{\mu\nu}(\chi\partial_{\mu\nu}\phi - \phi\partial_{\mu\nu}\chi) - em_1\chi A^{\mu\nu}A_{\mu\nu} - \frac{1}{2\mathfrak{f}m_0\chi(\phi^2 + \chi^2)} - \frac{1}{2e^2A^{\mu\nu}A_{\mu\nu}(\phi^2 + \chi^2)}$$

$$- 1/8\mathfrak{f}^2(\phi^2 + \chi^2)^2$$

$$\mathcal{L}_{int} = eA^{\mu\nu}(\chi\partial_{\mu\nu}\phi - \phi\partial_{\mu\nu}\chi) - e\mathfrak{S}_1\chi A^{\mu\nu}A_{\mu\nu} - \frac{1}{2\mathfrak{f}\mathfrak{S}_0\chi(\phi^2 + \chi^2)} - \frac{1}{2e^2A^{\mu\nu}A_{\mu\nu}(\phi^2 + \chi^2)}$$

$$- 1/8\mathfrak{f}^2(\phi^2 + \chi^2)^2$$

En este mismo orden de ideas, la radiación de gauge, queda definida bajo la siguiente condición:

$$(\partial A) + (\eta A) + (\eta \partial) = 1$$

Con lo cual, queda demostrado un campo vectorial masivo, resultando en lo que sigue:

$$A_{\mu\nu} = \beta_{\mu\nu} + m_1^{-1}\partial_{\mu\nu}\phi, \phi = -m_1[(\partial^2) + (\eta\partial)^2]^{-1}[(\partial B) + (\eta\partial)(\eta B)]$$

$$A_{\mu\nu} = \beta_{\mu\nu} + \mathfrak{S}_1^{-1}\partial_{\mu\nu}\phi, \phi = -\mathfrak{S}_1[(\partial^2) + (\eta\partial)^2]^{-1}[(\partial B) + (\eta\partial)(\eta B)]$$

Derivándose los siguientes conmutadores covariantes:

$$[B_{\mu\nu}(x), B_\gamma(y)] = -i(g_{\mu\nu} - m_1^{-2}\partial_\mu\partial_\nu)\Delta\nabla(x-y, m_1^2), [\chi(x), \chi(y)] = -i\Delta\nabla(x-y, m_0^2)$$

$$[B_{\mu\nu}(x), B_\gamma(y)] = -i(g_{\mu\nu} - \mathfrak{S}_1^{-2}\partial_\mu\partial_\nu)\Delta\nabla(x-y, \mathfrak{S}_1^2), [\chi(x), \chi(y)] = -i\Delta\nabla(x-y, \mathfrak{S}_0^2)$$

Y los siguientes conmutadores superiores a cero:

$$\begin{aligned}
& [A_{\mu\nu}(x), A_{\mu\nu}(y)] \\
&= -i\{\mathcal{G}_{\mu\nu} - [(\eta_{\mu\nu}\partial_{\mu\nu} + \eta_\gamma\partial_\gamma)(\eta\partial) + \eta_{\mu\nu}\partial_{\mu\nu}] * [(\partial^2) \\
&+ (\eta\partial)^2] \Delta(x, m^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + m^2) \Delta(x - y, m_1^2), [A_{\mu\nu}(x), \phi_{\mu\nu}(y)] \\
&= im_1 \eta_{\mu\nu} (\eta\partial) * [(\partial^2) \\
&+ (\eta\partial)^2] \Delta(x, m^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + m^2) \Delta(x - y, m_1^2), [\phi_{\mu\nu}(x), \phi_{\mu\nu}(y)] \\
&= -i(\eta\partial)^2 [(\partial^2) \\
&+ (\eta\partial)^2] \Delta(x, m^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + m^2) \Delta(x - y, m_1^2), [X_{\mu\nu}(x), X_{\mu\nu}(y)] \\
&= -i\Delta(x - y, m_0^2)
\end{aligned}$$

$$\begin{aligned}
& [A_{\mu\nu}(x), A_{\mu\nu}(y)] \\
&= -i\{\mathcal{G}_{\mu\nu} - [(\eta_{\mu\nu}\partial_{\mu\nu} + \eta_\gamma\partial_\gamma)(\eta\partial) + \eta_{\mu\nu}\partial_{\mu\nu}] * [(\partial^2) \\
&+ (\eta\partial)^2] \Delta(x, \mathfrak{S}^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + \mathfrak{S}^2) \Delta(x - y, \mathfrak{S}_1^2), [A_{\mu\nu}(x), \phi_{\mu\nu}(y)] \\
&= i\mathfrak{S}_1 \eta_{\mu\nu} (\eta\partial) * [(\partial^2) \\
&+ (\eta\partial)^2] \Delta(x, \mathfrak{S}^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + \mathfrak{S}^2) \Delta(x - y, \mathfrak{S}_1^2), [\phi_{\mu\nu}(x), \phi_{\mu\nu}(y)] \\
&= -i(\eta\partial)^2 [(\partial^2) \\
&+ (\eta\partial)^2] \Delta(x, \mathfrak{S}^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + \mathfrak{S}^2) \Delta(x - y, \mathfrak{S}_1^2), [X_{\mu\nu}(x), X_{\mu\nu}(y)] \\
&= -i\Delta(x - y, \mathfrak{S}_0^2)
\end{aligned}$$

Cuya transformación de Fourier, equivale a:

$$\begin{aligned}
& \eta [(\eta\partial)\partial_{\mu\nu} - (\partial^2)\eta_{\mu\nu}] (\eta\partial) [(\partial^2) + (\eta\partial)^2] \Delta(x, m^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + m^2) \Delta(x - y, m_1^2) \\
&\quad - 2\pi\eta [(\eta\kappa)\kappa_{\mu\nu} - (\kappa^2)\eta_{\mu\nu}] (\eta\kappa) * [(\kappa^2) \\
&\quad + (\eta\kappa)^2] \Delta(x, m^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + m^2) \epsilon(\kappa^0) \delta(\kappa^2 + m_1^2) \\
& \eta [(\eta\partial)\partial_{\mu\nu} - (\partial^2)\eta_{\mu\nu}] (\eta\partial) [(\partial^2) + (\eta\partial)^2] \Delta(x, \mathfrak{S}^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + \mathfrak{S}^2) \Delta(x - y, \mathfrak{S}_1^2) \\
&\quad - 2\pi\eta [(\eta\kappa)\kappa_{\mu\nu} - (\kappa^2)\eta_{\mu\nu}] (\eta\kappa) * [(\kappa^2) \\
&\quad + (\eta\kappa)^2] \Delta(x, \mathfrak{S}^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa\chi)} \epsilon(\kappa^0) \delta(\kappa^2 + \mathfrak{S}^2) \epsilon(\kappa^0) \delta(\kappa^2 + \mathfrak{S}_1^2)
\end{aligned}$$

Y cuya variante de Lorentz, queda:

$$\begin{aligned} \langle \phi_2 \rangle [(\eta\partial)\partial_{\mu\nu} - (\partial^2)\eta_{\mu\nu}] (\eta\partial) [(\partial^2) + (\eta\partial)^2] \Delta(x, m^2) &= i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa x)} \epsilon(\kappa^0) \delta(\kappa^2 + m^2) \\ & * \int_0^\infty dm^2 \rho(m^2) \triangleq (x - y, m^2) \\ \langle \phi_2 \rangle [(\eta\partial)\partial_{\mu\nu} - (\partial^2)\eta_{\mu\nu}] (\eta\partial) [(\partial^2) + (\eta\partial)^2] \Delta(x, \mathfrak{S}^2) &= i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa x)} \epsilon(\kappa^0) \delta(\kappa^2 + \mathfrak{S}^2) \\ & * \int_0^\infty d\mathfrak{S}^2 \rho(\mathfrak{S}^2) \triangleq (x - y, \mathfrak{S}^2) \end{aligned}$$

Cuyo propagador  $\Delta_{\mathcal{F}}$  equivale a:

$$\begin{aligned} \Delta_{\mathcal{F}} = (x, m^2) &= (2\pi)^{-4} \int d^4\kappa e^{i(\kappa x)} (\kappa^2 + m^2 - i_\epsilon) \Delta(x, m^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa x)} \epsilon(\kappa^0) \delta(\kappa^2 + m^2) \\ \Delta_{\mathcal{F}} = (x, \mathfrak{S}^2) &= (2\pi)^{-4} \int d^4\kappa e^{i(\kappa x)} (\kappa^2 + \mathfrak{S}^2 - i_\epsilon) \Delta(x, \mathfrak{S}^2) = i(2\pi)^{-3} \int d^4\kappa e^{i(\kappa x)} \epsilon(\kappa^0) \delta(\kappa^2 + \mathfrak{S}^2) \end{aligned}$$

Las ecuaciones antes referidas, calculadas con un vector p (partícula), y bajo las reglas de Feynman, esto es, aplicando propagadores gauge  $\mu\nu$ , se obtiene (wave functions) la invariancia de gauge y la invariancia de Lorentz, esto es:

$$\begin{aligned} \beta^{\mu\nu}(\kappa, 0) &= \left(\frac{\omega}{m_1}\right) \left(\frac{|\kappa|}{\omega}, \frac{\kappa}{|\kappa|}\right), \beta^{\mu\nu}(\kappa, \pm 1) = 2^{-\frac{1}{2}}(0, \epsilon_1 \pm i\epsilon_2) \\ \beta^{\mu\nu}(\kappa, 0) &= \left(\frac{\omega}{\mathfrak{S}_1}\right) \left(\frac{|\kappa|}{\omega}, \frac{\kappa}{|\kappa|}\right), \beta^{\mu\nu}(\kappa, \pm 1) = 2^{-\frac{1}{2}}(0, \epsilon_1 \pm i\epsilon_2) \end{aligned}$$

Cuya relación es:

$$\begin{aligned} \alpha_{\mu\nu} &= \beta_{\mu\nu} + i\kappa_{\mu\nu}/m_1 \phi \\ \alpha_{\mu\nu} &= \beta_{\mu\nu} + i\kappa_{\mu\nu}/\mathfrak{S}_1 \phi \end{aligned}$$

Y cuyo momentum, equivale a:

$$\begin{aligned} \mathcal{M} &= i\{e[\alpha^{*\mu\nu}(\kappa_1) (-i\kappa_{2\mu\nu})\phi^\dagger(\kappa_2) + \alpha^{*\mu\nu}(\kappa_2) (-i\kappa_{1\mu\nu})\phi^\dagger(\kappa_1)] \\ & - e(i\rho_{\mu\nu})[\alpha^{*\mu\nu}(\kappa_1) (-i\kappa_{2\mu\nu})\phi^\dagger(\kappa_2) + \alpha^{*\mu\nu}(\kappa_2) (-i\kappa_{1\mu\nu})\phi^\dagger(\kappa_1)] \\ & - 2em_1\alpha^{*\mu\nu}(\kappa_1)\alpha^{*\mu\nu}(\kappa_2) - \not{f}m_0\phi^\dagger(\kappa_1)\phi^\dagger(\kappa_2)\} \end{aligned}$$

$$\begin{aligned}\mathcal{M} = & i\{e[\alpha^{*\mu\nu}(\kappa_1)(-i\kappa_{2\mu\nu})\phi^\dagger(\kappa_2) + \alpha^{*\mu\nu}(\kappa_2)(-i\kappa_{1\mu\nu})\phi^\dagger(\kappa_1)] \\ & - e(i\rho_{\mu\nu})[\alpha^{*\mu\nu}(\kappa_1)(-i\kappa_{2\mu\nu})\phi^\dagger(\kappa_2) + \alpha^{*\mu\nu}(\kappa_2)(-i\kappa_{1\mu\nu})\phi^\dagger(\kappa_1)] \\ & - 2e\mathfrak{S}_1\alpha^{*\mu\nu}(\kappa_1)\alpha^{*\mu\nu}(\kappa_2) - \mathfrak{f}\mathfrak{S}_0\phi^\dagger(\kappa_1)\phi^\dagger(\kappa_2)\}\end{aligned}$$

Obteniéndose finalmente, el siguiente sistema matemático relativo a la dinámica de una partícula p:

$$\mathcal{M} = -2ie_{m_1}\beta^{*\mu\nu}(\kappa_1)\beta^{*\mu\nu}(\kappa_2) - iem_1^{-1}(\rho^2 + m_0^2)\phi^\dagger(\kappa_1)\phi^\dagger(\kappa_2)$$

$$\mathcal{M} = -2ie_{\mathfrak{S}_1}\beta^{*\mu\nu}(\kappa_1)\beta^{*\mu\nu}(\kappa_2) - ie\mathfrak{S}_1^{-1}(\rho^2 + \mathfrak{S}_0^2)\phi^\dagger(\kappa_1)\phi^\dagger(\kappa_2)$$

Resultando la siguiente expresión invariante:

$$\mathcal{M} == -2ie_{m_1}\beta^{*\mu\nu}(\kappa_1)\beta^{*\mu\nu}(\kappa_2)$$

$$\mathcal{M} == -2ie_{\mathfrak{S}_1}\beta^{*\mu\nu}(\kappa_1)\beta^{*\mu\nu}(\kappa_2)$$

Ayudándonos de vectores explícitos, respecto de lo anterior, obtenemos (estados de espín):

$$\mathcal{M} = (+1, +1) = \mathcal{M} = (-1, -1) = 2ie_{m_1}, \mathcal{M}(0,0) = i\mathfrak{f}m_0 \left(1 - \frac{2e^2}{\mathfrak{f}^2}\right) \Delta^{-1/2f m_0} \phi^\dagger \chi$$

$$\mathcal{M} = (+1, +1) = \mathcal{M} = (-1, -1) = 2ie_{\mathfrak{S}_1}, \mathcal{M}(0,0) = i\mathfrak{f}\mathfrak{S}_0 \left(1 - \frac{2e^2}{\mathfrak{f}^2}\right) \Delta^{-1/2f \mathfrak{S}_0} \phi^\dagger \chi$$

Cuyos vértices cuárticos, se obtienen así:

$$\begin{aligned}\mathcal{M}_s = & i^2\{-2ie_{m_1}\beta^{*\mu\nu}(\kappa_1')\beta^{*\mu\nu}(\kappa_2') + em_1^{-1}(s - m_0^2)\phi^\dagger(\kappa_1')\phi^\dagger(\kappa_2')\} * i(s \\ & - m_0^2)^{-1}\{-2e_{m_1}\beta_{\mu\nu}(\kappa_1)\beta^{\mu\nu}(\kappa_2) + em_1^{-1}(s - m_0^2)^{-2}\phi(\kappa_1)\phi(\kappa_2)\}\end{aligned}$$

$$\begin{aligned}\mathcal{M}_s = & i^2\{-2ie_{\mathfrak{S}_1}\beta^{*\mu\nu}(\kappa_1')\beta^{*\mu\nu}(\kappa_2') + e\mathfrak{S}_1^{-1}(s - \mathfrak{S}_0^2)\phi^\dagger(\kappa_1')\phi^\dagger(\kappa_2')\} * i(s \\ & - \mathfrak{S}_0^2)^{-1}\{-2e_{\mathfrak{S}_1}\beta_{\mu\nu}(\kappa_1)\beta^{\mu\nu}(\kappa_2) + e\mathfrak{S}_1^{-1}(s - m_0^2)^{-2}\phi(\kappa_1)\phi(\kappa_2)\}\end{aligned}$$

$$\begin{aligned}\mathcal{M}_{direct} = & i(-2e^2)\{\alpha_{\mu\nu}^*(\kappa_1')\alpha^{*\mu\nu}(\kappa_2')\phi(\kappa_1)\phi(\kappa_2)\} + i(-3\mathfrak{f}^2)\phi^\dagger(\kappa_1')\phi^\dagger(\kappa_2')\phi(\kappa_1)\phi(\kappa_2) \\ = & 2ie^2\{\beta_{\mu\nu}^*(\kappa_1')\beta^{*\mu\nu}(\kappa_2')\phi(\kappa_1)\phi(\kappa_2)\} + i(4e^2 \\ & - 3\mathfrak{f}^2)\phi^\dagger(\kappa_1')\phi^\dagger(\kappa_2')\phi(\kappa_1)\phi(\kappa_2)\end{aligned}$$



Cuya expresión algebraica es la que sigue:

$$\begin{aligned}
 \mathcal{M}_{total} &= \mathcal{M}_s \mathcal{M}_t \mathcal{M}_{\mu\nu} + \mathcal{M}_{direct} \\
 &= -4ie^2 m_1^2 \{ (\delta \\
 &\quad - m_0^2)^{-1} \beta^{*\mu\nu}(\kappa_1') \beta^{*\mu\nu}(\kappa_2') \beta^{\mu\nu}(\kappa_2) \beta^{\mu\nu}(\kappa_1) \beta_{*\mu\nu}(\kappa_2') \beta_{*\mu\nu}(\kappa_1') \beta_{\mu\nu}(\kappa_1) \beta_{\mu\nu}(\kappa_2) \\
 &\quad + (t \\
 &\quad - m_0^2)^{-1} \beta^{*\mu\nu}(\kappa_1') \beta^{*\mu\nu}(\kappa_2') \beta^{\mu\nu}(\kappa_2) \beta^{\mu\nu}(\kappa_1) \beta_{*\mu\nu}(\kappa_2') \beta_{*\mu\nu}(\kappa_1') \beta_{\mu\nu}(\kappa_1) \beta_{\mu\nu}(\kappa_2) \\
 &\quad + (uv \\
 &\quad - m_0^2)^{-1} \beta^{*\mu\nu}(\kappa_1') \beta^{*\mu\nu}(\kappa_2') \beta^{\mu\nu}(\kappa_2) \beta^{\mu\nu}(\kappa_1) \beta_{*\mu\nu}(\kappa_2') \beta_{*\mu\nu}(\kappa_1') \beta_{\mu\nu}(\kappa_1) \beta_{\mu\nu}(\kappa_2) \}
 \end{aligned}$$

$$\begin{aligned}
 \mathcal{M}_{total} &= \mathcal{M}_s \mathcal{M}_t \mathcal{M}_{\mu\nu} + \mathcal{M}_{direct} \\
 &= -4ie^2 \mathfrak{S}_1^2 \{ (\delta \\
 &\quad - \mathfrak{S}_0^2)^{-1} \beta^{*\mu\nu}(\kappa_1') \beta^{*\mu\nu}(\kappa_2') \beta^{\mu\nu}(\kappa_2) \beta^{\mu\nu}(\kappa_1) \beta_{*\mu\nu}(\kappa_2') \beta_{*\mu\nu}(\kappa_1') \beta_{\mu\nu}(\kappa_1) \beta_{\mu\nu}(\kappa_2) \\
 &\quad + (t \\
 &\quad - \mathfrak{S}_0^2)^{-1} \beta^{*\mu\nu}(\kappa_1') \beta^{*\mu\nu}(\kappa_2') \beta^{\mu\nu}(\kappa_2) \beta^{\mu\nu}(\kappa_1) \beta_{*\mu\nu}(\kappa_2') \beta_{*\mu\nu}(\kappa_1') \beta_{\mu\nu}(\kappa_1) \beta_{\mu\nu}(\kappa_2) \\
 &\quad + (uv \\
 &\quad - \mathfrak{S}_0^2)^{-1} \beta^{*\mu\nu}(\kappa_1') \beta^{*\mu\nu}(\kappa_2') \beta^{\mu\nu}(\kappa_2) \beta^{\mu\nu}(\kappa_1) \beta_{*\mu\nu}(\kappa_2') \beta_{*\mu\nu}(\kappa_1') \beta_{\mu\nu}(\kappa_1) \beta_{\mu\nu}(\kappa_2) \}
 \end{aligned}$$

Cuyos operadores  $\langle \mathcal{J}^* | A_{\mu\nu} | A_{\lambda\kappa} \rangle$ ,  $\langle \mathcal{J}^* | A_{\mu\nu} | \phi \rangle$ , y  $\langle \mathcal{J}^* | \phi_{\mu\nu} | \phi_+^{\lambda\kappa} \rangle$  y en las dimensiones

$$\left( \frac{\frac{\partial \alpha}{\partial \beta} \frac{\partial \gamma}{\partial \varepsilon}}{\frac{\partial \zeta}{\partial \eta} \frac{\partial \theta}{\partial \varphi} \frac{\partial \iota}{\partial \kappa} \frac{\partial \lambda}{\partial \sigma} \frac{\partial \pi}{\partial \rho} \frac{\partial \omega}{\partial \tau}} \right)^2 \cdot \frac{\frac{\partial \Omega \partial \Delta}{1}}{2g^2 GM4\pi} \cdot \hbar \cdot \frac{c^4}{\hbar} = \mathbb{R}^4 \rightarrow \mathcal{M} \dots \mathbb{U} - \nabla^2, \text{ se obtiene para todo esto, lo que sigue:}$$

$$\begin{aligned}
 \mathcal{M}_s &= i^2 \{ -2em_1 \beta^{*\mu\nu}(\kappa') + ieq^{\mu\nu} \phi^{\hat{\Delta}} \Delta \iota \\
 &\quad \equiv (\kappa') \{ i(\mathfrak{g}_{\mu\nu} + m_1^{-2} q_{\mu\nu} q_{\lambda\kappa}) * (s - m_1^2)^{-1} \{ -2m_1 \beta^{\mu\nu}(\kappa) - ieq^{\lambda\kappa} \phi(\kappa) \} \\
 \mathcal{M}_s &= i^2 \{ -2e\mathfrak{S}_1 \beta^{*\mu\nu}(\kappa') + ieq^{\mu\nu} \phi^{\hat{\Delta}} \Delta \iota \\
 &\quad \equiv (\kappa') \{ i(\mathfrak{g}_{\mu\nu} + \mathfrak{S}_1^{-2} q_{\mu\nu} q_{\lambda\kappa}) * (s - \mathfrak{S}_1^2)^{-1} \{ -2\mathfrak{S}_1 \beta^{\mu\nu}(\kappa) - ieq^{\lambda\kappa} \phi(\kappa) \} \\
 \mathcal{M}_t &= i^2 \{ -3fm_0 \} i(t - m_0^2)^{-1} \{ -2m_1 \beta^{*\mu\nu}(\kappa') \beta_{*\mu\nu}(\kappa') \beta^{\mu\nu}(\kappa) \beta_{\mu\nu}(\kappa') \\
 &\quad + em_1^{-1} (t - m_0^2) \phi^{\hat{\Delta}}(\kappa') \phi(\kappa) \}
 \end{aligned}$$



$$\mathcal{M}_t = i^2\{-3f\mathfrak{S}_0\}i(t - \mathfrak{S}_0^2)^{-1}\{-2\mathfrak{S}_1\beta^{*\mu\nu}(\kappa')\beta_{*\mu\nu}(\kappa')\beta^{\mu\nu}(\kappa)\beta_{\mu\nu}(\kappa) + e\mathfrak{S}_1^{-1}(t - \mathfrak{S}_0^2)\phi^\ddagger(\kappa')\phi(\kappa)\}$$

$$\mathcal{M}_{direct} = i\{-2e^2[\beta_{*\mu\nu}(\kappa') - im_1^{-1}\kappa'_{\mu\nu}\phi^\ddagger(\kappa')]\} \doteq [\beta^{\mu\nu}(\kappa) + im_1^{-1}\kappa^{\mu\nu}\phi(\kappa)] - \mathfrak{f}^2\phi^\ddagger(\kappa')\phi(\kappa)\}$$

$$\mathcal{M}_{direct} = i\{-2e^2[\beta_{*\mu\nu}(\kappa') - i\mathfrak{S}_1^{-1}\kappa'_{\mu\nu}\phi^\ddagger(\kappa')]\} \doteq [\beta^{\mu\nu}(\kappa) + i\mathfrak{S}_1^{-1}\kappa^{\mu\nu}\phi(\kappa)] - \mathfrak{f}^2\phi^\ddagger(\kappa')\phi(\kappa)\}$$

$$\begin{aligned} \mathcal{M}_{total} = & -2im_1^2\{2e^2(s - m_1^2)^{-1}[\beta_{*\mu\nu}(\kappa')\beta^{\mu\nu}(\kappa) + m_1^{-2}\wp'_{\mu\nu}\beta^{*\mu\nu}(\kappa')\wp_{\mu\nu}\beta^{\mu\nu}(\kappa)] + 3\mathfrak{f}^2(t \\ & - m_0^2)^{-1}\beta_{*\mu\nu}(\kappa')\beta^{\mu\nu}(\kappa) + 2e^2(u - m_1^2)^{-1}[\beta_{*\mu\nu}(\kappa')\beta^{\mu\nu}(\kappa) \\ & + m_1^{-2}\wp_{\mu\nu}\beta^{*\mu\nu}(\kappa')\wp'_{\mu\nu}\beta^{\mu\nu}(\kappa)]\} - 2ie^2\beta_{\mu\nu}^{**}(\kappa')\beta^{\mu\nu}(\kappa) \end{aligned}$$

$$\begin{aligned} \mathcal{M}_{total} = & -2i\mathfrak{S}_1^2\{2e^2(s - \mathfrak{S}_1^2)^{-1}[\beta_{*\mu\nu}(\kappa')\beta^{\mu\nu}(\kappa) + \mathfrak{S}_1^{-2}\wp'_{\mu\nu}\beta^{*\mu\nu}(\kappa')\wp_{\mu\nu}\beta^{\mu\nu}(\kappa)] + 3\mathfrak{f}^2(t \\ & - \mathfrak{S}_0^2)^{-1}\beta_{*\mu\nu}(\kappa')\beta^{\mu\nu}(\kappa) + 2e^2(u - \mathfrak{S}_1^2)^{-1}[\beta_{*\mu\nu}(\kappa')\beta^{\mu\nu}(\kappa) \\ & + \mathfrak{S}_1^{-2}\wp_{\mu\nu}\beta^{*\mu\nu}(\kappa')\wp'_{\mu\nu}\beta^{\mu\nu}(\kappa)]\} - 2ie^2\beta_{\mu\nu}^{**}(\kappa')\beta^{\mu\nu}(\kappa) \end{aligned}$$

$$\mathcal{M}_{total} = \mathcal{M}_s + \mathcal{M}_t + \mathcal{M}_{\mu\nu} + \mathcal{M}_{direct}$$

$$= -9i\mathfrak{f}^2m_0^2\{(s - m_0^2)^{-1} + (t - m_0^2)^{-1} + (uv - m_0^2)^{-1} + (3m_0^2)^{-1}\}$$

$$\mathcal{M}_{total} = \mathcal{M}_s + \mathcal{M}_t + \mathcal{M}_{\mu\nu} + \mathcal{M}_{direct}$$

$$= -9i\mathfrak{f}^2\mathfrak{S}_0^2\{(s - \mathfrak{S}_0^2)^{-1} + (t - \mathfrak{S}_0^2)^{-1} + (uv - \mathfrak{S}_0^2)^{-1} + (3\mathfrak{S}_0^2)^{-1}\}$$

Cuyo equivalente lagrangiano, se expresa así:

$$\mathcal{L}'_{int} = em_1\beta^{\mu\nu}\beta_{\mu\nu}\chi - \frac{1}{2\mathfrak{f}m_0\chi^3} - \frac{1}{2e^2\beta^{\mu\nu}\beta_{\mu\nu}\chi^2} - 1/8\mathfrak{f}^2\chi^4$$

$$\mathcal{L}'_{int} = e\mathfrak{S}_1\beta^{\mu\nu}\beta_{\mu\nu}\chi - \frac{1}{2\mathfrak{f}\mathfrak{S}_0\chi^3} - \frac{1}{2e^2\beta^{\mu\nu}\beta_{\mu\nu}\mathfrak{S}^2} - 1/8\mathfrak{f}^2\mathfrak{S}^4$$

$$\Phi_1(x) = \mathcal{R}(x) \cos \boxtimes(x)$$

$$\Phi_2(x) = \mathcal{R}(x) \sin \boxtimes(x)$$

$$A_{\mu\nu}(x)B_{\mu\nu}(x) - e^{-1}\partial_{\mu\nu} \boxtimes(x)$$

Y cuya representación del lagrangiano en  $\mathbb{R}^4$  es igual a:

$$\mathcal{L}' = -\frac{1}{4\mathcal{F}^{\mu\nu}\mathcal{F}_{\mu\nu}} - \frac{1}{2\mathcal{g}^{\mu\nu}\partial_{\mu\nu}\mathcal{R}\partial^{\mu\nu}\mathfrak{R}} - \frac{1}{2e^2\beta^{\mu\nu}\beta_{\mu\nu}\mathcal{R}^2} + \frac{1}{4m_0^2\mathfrak{R}^2} - 1/8\mathfrak{f}^2\mathbb{R}^4$$

$$\mathcal{L}' = -\frac{1}{4\mathcal{F}^{\mu\nu}\mathcal{F}_{\mu\nu}} - \frac{1}{2\mathcal{g}^{\mu\nu}\partial_{\mu\nu}\mathcal{R}\partial^{\mu\nu}\mathfrak{R}} - \frac{1}{2e^2\beta^{\mu\nu}\beta_{\mu\nu}\mathcal{R}^2} + \frac{1}{4\mathfrak{S}_0^2\mathfrak{R}^2} - 1/8\mathfrak{f}^2\mathbb{R}^4$$

$$\mathcal{L}'_0 = -\frac{1}{4\mathcal{F}^{\mu\nu}\mathcal{F}_{\mu\nu}} - \frac{1}{2m_1^2\beta^{\mu\nu}\beta_{\mu\nu}} - \frac{1}{2\mathcal{g}^{\mu\nu}\partial_{\mu\nu}\chi\partial_{\lambda\kappa}\chi} - 1/2m_0^2\chi^2$$



$$\mathcal{L}'_0 = -\frac{1}{4\mathcal{F}^{\mu\nu}\mathcal{F}_{\mu\nu}} - \frac{1}{2\mathfrak{S}_1^2\beta^{\mu\nu}\beta_{\mu\nu}} - \frac{1}{2g^{\mu\nu}\partial_{\mu\nu}\chi\partial_{\lambda\kappa}\chi} - 1/2\mathfrak{S}_0^2\chi^2$$

$$\mathcal{L}_{total} = \mathcal{L}(A, \phi) - \psi_{\alpha}^{-}(\gamma^{\mu\nu}\nabla_{\mu\nu} + \mathcal{M})\psi_{\alpha} + g[\phi_1(\psi_1^{-}\psi_2 + \psi_2^{-}\psi_1) + \phi_2(\psi_1^{-}\psi_1 + \psi_2^{-}\psi_2)]$$

Reduciéndose la simetría de Yukawa, a lo que sigue:

$$\partial_{\mu\nu}j^{\mu\nu}(\psi) = g[\phi_1(\psi_1^{-}\psi_1 + \psi_2^{-}\psi_2) + \phi_2(\psi_1^{-}\psi_2 + \psi_2^{-}\psi_1)] = -\partial_{\mu\nu}j^{\mu\nu}(\phi)$$

$$\partial_{\mu\nu}j^{\mu\nu}(\phi) = g\eta[\phi_1(\psi_1^{-}\psi_1 + \psi_2^{-}\psi_2) + \phi_2(\psi_1^{-}\psi_2 + \psi_2^{-}\psi_1)] = -\partial_{\mu\nu}j^{\mu\nu}(\psi)$$

Finalmente, la densidad del lagrangiano, queda expresada así:

$$\mathcal{L} = -1/2(\nabla\phi_1)^2 - 1/2(\nabla\phi_2)^2 - \mathcal{V}(\phi_1^2 + \phi_2^2) - 1/4\mathcal{F}^{\mu\nu}\mathcal{F}_{\mu\nu}$$

En la que:

$$\nabla_{\mu\nu}\phi_1 = \frac{\partial_{\mu\nu}\phi_1 - \frac{e}{\xi}\mathcal{A}B_{\mu\nu}\phi_2}{\xi\lambda\kappa} \cdot \omega$$

$$\nabla_{\mu\nu}\phi_2 = \frac{\partial_{\mu\nu}\phi_2 + \frac{e}{\lambda\kappa}\mathcal{A}B_{\mu\nu}\phi_1}{\lambda\kappa} \cdot \rho$$

$$\mathcal{F}_{\mu\nu} = \partial_{\mu\nu}\delta_{\mu\nu}\mathcal{A}B_{\mu\nu} - \frac{\partial^{\mu\nu}\delta^{\mu\nu}h \cdot \frac{c^{\mu\nu}}{\hbar}}{\lambda\kappa} \cdot \sigma\rho(\tau)^2$$

En ese mismo orden de ideas, para efectos de conservar la invariancia de gauge, es preciso calcular lo que sigue:

$$\partial^{\mu\nu}\{\partial_{\mu\nu}(\Delta\phi_1) - e\phi_0\mathcal{A}_{\mu\nu}\} = 1$$

$$\{\partial^2 - 4\phi_0^2\mathcal{V}''\}(\phi_0^2)\{\Delta\phi_2\} = 1$$

$$\partial_{\mu\nu\kappa\lambda}\mathcal{F}^{\mu\nu}\mathcal{F}_{\mu\nu} = e\phi_0\{\partial^{\mu\nu}(\Delta\phi_1) - e\phi_0\mathcal{A}_{\mu\nu}\}$$

Cuyas variables, corresponden:

$$B_{\mu\nu} = \mathcal{A}_{\mu\nu} - (e\phi_0)^{-1}\partial_{\mu\nu}(\Delta\phi_1), \mathbb{G}_{\mu\nu} = \partial_{\mu\nu}B_{\mu\nu} - \partial^{\mu\nu}B^{\mu\nu} = \mathcal{F}_{\mu\nu}$$

Bajo la forma de:

$$\partial_{\mu\nu}B^{\mu\nu} = 1, \partial_{\mu\nu}\mathbb{G}^{\mu\nu} + e^2\phi_0^2B^{\mu\nu} = 1$$

## CONCLUSIONES.

A través del presente Artículo Científico, pretendo, no solamente reforzar las líneas teóricas contenidas en trabajos anteriores, sino también, formular algunas precisiones adicionales, siendo éstas:





Que, las ecuaciones de Yang – Mills, son aplicables a los campos cuánticos, indistintamente, si se tratan o no, de partículas con o sin masa, verbigracia, los campos electrodébiles o cromodinámicos cuánticos, según sea el caso.

Que, la trayectoria y movimiento de partículas, puede ser trazada, no necesariamente de forma arbitraria o imaginaria, sino en relación al momentum de las mismas y su configuración vectorial – escalar, sea rompiendo o no, las simetrías existentes.

Que los espacios o campos cuánticos, son susceptibles de curvatura geométrica, lo que ocurre con las partículas con masa, deformando su entorno, afectando la dinámica de las partículas sin masa, a propósito de un campo cuántico cuatridimensional  $\mathbb{R}^4$ , lo que funde la teoría cuántica de campos y la teoría de la relatividad general, en sentido estricto.

#### **REFERENCIAS BIBLIOGRÁFICAS.**

Higgs, Peter W. (1964). Broken Symmetries And The Masses Of Gauge Bosons, *Physical Letters Review* pags. 508 – 509.

Higgs, Peter W. (1966). Spontaneous Symmetry Breakdown without Massless Bosons, *Physical Review*, pags. 1156-1163.

Yang. C. N. and Mills, R. L. (1954). Conservation of Isotopic Spin and Isotopic Gauge Invariance. *Physical Review*, 191-195.

Albuja Bustamante, M. I. (2024). Demostración del Espectro Hamiltoniano para un Campo de Yang-Mills no Abelianos que Poseen una Brecha de Masa Finita con Respecto al Estado de Vacío. *Ciencia Latina Revista Científica Multidisciplinar*, 8(1), 3850-3921. [https://doi.org/10.37811/cl\\_rcm.v8i1.9738](https://doi.org/10.37811/cl_rcm.v8i1.9738).

Albuja Bustamante, M. I. (2024). Teoría de Campos: Reforzamiento Teórico – Matemático al Modelo Estándar de Partículas, bajo la estructura ecuacional de Yang – Mills. *Ciencia Latina Revista Científica Multidisciplinar*, 8(2), 7905-7956. [https://doi.org/10.37811/cl\\_rcm.v8i2.10737](https://doi.org/10.37811/cl_rcm.v8i2.10737)



## APÉNDICE A

En relación a las conclusiones contenidas en este manuscrito, cabe precisar, que la curvatura geométrica o deformación de los campos cuánticos, se materializa cuando las partículas con o sin masa, en sus trayectorias de movimiento, se aproximan, alcanzan o superan la velocidad de la luz, lo que ocurre, a propósito de la brecha de masa o salto de energía inherente a una partícula  $\eta$  respecto del estado de vacío, que es igual a cero.

Ahora bien, para demostrar la hipótesis antes referida, se aplicará el siguiente esquema relativo de campos, a propósito de la mecánica einsteniana aplicable en escala cuántica:

### 1. Teorización inicial.

$$\int \xi dS = \frac{1}{c \int i_{\mu\nu} d\vartheta} + \int \xi dS = (curl\xi)_{\mu\nu} d\vartheta - curl\xi = \frac{1}{c} \cdot \mu\nu(u + v)$$

$$0 = \frac{\partial}{\partial\tau}(\text{div } \mu\nu) + \text{div } \nu\mu$$

$$curl\xi = \frac{1}{c} \left( \mu\nu + \nu\mu + \frac{\lambda}{\phi} \cdot \partial\varphi^2 \partial\psi_{\omega-gt} \delta_{\mathbb{R}^3}^{\tau} \frac{\hbar h}{\mathbb{R}^3} \mathbb{E} - \frac{\mathcal{E}}{\tau\lambda\Psi\Delta\pm} \mathbb{I} \otimes \frac{\mathbb{A}}{\mathbb{B}} \mathbb{Q}\mathbb{N}\mathbb{I}\mathbb{O}^4 + \mathcal{M}\mathcal{F}\mathcal{F}/\mathcal{M} - \frac{klm}{\sigma\rho\omega} \mathcal{E} + \Omega\Phi - \mathbb{I}\Delta^{\mathbb{K}} \right)$$

### 2. Variable de Lorentz.

$$-div c\|\mu, \nu\| = \frac{\partial}{\partial(\mu^2 + \nu^2)} + \rho \blacksquare q\mu\nu + \frac{\partial}{\partial t} \leftrightarrow \int \mu\nu \langle c|\varepsilon_{\mathbb{S}}|\varepsilon_{\sigma}^{\mathbb{S}} \rangle d\varrho$$

$$[curl\mu, \mu] + [curl\nu, \nu] = \frac{\partial c}{\partial x} \left\{ \frac{1}{c} \|\mu, \nu\| \right\} + \mathcal{G}\mathcal{I}\mathcal{O} \frac{\mu\nu}{c}$$

$$-[[curl\mu, \mu]] \frac{\delta y^y}{\delta x_x} = \frac{\partial}{\partial x} \left( \frac{\mu^2}{2} - \mu_x \mu_x \right) - \frac{\partial}{\partial y} \left( \frac{\mu^2}{2} - \mu_x \mu_y \right) - \frac{\partial}{\partial z} \left( \frac{\mu^2}{2} - \mu_x \mu_z \right)$$

$$-[[curl\nu, \nu]] \frac{\delta y^y}{\delta x_x} = \frac{\partial}{\partial x} \left( \frac{\nu^2}{2} - \nu_x \nu_x \right) - \frac{\partial}{\partial y} \left( \frac{\nu^2}{2} - \nu_x \nu_y \right) - \frac{\partial}{\partial z} \left( \frac{\nu^2}{2} - \nu_x \nu_z \right)$$

$$\wp_{\mu\nu} = \frac{1}{2(\mu^2 + \nu^2)} - \mu_x \mu_x - \nu_y \nu_y | \wp_{xy} - \wp_{yx} + \mu_x \mu_y - \nu_y \nu_x |$$

$$\wp \langle \mathbb{E} + \frac{q}{\hbar} \cdot c \rangle \tilde{\mathbb{X}}_{\nu}^y \mu = \frac{\partial \wp_{xx}}{\partial x} - \frac{\partial \wp_{xy}}{\partial y} - \frac{\partial \wp_{xz}}{\partial z} - \frac{1}{c^2 \partial \mathfrak{R}_{xyz}} / \partial \tau$$

$$\int \mathbb{I}_{xyz} d^{\tau} = \frac{\partial}{\partial \mathfrak{R}} \left\| \int \frac{1}{c^4 \mathcal{S}_{xyz}} d^{\tau} \right\| + \int \wp_{xyz} \cos(xyz) d\sigma$$



$$\ddagger_{xyz} = -\frac{\partial \wp_{xx}}{\partial x} - \frac{\partial \wp_{xy}}{\partial y} - \frac{\partial \wp_{xz}}{\partial z} - \frac{1}{c^4 \partial \mathcal{S}_{xyz}} / \partial \tau$$

$$\delta \ell = \frac{\partial \mathcal{S}_x}{\partial x} - \frac{\partial \mathcal{S}_y}{\partial y} - \frac{\partial \mathcal{S}_z}{\partial z} - \frac{\partial \mathcal{S}}{\partial \exists_t}$$

$$\frac{\partial \kappa}{\partial \lambda_\tau} = \partial \nabla \frac{\sum_v^\mu \wp_{\mathcal{G}}^{\text{def}} \mathbb{Q}_{\mathcal{G}}^{\text{def}}}{\partial \mathcal{S}(\sum_\mu^v \wp_{\mathcal{G}}^{\text{def}} \mathbb{Q}_{\mathcal{G}}^{\text{def}})} = \kappa \sqrt{\varphi_{\mathcal{G}}}$$

$$\mathbf{e}_t = -\text{div} \mathbb{Z} - \frac{\partial}{\partial \mathcal{M}} \cdot \partial t \left( \mu \epsilon \mathfrak{S} + \frac{v \epsilon \beta}{2} \right)$$

$$\frac{\partial}{\partial t} \left\| \int \mu \epsilon \mathfrak{S} + \frac{v \epsilon \beta}{2} \cdot d\tau \right\| = \int \mathcal{S}_\epsilon d\sigma - \int \frac{\mu v d\tau}{\omega}$$

$$\omega = \mu^2 - \frac{v^2}{2} + \omega_\epsilon = \frac{1}{\epsilon} - \frac{1 \mathfrak{R}^2}{2} + \omega_m = \frac{1}{\mu v} - \frac{1 \mathcal{M}^2}{2}$$

$$\mu v = \text{div} \mathfrak{S} - \frac{\partial \omega}{\partial t} - \frac{\partial \omega_\epsilon}{\partial t} - \frac{\partial \omega_m}{\partial t}$$

$$\Lambda^{\mu\nu} = -\delta \left| \int \mathfrak{R} \mathfrak{S} / 2! \cdot \varphi \phi \rho d\tau / \text{grad}^2 \right|$$

$$\mathcal{E} = \int \left( \varphi \rho - \frac{1}{2 \epsilon \text{grad}^2 \varphi} \right) d\tau$$

$$\delta_\varphi \mathcal{E} = \int \left[ \rho \delta \varphi - \epsilon \left( \frac{\partial \varphi}{\partial x} \frac{\partial \varphi}{\partial x} \dots \right) d\tau \right] = \int \left[ \rho \delta \varphi + \left( \frac{\beta_{xyz} \partial \delta \varphi}{\partial xyz} \dots \right) d\tau \right] = \int |\rho - \text{div} \mathfrak{S}| \delta \varphi d\tau \equiv 0$$

$$\delta \mathcal{E} = \int \varphi \delta \rho - \frac{1}{2 e^{-i\omega t} \delta \epsilon \epsilon} \cdot d\tau$$

$$\delta \mathcal{E} = \int -\varphi \text{grad}(\rho \varrho) + \frac{1}{2 \mathbf{e}^2 \epsilon^4} \text{grad} \epsilon_{\epsilon \psi} \cdot \begin{matrix} \rho^2 & \varrho^2 & \sigma^2 \\ \lambda \tau^4 & \phi^4 & \omega^4 \\ \pi^\infty & \eta^\infty & \zeta^\infty \end{matrix} \frac{1}{\Psi \sqrt{\Phi}} + \mathbf{K} \Lambda_\nu^\mu$$

$$\delta_{xyz} \mathcal{E} = \int -\mathbf{e}_{xyz} \rho + \frac{1}{2 \mathbf{e}^2} \frac{\partial \mathcal{E}}{\partial xyz} \cdot \delta_{xyz} d\tau$$

$$\begin{aligned} \frac{1}{2 \mathbf{e}^2 \partial \mathcal{E}} \frac{\partial}{\partial xyz} &= \partial xyz \left( \frac{\mu v}{2 \epsilon \epsilon^2} \right) - \epsilon \left( \frac{\epsilon_x \partial \epsilon_x}{\partial x} + \frac{\epsilon_y \partial \epsilon_y}{\partial y} + \frac{\epsilon_z \partial \epsilon_z}{\partial z} \right) = \frac{1}{2 \mathbf{e}^2 \partial \epsilon} \\ &= \frac{\partial}{\partial x \left( \frac{\mu v}{2} - \mu_x v_x \right)} - \frac{\partial}{\partial y \left( \frac{\mu v}{2} - \mu_x v_y \right)} - \frac{\partial}{\partial z \left( \frac{\mu v}{2} - \mu_x v_z \right)} + \epsilon_{xyz} \rho \end{aligned}$$

$$\wp_{xx} = \mu^2 + \frac{v^2}{2} - \mu_x^2 - v_x^2$$

$$\wp_{xy} = -\mu_x \mu_y - v_x v_y$$



$$\wp_{xx}^{(e)} = \frac{1}{\varepsilon} - 1 \left( \frac{\xi^2}{2} - \xi_x^2 \right)$$

$$\wp_{xy}^{(e)} = \frac{1}{\varepsilon} - 1 \xi_x \xi_y$$

$$\wp_{xx}^{(mM)} = \frac{1}{\mu\nu} - 1 \left( \frac{\mathcal{M}^2}{2} - m_x^2 \right)$$

$$\wp_{xx}^{(mM)} = \frac{1}{\mu\nu} - 1 \mathcal{M}_x m_x$$

$$\nabla_x = \frac{\partial \wp_{xx}^{(e)}}{\partial x} - \frac{\partial \wp_{xy}^{(e)}}{\partial y} - \frac{\partial \wp_{xz}^{(e)}}{\partial z} - \frac{\partial \wp_{xx}^{(mM)}}{\partial x} - \frac{\partial \wp_{xy}^{(mM)}}{\partial y} - \frac{\partial \wp_{xz}^{(mM)}}{\partial z} - \frac{1}{c^4 \partial \delta_{xyz}} / \partial \tau$$

$$\dagger = \mathbf{e} \wp + \frac{1}{c} (\mu, \nu) - \frac{1}{2} \text{grad} (\xi \wp) + (\wp \nabla) \mu \nu + \frac{1}{c (\xi \wp)} + (\wp \Delta) - \frac{1}{2 \text{grad}} (\nu, \mu) + (\mathcal{M} m \nabla) \hbar - 1/c (\nu, \mu) + (\mathcal{M} m \nabla) \hbar$$

$$\text{curl } \xi = \frac{1}{c (\varepsilon \varepsilon \pm \sum \mathbb{Q}_g \rho_g + \sum \mathbb{Q}_i \rho_i)} \text{div } \varepsilon \varepsilon = \sum \mathbb{Q}_g \rho_g + \sum \mathbb{Q}_i \rho_i$$

$$\wp = (\varepsilon - 1) \left( \varepsilon \mathbf{e} + \frac{1}{c(\mu, \nu)} \right)$$

$$\mathcal{M} m = (\mu\nu - 1) \left( \lambda \hbar - \frac{1}{c(\mu, \nu)} \right)$$

$$\imath = (\mathcal{L} \lambda - 1) \left( \varepsilon \mathbf{e} + \frac{1}{c(\mu, \nu)} \right)$$

### 3. Variable de Fizeau.

$$\mathcal{V}_x = \mathcal{V}_o + \varrho_i \left( 1 - \frac{1}{\eta^2} \right)$$

$$\wp_y = (\varepsilon \varepsilon - 1) \left( 1 - \frac{\alpha \varrho_x}{c} \right) \zeta$$

$$\mathcal{M} m_y = (\mu\nu - 1) \left( 1 - \frac{\alpha \varrho_x}{c} \right) \zeta$$

$$\mathbb{C} \alpha = \mathcal{V}_e - \frac{\mathcal{V} (\varepsilon \varepsilon - 1) \alpha \varrho_x}{c} + \varrho_x (\varepsilon \varepsilon - 1)$$

$$\mathbb{C} = \mathcal{V} \mu \alpha \frac{(\mu\nu - 1) \varrho_x}{c} + \varrho_x (\mu\nu - 1) \alpha$$

$$\mathcal{V} = \mathcal{V}_o + \varrho_x \left( 1 - \frac{1}{\eta^2} \right)$$

### 4. Variable de la velocidad de la luz.

$$\Delta \varphi - \frac{1}{c^2 \partial^2 \tau} \varphi = \frac{1}{c} \frac{\mathbf{e}}{c \leftrightarrow} = \text{curl } \hbar = c \text{curl} (\text{curl } \mathbf{e}) = -c (\Delta \Gamma \varepsilon + \text{grad} (\text{div } \mathbf{e})) = \mathbb{C} \alpha \mathbf{e}$$



## 5. Principio de Relatividad.

$$\frac{\overline{\omega}_{\mu\nu} d^2 \tau_{\mu\nu}}{dt^2} = \mathbb{R}^{\mu\nu} \mathfrak{R}_{\mu\nu} / \mathcal{R} \mathcal{E}$$

$$X_{\mu}^{\hat{a}} X_{\nu}^{\hat{a}} = X_{\mu}^{\overline{m}} X_{\nu}^{\overline{m}}$$

$$\frac{dx_{\mu}^{\hat{a}}}{dt_{\nu}^{\hat{a}}} = dx_{\mu}^{\overline{m}} dt_{\nu}^{\overline{m}} - \mathcal{V}$$

$$\frac{d^2 x_{\mu}^{\hat{a}}}{d^2 t_{\nu}^{\hat{a}}} = d^2 x_{\mu}^{\overline{m}} d^2 t_{\nu}^{\overline{m}} - \mathcal{V}$$

$$V = \left\| \mathcal{V}_o + \varrho_i \left( 1 - \frac{1}{\eta^2} \right) \right\| - \varrho_i = \mathcal{V}_o - \frac{\varrho_i}{\eta^2}$$

## 6. Transformaciones de Lorentz.

$$\lambda^2 (\chi^2 + y^2 + z^2 - c^2 t^2) = (\chi^{\overline{m}2} + y^{\overline{m}2} + z^{\overline{m}2} - c^{\overline{m}2} t^{\overline{m}2}) = \alpha_{1\mu 1\nu}^2 + \alpha_{2\mu 2\nu}^2 + \alpha_{3\mu 3\nu}^2 + \alpha_{\eta\mu\eta\nu}^2 = 1$$

$$\alpha_{\eta} = \frac{1}{\sqrt{1-\beta^2}} + \frac{i\beta}{\sqrt{1-\beta^2}} - \frac{-1}{\sqrt{1-\beta^2}} + \frac{-i\beta}{\sqrt{1-\beta^2}}$$

$$x' = x + \frac{i\beta_{\mu\nu}}{\sqrt{1-\beta^2}} + \mu\nu' = \frac{\mu\nu - i\beta_{xyz}}{\sqrt{1-\beta^2}} + x' = \frac{x - \beta_{ct}}{\sqrt{1-\beta^2}} = t = t - \frac{\beta}{c} x / \sqrt{1-\beta^2}$$

$$x' = x - \frac{vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\mu\nu' = t - \frac{\frac{v}{c^2} x}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\frac{\mathfrak{X}^2}{\sqrt{1 - \frac{v^2}{c^2}}} + \frac{\mathfrak{Y}^2}{\mathfrak{R}^2} + \frac{\mathfrak{Z}^2}{\mathfrak{R}^2} = 1$$

$$\mathfrak{X}_o = \mathfrak{X} / \sqrt{1 - \frac{q^2}{c^2}}$$

$$\Delta t = \Delta t' \frac{\mathfrak{X}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\sum \Delta t = \sum \Delta t' \frac{\mathfrak{X}}{\sqrt{1 - \frac{q^2}{c^2}}}$$

$$\sum \Delta t' = \sum \Delta t \cdot \sqrt{1 - \frac{q^2}{c^2}}$$



$$x' = \lambda(\mu\nu)x - vt / \sqrt{1 - \frac{v^2}{c^2}}$$

$$t = \lambda(\mu\nu)t - v/c^2 x / \sqrt{1 - \frac{v^2}{c^2}}$$

### 7. Teorema de Velocidades.

$$q_x = q'_x + \frac{v}{1} + q'_x v / c^2$$

$$q_y = \frac{\sqrt{1 - \frac{v^2}{c^2}} q'_y}{1} + q'_x \mu\nu / c^2$$

$$q_z = \frac{\sqrt{1 - \frac{v^2}{c^2}} q'_z}{1} + q'_x \mu\nu / c^2$$

$$q^2 = q'^2 + v^2 + 2q'^{\mu\nu} \cos\theta' - \left(\frac{q'^{\mu\nu}}{c} \sin\theta'\right)^2 + \frac{q'^{\mu\nu}}{c^2} (\cos\theta')^2$$

$$\frac{q^2}{c^2} = 1 + \frac{q'^{\mu\nu}}{c} (\cos\theta')^2 - \frac{\left(1 - \frac{q'^2}{c^2}\right) \left(1 - \frac{v^2}{c^2}\right)}{\left(1 + \frac{q'^{\mu\nu}}{c} \cos\theta'\right)^2}$$

$$q = q' + \frac{v}{1} + \frac{q'^{\mu\nu}}{c^2}$$

$$v = v_o + \frac{q}{1 + \frac{v_o q}{c^2}}$$

$$v = v_o + q \left(1 - \frac{1}{n^2}\right)$$

$$\sin\omega \left(t - lx + my + \frac{nz}{c}\right)$$

$$\sin\omega' \left(t' - l'x' + m'y' + \frac{n'z'}{c'}\right)$$

$$\omega' = \omega \frac{1 - \frac{lv}{c}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$l' = l - \frac{v}{c} - l \frac{lv}{c}$$

$$m' = \frac{m}{1 - \frac{lv}{c}} \sqrt{1 - \frac{v^2}{c^2}}$$



$$n' = \frac{n}{1 - \frac{lv}{c}} \sqrt{1 - \frac{v^2}{c^2}}$$

$$\frac{\partial}{\partial x} = b \left( \frac{\partial}{\partial x} - \frac{v}{c^2} \frac{\partial}{\partial t'} \right) + \frac{\partial}{\partial y} = b \left( \frac{\partial}{\partial y} - \frac{v}{c^2} \frac{\partial}{\partial t'} \right) + \frac{\partial}{\partial z} = b \left( \frac{\partial}{\partial z} - \frac{v}{c^2} \frac{\partial}{\partial t'} \right)$$

$$\rho' = b \left( 1 - \frac{v q_x}{c^2} \right) \rho$$

$$q'_x = q_x - \frac{v}{1 - \frac{q_x v}{c^2}}$$

$$q'_y = q_y / b \left( 1 - \frac{q_x v}{c^2} \right)$$

$$q'_z = q_z / b \left( 1 - \frac{q_x v}{c^2} \right)$$

$$\rho = \rho' / \sqrt{1 - \frac{v^2}{c^2}}$$

$$d\tau_0 = d\tau' = \frac{d\tau}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\rho_0 = \rho / \sqrt{1 - \frac{q^2}{c^2}}$$

$$\phi = \omega \left( t - lx + my + \frac{nz}{c} \right)$$

$$\phi' = \omega' \left( t' - l'x' + m'y' + \frac{n'z'}{c'} \right) \sin\phi$$

$$\mathfrak{A}' = \mathfrak{A} \frac{1 - \frac{v}{c} \cos\phi}{\sqrt{1 - \frac{v^2}{c^2}}}$$

## 8. Ecuaciones de Movimiento.

$$dq' = \frac{dq}{1 - \frac{qv}{c^2}} + \frac{q \frac{v}{c^2} dq}{(1 - qv/c^2)^2} = dq / (1 - qv/c^2)^2$$

$$dt = dt' + \frac{\frac{v}{c^2} dx'}{\sqrt{1 - \frac{v^2}{c^2}}} = dt' / \sqrt{1 - \frac{q^2}{c^2}}$$

$$m \frac{dq}{dt} / \left( \sqrt{1 - \frac{q^2}{c^2}} \right)^3 = \varepsilon \mathbf{e}_x \varepsilon_{\varphi} \varepsilon_v^u$$



$$\frac{dq}{dt} / \left( \sqrt{1 - \frac{q^2}{c^2}} \right)^{\frac{3}{2}} = \frac{d}{dt \left| \frac{q}{\sqrt{1 - \frac{q^2}{c^2}}} \right|} = \frac{d}{dt \left| \frac{mq}{\sqrt{1 - \frac{q^2}{c^2}}} \right|} = \dot{f}_{xyz}$$

$$\frac{d}{dt \left\langle \frac{mq}{\sqrt{1 - \frac{q^2}{c^2}}} \right\rangle} = \dot{f}_k$$

$$\dot{f}_{kq} = q \cdot \frac{d}{dt} \left| \frac{mq}{\sqrt{1 - \frac{q^2}{c^2}}} \right| = \frac{d}{dt} \left| \frac{mq^2}{\sqrt{1 - \frac{q^2}{c^2}}} \right| - \frac{mqq}{\sqrt{3}} = \frac{d}{dt} \left| \frac{mq^2}{\sqrt{1 - \frac{q^2}{c^2}}} \right| + mc^2 \sqrt{1 - \frac{q^2}{c^2}}$$

$$\dot{f}_{kq} = d/dt \left| \frac{mc^2}{\sqrt{1 - \frac{q^2}{c^2}}} \right|$$

$$\mathcal{E}_{\text{def}} = mc^2 / \sqrt{1 - \frac{q^2}{c^2}}$$

$$\mathcal{E}_{\text{def}} = mc^2 + \mathcal{M}/2q^2$$

## 9. Energía Inercial.

$$x = ct + \alpha + l'/b \left( 1 + \frac{v}{c} \right)$$

$$l_1 = l' \sqrt{1 - \frac{v}{c} - \frac{v}{c}}$$

$$l_2 = l' \sqrt{1 + \frac{v}{c} - \frac{v}{c}}$$

$$\mathfrak{A}_1 = \mathfrak{A}' \sqrt{1 + \frac{v}{c} - \frac{v}{c}}$$

$$\mathfrak{A}_2 = \mathfrak{A}' \sqrt{1 - \frac{v}{c} + \frac{v}{c}}$$

$$\eta_1 = \frac{\dot{f}_{t1}}{2A_1^2} = \frac{1}{2\dot{f}'} A'^2 \sqrt{1 + \frac{v}{c} - \frac{v}{c}}$$

$$\eta_2 = \frac{\dot{f}_{t2}}{2A_2^2} = \frac{1}{2\dot{f}'} A'^2 \sqrt{1 - \frac{v}{c} + \frac{v}{c}}$$





$$\eta_1 + \eta_2 = 2\eta' / \sqrt{1 - \frac{v^2}{c^2}}$$

$$I_1 = \frac{\hbar t_1}{2cA_1^2} = \frac{1}{2c\hbar t'} A'^2 \sqrt{1 + \frac{v}{c} - \frac{v}{c}}$$

$$I_2 = \frac{\hbar t_2}{2cA_2^2} = \frac{1}{2c\hbar t'} A'^2 \sqrt{1 - \frac{v}{c} + \frac{v}{c}}$$

$$I_1 - I_2 = 2\eta' / c^2 \cdot v / \sqrt{1 - \frac{v^2}{c^2}}$$

$$\mathcal{E}_{\text{def}} = mc^2 / \sqrt{1 - \frac{v^2}{c^2}}$$

$$\Delta\mathcal{E}_{\text{def}} = \Delta\mathcal{E}'_{\text{def}} / \sqrt{1 - \frac{v^2}{c^2}}$$

$$(\mathcal{E}_{\text{def}} + \Delta\mathcal{E}_{\text{def}}) = [\mathcal{M} + \Delta\mathcal{E}'_{\text{def}}/c^2] / \sqrt{1 - \frac{v^2}{c^2}}$$

$$\beta = \frac{\mathcal{M}v}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\Delta\beta = (I_1 - I_2) = \frac{\Delta\mathcal{E}'_v}{c^2} / \sqrt{1 - \frac{v^2}{c^2}}$$

$$(\beta + \Delta\beta) = [\mathcal{M} + \Delta\mathcal{E}'_{\text{def}}/c^2]v / \sqrt{1 - \frac{v^2}{c^2}}$$

## 10. Variable de cuatro dimensiones de Minkowski:

$$A'_{xyz} = A_{xyz} + i\beta A_{\mu\nu} / \sqrt{1 - \beta^2}$$

$$A'_{\mu\nu} = A_{\mu\nu} - i\beta A_{xyz} / \sqrt{1 - \beta^2}$$

$$\mathfrak{X}'_{\mu\nu} = \sum \alpha_{\mu\nu} \mathfrak{X}_{\mu\nu}$$

$$\mathfrak{X}'_{\mu\nu} = \sum_{\mu\nu} \alpha_{\mu\nu} \mathfrak{X}_{\mu\nu}$$

$$\mathfrak{X}'_{\mu\nu} = \sum_{\sigma\tau} \alpha_{\mu\sigma} \mathfrak{X}_{\nu\tau} \mathfrak{X}_{\mu\nu}$$



$$\mathfrak{F}'_{\tau_1 \dots \tau_n} = \sum_{\sigma_1 \dots \sigma_n} \alpha_{\tau_1 \sigma_1} \alpha_{\tau_2 \sigma_2} \dots \alpha_{\tau_n \sigma_n} \mathfrak{F}_{\sigma_1 \dots \sigma_n}$$

$$\begin{matrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{matrix}$$

### 11. Variable tensorial.

$$(\mathfrak{F}_{\sigma_1 \dots \sigma_n}) \pm (\mathfrak{U}_{\sigma_1 \dots \sigma_n}) = (\mathfrak{F}_{\sigma_1 \dots \sigma_n} \pm \mathfrak{U}_{\sigma_1 \dots \sigma_n})$$

$$\mathfrak{F}_{\sigma_1 \dots \sigma_n} \mathfrak{U}_{\tau_1 \dots \tau_n}$$

$$\mathfrak{F}'_{\delta_1 \dots \delta_n} = \sum_{\sigma_1 \dots \sigma_n} \alpha_{\delta_1 \sigma_1} \alpha_{\delta_2 \sigma_2} \dots \alpha_{\delta_n \sigma_n} \mathfrak{F}_{\sigma_1 \dots \sigma_n}$$

$$\mathfrak{U}'_{t_1 \dots t_n} = \sum_{\tau_1 \dots \tau_n} \alpha_{t_1 \tau_1} \alpha_{t_2 \tau_2} \dots \alpha_{t_n \tau_n} \mathfrak{U}_{\tau_1 \dots \tau_n}$$

$$\mathfrak{F}'_{\delta_1 \dots \delta_n} \mathfrak{U}'_{t_1 \dots t_n} = \sum_{\sigma_1 \dots \sigma_n \tau_1 \dots \tau_n} \alpha_{\delta_1 \sigma_1} \dots \alpha_{\delta_n \sigma_n} \alpha_{t_1 \tau_1} \dots \alpha_{t_n \tau_n} \mathfrak{F}_{\sigma_1 \dots \sigma_n} \mathfrak{U}_{\tau_1 \dots \tau_n}$$

$$(\mathfrak{F}_{\sigma_1 \dots \sigma_n})(\mathfrak{U}_{\tau_1 \dots \tau_n}) = (\mathfrak{F}_{\sigma_1 \dots \sigma_n} \mathfrak{U}_{\tau_1 \dots \tau_n})$$

$$\sum_{\sigma_1 \dots \sigma_n} \mathfrak{U}_{\sigma_1 \dots \sigma_n} \mathfrak{F}_{\sigma_1 \dots \sigma_n} = \mathfrak{B}_{\sigma_{n+1} \dots \sigma_m}$$

$$\mathfrak{U}'_{\delta_1 \dots \delta_n} = \sum_{\tau_1 \dots \tau_n} \alpha_{\delta_1 \tau_1} \alpha_{\delta_2 \tau_2} \dots \alpha_{\delta_n \tau_n} \mathfrak{U}'_{\tau_1 \dots \tau_n}$$

$$\mathfrak{F}'_{\sigma_1 \dots \sigma_n} = \sum_{\sigma_1 \dots \sigma_n} \alpha_{\delta_1 \sigma_1} \alpha_{\delta_2 \sigma_2} \dots \alpha_{\delta_n \sigma_n} \mathfrak{F}_{\sigma_1 \dots \sigma_n}$$

$$\mathfrak{B}'_{\delta_{n+1} \dots \delta_m} = \sum_{\delta_1 \dots \delta_n \tau_1 \dots \tau_n \sigma_1 \dots \sigma_n} \alpha_{\delta_1 \tau_1} \dots \alpha_{\delta_n \tau_n} \alpha_{\delta_1 \sigma_1} \dots \alpha_{\delta_n \sigma_n} \mathfrak{U}_{\tau_1 \dots \tau_n} \mathfrak{F}_{\sigma_1 \dots \sigma_n}$$

$$\mathfrak{B}'_{\delta_{n+1} \dots \delta_m} = \sum_{\sigma_{n+1} \dots \sigma_m} \alpha_{\delta_{n+1} \sigma_{n+1}} \dots \alpha_{\delta_m \sigma_m} \mathfrak{U}'_{\sigma_{n+1} \dots \sigma_m}$$

$$(\mathfrak{U}'_{\sigma_1 \dots \sigma_n})(\mathfrak{F}'_{\sigma_1 \dots \sigma_n}) = (\mathfrak{B}'_{\sigma_{n+1} \dots \sigma_m})$$

$$(\mathfrak{F}_{\mu\nu})(\mathfrak{U}_{\mu\nu}) = (\mathfrak{B})$$

$$\mathfrak{B} = \frac{\sum_u \nu \frac{\sum_{\mu\nu} (\mathfrak{F}_{\mu\nu} \mathfrak{U}_{\mu\nu} \mathfrak{G}_{\mu\nu} \mathfrak{F}_{\mu\nu}^2 \mathfrak{U}_{\mu\nu}^2 \mathfrak{G}_{\mu\nu}^2)^{\rho} 1}{2} \sum_{\text{if } \text{lm}} 1}{\frac{6}{24}} (\mathfrak{B}_{\text{iflm}})(\mathfrak{G}_{\text{iflm}})$$

$$\mathfrak{X}_{\mu\nu} = \sum_{\mu\nu} \alpha_{\mu\nu} \mathfrak{X}'_{\mu\nu}$$



$$\frac{\partial}{\mathfrak{X}'_{\mu\nu}} = \sum_{\mu\nu} \alpha_{\mu\nu} \frac{\partial}{\mathfrak{X}'_{\nu\mu}}$$

$$\left(\frac{\partial}{\partial\chi_\tau}\right)(\mathfrak{I}_{\sigma_1\dots\sigma_n}) = \|\partial\mathfrak{I}_{\sigma_1\dots\sigma_n}/\partial\chi_\tau\|$$

$$\left(\frac{\partial}{\partial\chi_{\sigma\mu\nu}}\right)(\mathfrak{I}_{\sigma_1\dots\sigma_n}) = \sum_{\sigma\mu\nu} \frac{\partial}{\partial\chi_{\sigma\mu\nu}}(\mathfrak{I}_{\sigma\mu\nu\dots\sigma_{\mu\nu-1}\sigma_{\nu\mu+1}\dots\sigma_{\nu\mu}})$$

$$\left(\frac{\partial}{\partial\mu\nu}\right)\mathfrak{I} = \left(\frac{\partial\mathfrak{I}}{\partial\chi_{\mu\nu}}\right)$$

$$\left(\frac{\partial}{\partial\chi_{\mu\nu}}\right)(\mathfrak{I}_{\mu\nu}) = \sum_{\mu\nu} \left(\frac{\partial\mathfrak{I}_{\mu\nu}}{\partial\chi_{\mu\nu}}\right)$$

$$\left(\frac{\partial}{\partial X_\tau}\right)\left|\left(\frac{\partial}{\partial X_\tau}\right)(\mathfrak{I}_{\sigma_1\dots\sigma_n})\right| = \left(\frac{\partial}{\partial X_\tau}\right)\left(\frac{\partial\mathfrak{I}_{\sigma_1\dots\sigma_n}}{\partial X_\tau}\right) = \left(\frac{\sum_\tau \partial^2 \mathfrak{I}_{\sigma_1\dots\sigma_n}}{\partial X_\tau^2}\right)(\square \mathfrak{I}_{\sigma_1\dots\sigma_n})$$

## 12. Estado de vacío.

$$\frac{1}{2\left\|\frac{1}{v} - V + \frac{1}{v} + V\right\|} \partial t = \frac{\partial\tau}{\partial X^\Gamma} + \frac{1}{v} - V \frac{\partial\tau}{\partial t}, \frac{\partial\tau}{\partial X^\Gamma} + \frac{v}{\sqrt{V^2 - v^2}} \frac{\partial\tau}{\partial t} = 0$$

$$\tau = \alpha \left(t - \frac{v}{V^2} - v^2 x'\right)$$

$$\xi = V\tau$$

$$\xi = \alpha V \left(t - \frac{v}{V^2} - v^2 x'\right)$$

$$x'/v - V = t$$

$$\xi = \alpha \cdot V^2 / \sqrt{\frac{V^2 - v^2}{x'}}$$

$$\eta = V_\tau = \alpha V \left(t - \frac{v}{V^2} - v^2 x'\right)$$

$$\beta = \frac{1}{1} - (v/V)^2$$

$$\varphi X^2 / (\sqrt{1 - (v/V)^2})^2 + y^2 + z^2 = \mathcal{R}^2$$

$$\tau = 1/\sqrt{1 - (v/V)^2} |t - v/V^2 x|$$

$$\tau = t\sqrt{1 - (v/V)^2} = t - (1 - \sqrt{1 - (v/V)^2}) t$$

$$x = \omega_\xi + \frac{v}{1} + \frac{v\omega_\xi}{V^2 t}$$

$$y = \frac{\sqrt{1 - (v/V)^2}}{1} + \frac{v\omega_\xi}{V^2} \omega_{\eta^+}$$

$$u^2 = \left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2$$



$$\omega^2 = \omega_\xi^2 + \omega_\eta^2$$

$$\alpha = \arctg \omega_y / \omega_x$$

$$u = \frac{\sqrt{v^2 + \omega^2 + 2v\omega \cos \alpha - (v\omega \sin \frac{\alpha}{V})^2}}{1 + v\omega \cos \alpha / V^2}$$

$$U = v + \frac{\omega}{1} + v\omega/V^2$$

$$U = V.2V - \kappa - \frac{\lambda}{2V} - \kappa - \lambda + \frac{\kappa\lambda}{V} \lll V$$

$$U = V + \frac{\omega}{1} + \frac{\omega}{v} = V$$

$$v + \frac{\omega}{1} + \frac{v\omega}{V^2}$$

$$\frac{1}{V\partial X} = \partial\beta \left(N - \frac{v}{V}Y\right) - \frac{\partial\beta \left(M + \frac{v}{V}Z\right)}{V} \frac{\partial\beta \left(Y - \frac{v}{V}N\right)}{\partial\tau} = \frac{\partial L}{\partial\zeta} - \frac{\partial\beta \left(N - \frac{v}{V}Y\right)}{\partial\zeta}$$

$$\beta = \frac{1}{\sqrt{1 - (v/V)^2}}$$

$$\left(\beta\xi - \frac{\alpha\beta v}{V}\xi\right)^2 + \left(\eta - \frac{b\beta v}{V\xi}\right)^2 + \left(\zeta - \frac{c\beta v}{V}\right)^2 = \mathcal{R}^2$$

$$S'/S = \sqrt{1 - \left(\frac{v}{V}\right)^2 - v/V \cos \varphi}$$

$$\frac{E'}{E} = \frac{A'^2}{16\pi} S' \frac{A^2}{16\pi} S = 1 - \frac{v}{V} \cos \varphi / \sqrt{1 - (v/V)^2}$$

$$\frac{E'}{E} = \sqrt{1 - \frac{v}{V} + \frac{v}{V}}$$

$$A^t = A.1 - \frac{\frac{v}{V} \cos \varphi}{\sqrt{1 - (v/V)^2}}$$

$$\cos \varphi^t = \cos \varphi - \frac{v}{V} - \frac{v}{V} \cos \varphi$$

$$v^t = v.1 - \frac{v}{V} \cos \frac{\varphi}{\sqrt{1 - (v/V)^2}}$$

$$A^m = A^n.1 + \frac{v}{V} \cos \varphi^n / \sqrt{1 - (v/V)^2} = A.1 - \frac{2.v}{V} \cos \varphi + \left(\frac{v}{V}\right)^2 - \left(\frac{v}{V}\right)^2$$

$$\cos \varphi^m = \cos \varphi^n + \frac{v}{V} + \frac{v}{V} \cos \varphi^n = -(1 + \left(\frac{v}{V}\right)^2) \cos \varphi - \frac{2.v}{V} - 2.\frac{v}{V} \cos \varphi + \left(\frac{v}{V}\right)^2$$



$$v^m = v^n \cdot 1 + \frac{v}{V} \cos \frac{\varphi^n}{\sqrt{1 - (v/V)^2}} = v \cdot 1 - 2 \cdot \frac{v}{V} \cos \varphi + \left(\frac{v}{V}\right)^2 - \left(\frac{v}{V}\right)^2$$

$$P = 2 \cdot \frac{A^2}{16\pi} \left( \cos \varphi - \frac{v}{V} - \left(\frac{v}{V}\right)^2 / \cos \varphi^2 \right)$$

$$\frac{1}{V \left( \mu_\xi \eta \zeta \rho^\dagger + \frac{\partial X^\dagger}{\partial \tau} \right)} = \frac{\partial N^\dagger}{\partial \eta} - \frac{\partial M^\dagger}{\partial \zeta}$$

$$\frac{\mu d^2 x}{dt^2} = \epsilon(X, Y, Z)$$

$$\frac{\mu d^2 \xi \eta \zeta}{dt^2} = \frac{\epsilon}{\mu} - \frac{\frac{1}{\beta^3(X^\dagger, Y^\dagger, Z^\dagger)}}{V(M, N)}$$

$$\mathcal{L}m = u / (\sqrt{1 - v/V})^3$$

$$\mathcal{T}m = \frac{u}{1} - (v/V)^2$$

$$\mathcal{W} = \int \epsilon X dx = \int_0^v \beta^3 v d\mu = \mu v V^2 (1 / \sqrt{1 - (v/V)^2} - 1)$$

$$P = \int X dx = \frac{\mu v}{\epsilon} \cdot V^2 \left( \frac{1}{\sqrt{1 - (v/V)^2}} - 1 \right)$$

$$-\frac{d^2 y}{dt^2} = \frac{v^2}{\mathfrak{R}} = \frac{\epsilon}{\mu} \cdot \frac{v}{V} \cdot N \cdot \sqrt{1 - (v/V)^2}$$

$$\mathfrak{R} = V^2 \cdot \frac{\mu}{\epsilon} \cdot \frac{v}{V} \cdot 1/N$$

### 13. Estado Fundamental de Vacío.

$$\left( \frac{\partial}{\partial \mathfrak{X}_{\mu\nu}} \right) (\mathfrak{F}_{\mu\nu}) = (\mathfrak{X}_{\mu\nu}) (\mathfrak{F}^*_{\mu\nu}) = 0$$

$$\frac{1}{2(\mathfrak{F}_{\mu\nu})} (\mathfrak{F}_{\mu\nu}) = \hbar^2 - e^2$$

$$\frac{1}{2i(\mathfrak{F}_{\mu\nu})} (\mathfrak{F}^*_{\mu\nu}) = (e\hbar)$$

$$-(\mathfrak{F}_{\mu\nu})(\mathfrak{F}_{\mu\nu}) = \rho^2 \left( 1 - \frac{\rho^2}{c^2} \right) = p_0^2$$

$$(\mathfrak{F}_{\mu\nu}) (\mathfrak{F}_{\mu\nu}) = (\mathfrak{R}_{\mu\nu})$$

$$(\mathfrak{K}_{\mu\nu}) = -\left(\frac{\partial}{\partial \mathfrak{X}_{\mu\nu}}\right)(\mathfrak{T}_{\mu\nu}) = 1/2\|(\mathfrak{F}_{u\sigma})(\mathfrak{F}_{v\sigma}) - (\mathfrak{F}^*_{u\sigma})(\mathfrak{F}^*_{v\sigma})\|$$

#### 14. Movimiento Isotrópico.

$$(\mathfrak{S}_{\mu\nu}) = \left(\frac{dx_{\mu\nu}}{\sqrt{-\sum dx_{\sigma}^2}}\right)$$

$$(\mathfrak{F}_{\mu\nu}^{(e)}) = (\mathfrak{F}_{\mu\nu})(\mathfrak{S}_{\mu\nu})$$

$$\mathfrak{F}_{\eta}^{(e)} = \frac{1}{c} \frac{q_x}{\sqrt{1 - \frac{\rho^2}{c^2} e_x}} \cdot e_x + \frac{q_{\eta}}{c} \cdot e_{\eta} + \frac{q_3}{c} \cdot e_z$$

$$(\mathfrak{F}_{\mu\nu}^{(m)}) = -i(\mathfrak{F}^*_{\mu\nu})(\mathfrak{S}_{\mu\nu})$$

$$\mathfrak{F}_{\eta}^{(m)} = i/\sqrt{1 - \frac{\rho^2}{c^2} \cdot \frac{q_x}{c} \cdot \mathfrak{h}_x + \frac{q_{\eta}}{c} \cdot \mathfrak{h}_{\eta} + \frac{q_3}{c} \cdot \mathfrak{h}_3}$$

$$\mathfrak{F}_i^{\dagger} = \frac{\frac{\rho_0}{\sqrt{1 - \frac{\rho^2}{c^2} q_x}}}{c} = \rho \cdot q_x/c$$

$$\left(\frac{\partial}{\partial \mathfrak{X}_{\mu\nu}}\right)(\mathfrak{F}_{\mu\nu} + \mathfrak{P}_{\mu\nu}) = \frac{1}{c(\mathfrak{F}_{\mu\nu}^{\dagger})} + p_0(\mathfrak{S}_{\mu\nu}) - \left(\frac{\partial}{\partial \mathfrak{X}_{\mu\nu}}\right)(\mathfrak{F}^*_{\mu\nu} + i\mathfrak{M}_{\mu\nu}) = 0$$

$$(\mathfrak{S}_{\mu\nu})\left(\frac{\partial(\mathfrak{F}_{\mu\nu} + \mathfrak{P}_{\mu\nu})}{\partial \mathfrak{X}_{\mu\nu}}\right) = (\mathfrak{F}_i^{\dagger})(\mathfrak{S}_{\mu\nu}) = \rho_0(\mathfrak{S}_{\mu\nu})(\mathfrak{S}_{\mu\nu}) = -\rho_0$$

$$\rho_0 = -(\mathfrak{S}_{\mu\nu})(\partial(\mathfrak{F}_{\mu\nu} + \mathfrak{P}_{\mu\nu})/\partial \mathfrak{X}_{\mu\nu})$$

#### 15. Tensor de Energía.

$$(\mathfrak{T}_{\mu\nu}^0) = \left(\frac{1}{2(\mathfrak{F}_{\mu\sigma})(\mathfrak{F}_{v\sigma})} - (\mathfrak{F}^{\dagger}_{\mu\sigma})(\mathfrak{F}^*_{v\sigma})\right)$$

$$(\mathfrak{T}_{\mu\nu}^e) = \frac{1}{\varepsilon} - 1 \left( (\mathfrak{T}_{\mu\sigma})(\mathfrak{T}_{v\sigma}) - \frac{1}{4(\delta_{\mu\sigma})(\delta_{v\sigma})(\mathfrak{T}_{\sigma\tau})(\mathfrak{T}_{\sigma\tau})} \right)$$

$$f^0 = -ediv p^{**} - \mathfrak{h}div m^{**} + e\left(\frac{1}{c}\left(i, \frac{q}{c}\right) + \rho\right) + \left|\frac{i}{c} + \frac{q}{c} \cdot p, \mathfrak{h}\right| + \left\|\frac{\rho^{**}}{c} - rot\rho^*, \mathfrak{h}\right\| - \left\|\frac{m^{**}}{c} - rotm^*, e\right\|$$

$$\varphi^0 = e\left(i + \rho q\right) + c\left(e, \frac{\rho^{**}}{c} - rot\rho^*\right) + c\left(\mathfrak{h}, \frac{m^{**}}{c} - rotm^*\right)$$

$$\omega = \sigma, \varphi, \phi(e^{*2} - \left(\frac{q}{c}, e^*\right)^2)\sqrt{1 - q^2/c^2}$$



$$\begin{aligned}
-\dot{f}_x &= \frac{\partial \rho}{\partial x} + \frac{\mu^x \lambda q_x}{w^2 \partial q_x} + \frac{\mu^x \lambda q_y}{w^2 \partial q_x} + \frac{\mu^x \lambda q_z}{w^2 \partial q_x} + \frac{\mu^x \lambda q_x}{w^2 \partial q_x} \\
&\quad + q_x \left( \frac{\partial}{\partial x} \left( \frac{\mu^x \lambda q_x}{w^2 \partial q_x} \right) + \frac{\partial}{\partial y} \left( \frac{\mu^x \lambda q_y}{w^2 \partial q_x} \right) + \frac{\partial}{\partial z} \left( \frac{\mu^x \lambda q_z}{w^2 \partial q_x} \right) + \frac{\partial}{\partial t} \left( \frac{\mu^x}{w^2} \right) \right) - \frac{i}{c} \cdot \eta \\
&= -\frac{i}{c} \frac{\partial \rho}{\partial t} - \dot{f}_x \\
&= \frac{\partial \rho}{\partial x} + \frac{\mu^*}{1} - \frac{q^2}{c^2 \left( \frac{\lambda q_x \partial q_x}{\partial x} + \frac{\lambda q_y \partial q_x}{\partial y} + \frac{\lambda q_z \partial q_x}{\partial z} + \frac{\partial q_x}{\partial t} \right)} + \lambda q_x \mathfrak{A} - \frac{1}{c^2} \cdot \eta \cdot \kappa_4 \\
&= -\frac{1}{c^2} \frac{\partial \rho}{\partial t} \cdot \kappa_4 + \mathcal{A}
\end{aligned}$$

## 16. Dinámica del punto de masa.

$$\begin{aligned}
-\frac{\int \mathfrak{K}_{\mu\nu} dx_1 \dots dx_4}{\partial \mathfrak{X}_{\mu\nu} dx_1} \dots dx_4 &= \frac{\partial \mathfrak{X}_{\mu\nu 4}}{\partial \mathfrak{X}_{\mu\nu 4} dx_1} \dots dx_4 \\
&\quad \int dx_4 \frac{\partial}{\partial x_4 \left( \int \mathfrak{X}_{\mu\nu 4} \int dx_1 dx_2 dx_3 \right)} \\
-\int \frac{\longrightarrow}{\mathfrak{K}_{\mu\nu 4}} dx_4 &= |\mathfrak{X}_{\mu\nu 4}| \left\| \mathfrak{G}_{x^{\dagger 4}}^{\dagger 4} \right\| \frac{\longrightarrow}{\mathfrak{K}_{\mu\nu 4}} = \frac{d\mathfrak{X}_{\mu\nu 4}}{dx_4} \int \frac{i}{c} \varphi \dot{f}_x g_x \eta
\end{aligned}$$

## 17. Ecuaciones einsteinianas de campo.

$$\begin{aligned}
\sum_{\mu\nu} \partial / \partial \mathcal{X}_{\mu\nu} \left( \sqrt{-g} \gamma_{\sigma\mu} \mathcal{T}_{\mu\nu} \right) &= \frac{1}{2 \sum_{\mu\nu} \sqrt{-g} \cdot \partial \gamma_{\mu\nu}} = \frac{1}{2 \sum_{\mu\nu} \frac{\partial}{\partial \mathcal{X}_{\mu\nu}} \left( \sqrt{-g} g_{\sigma\mu} \Theta_{\mu\nu} \right)} \\
&= 1/2 \sum_{\mu\nu} \sqrt{-g} \cdot \partial g_{\mu\nu} / \partial \mathcal{X}_{\sigma} \cdot \Theta_{\mu\nu} \\
-2x t_{\sigma\gamma} &= \sqrt{-g} \left( \frac{\sum_{\rho\varrho\tau} \gamma_{\beta\mu\nu} \partial g_{\varrho\tau}}{\partial \mathcal{X}_{\sigma}} \partial \gamma_{\varrho\tau} - 1/2 \sum_{\alpha\rho\varrho\tau} \frac{\delta_{\sigma\mu\nu} \gamma_{\alpha\tau} \partial g_{\varrho\tau}}{\partial \mathcal{X}_{\alpha}} \partial \gamma_{\varrho\tau} \right)
\end{aligned}$$

### 17.1. Variable hamiltoniana.

$$\begin{aligned}
\int (\delta \mathcal{H} - 2x \sum_{\mu\nu} \sqrt{-g} \mathcal{T}_{\mu\nu} \delta \gamma_{\mu\nu}) d\tau &= 0 \\
\mathcal{H} &= \frac{1}{2\sqrt{-g} \sum_{\alpha\beta\rho\varrho\sigma} \gamma_{\zeta\omega\sigma} \partial g_{\alpha\beta\rho\varrho\sigma}} \partial \mathcal{X}_{\zeta\omega\sigma} \\
\delta(\sqrt{-g}) &= -\frac{1}{2 \sum_{\mu\nu} -g g_{\mu\nu} \delta \gamma_{\mu\nu}}
\end{aligned}$$



$$\delta\left(\frac{\partial g_{\mu\nu}}{\partial X_{\mu\nu}}\right) = \frac{\partial}{\partial X_{\alpha}}(\delta g_{\mu\nu}) = -\sum_{\mu\nu} \partial/\partial X_{\alpha}(g_{\mu\nu}\delta\gamma_{\mu\nu})\delta(\partial\gamma_{\mu\nu}/\partial X_{\mu\nu}) = \partial/\partial X_{\alpha}(\delta\gamma_{\mu\nu})$$

$$\int \delta\mathcal{H}d\tau = \sum_{\mu\nu} \left(-\frac{\partial}{\partial X_{\alpha}}\left(\frac{\sqrt{-g}\gamma_{\mu\nu}\partial g_{\mu\nu}}{\partial X_{\beta}}\right) + \sqrt{-\frac{g\gamma_{\mu\nu}g\gamma_{\nu\mu}\partial g_{\mu\nu}}{\partial X_{\beta} \mu\nu\nu\mu}} + \frac{1}{2\sqrt{-g\cdot\frac{\partial g_{\mu\nu}}{\partial X_{\alpha}}\frac{\partial g_{\mu\nu}}{\partial X_{\beta}}}}\right. \\ \left.- 1/4g_{\mu\nu}\gamma_{\nu\mu}\frac{\partial g_{\mu\nu}}{\partial X_{\alpha}}\frac{\partial g_{\mu\nu}}{\partial X_{\beta}}\right)\delta\gamma_{\mu\nu}\cdot dt$$

### 17.2. Sistema de Coordenadas.

$$\mathcal{J}' = \int \sqrt{-g} \sum_{\substack{\mu\nu \\ \nu\mu \\ \alpha\beta\gamma\delta \\ \varepsilon\zeta\eta \\ \rho\varrho\sigma\varsigma}} \pi_{\mu\nu} \pi_{\nu\mu} \gamma_{\mu\nu} \gamma_{\nu\mu} \mathfrak{P}_{\mu\nu} \mathfrak{P}_{\nu\mu} \partial/\partial X_{\mu\nu} (\pi_{\mu\nu} \pi_{\nu\mu} \gamma_{\mu\nu} \gamma_{\nu\mu} \mathfrak{P}_{\mu\nu} \mathfrak{P}_{\nu\mu}) \mathfrak{P}_{\mu\nu} \mathfrak{P}_{\nu\mu} \partial/\partial X_{\nu\mu} dt$$

$$\rho_{\mu\nu} \int -4 \int +4 \int \sum_{\mu\nu} \int \alpha\beta\gamma\delta\varepsilon\zeta\eta\theta\iota\kappa\lambda\xi\omicron\pi\rho\varrho\sigma\tau\upsilon\phi\psi\omega = \frac{\partial X_{\mu\nu}}{\partial X_{\nu\mu}} = \delta\gamma_{\mu\nu} - \frac{\partial(\Delta X_{\mu\nu})}{\partial X_{\mu\nu}} \\ = \delta\gamma_{\nu\mu} - \frac{\partial(\Delta X_{\nu\mu})}{\partial X_{\nu\mu}} \cdot d\tau - \frac{\partial^2(\Delta X_{\mu\nu})}{\partial X_{\nu\mu}}$$

### 17.3. Formalización de las ecuaciones einsteinianas de campo.

$$\delta \left| \int ds = 0 \right|$$

$$ds^2 = \sum_{\mu\nu} dx_{\mu\nu}^2$$

$$ds^2 = \sum_{\mu\nu} g_{\mu\nu} dx_{\mu} dx_{\nu}$$

$$ds^2 = \sum_{\mu\nu} g_{\mu\nu} dx_{\mu} dx_{\nu} = -\sum_{\mu\nu} dx_{\mu\nu}^2$$

$$\sum_{\mu\nu} \mathfrak{A}_{\mu\nu} dx_{\mu\nu} = \phi$$

$$\sum_{\mu\nu} \mathfrak{A}'_{\mu\nu} dx'_{\mu\nu} = \sum_{\alpha} \mathfrak{A}'_{\alpha} dx'_{\alpha} = \sum_{\alpha\mu\nu} \frac{\mathfrak{A}'_{\alpha\mu\nu} \cdot \partial x'_{\alpha}}{\partial x'_{\mu\nu}} \cdot dx_{\mu\nu} = \phi$$

$$\sum_{\mu\nu} A_{\mu\nu} d\mu^{(1)} d\nu^{(2)} = \Phi$$

$$\sum_{\mu\nu} A'_{\mu\nu} d\mu^{(1)'} d\nu^{(2)'} = \sum_{\mu\nu} A_{\alpha\beta} d\alpha^{(1)} d\beta^{(2)} = \frac{\sum_{\mu\nu\alpha\beta} \partial x_{\alpha}}{\partial x'_{\mu}} \cdot \partial x_{\beta} / \partial x'_{\nu} A_{\alpha\beta} d\mu^{(1)'} d\nu^{(2)'}$$

$$\sum_{\mu\nu} A'_{\mu\nu} d\mu' d\nu' = \sum_{\mu\nu} A_{\alpha\beta} d\alpha^{\beta} d\beta^{\alpha} = \frac{\sum_{\mu\nu\alpha\beta} \partial x_{\alpha}}{\partial x'_{\mu}} \cdot \partial x_{\beta} / \partial x'_{\nu} A_{\alpha\beta} d\mu' d\nu'$$



$$\begin{aligned}
A'_{\mu\nu} &= A'_{\mu} B'_{\nu} = \frac{\sum_{\alpha\beta} \frac{\partial x_{\alpha}}{\partial x'_{\mu}} \partial x_{\beta}}{\partial x'_{\nu}} A'_{\alpha} B'_{\beta} = \sum_{\alpha\beta} \frac{\partial x_{\alpha}}{\partial x'_{\mu}} \cdot \frac{\partial x_{\beta}}{\partial x'_{\nu}} \cdot A_{\alpha\beta} A^{\alpha\beta} \\
&\sum_{\substack{\alpha\beta\gamma\rho\sigma \\ \varsigma\tau\mu\nu}} \left\| A_{\varsigma\tau\mu\nu}^{\alpha\beta\gamma\rho\sigma} B_{\varsigma\tau\mu\nu}^{\alpha\beta\gamma\rho\sigma} \right\| = \Gamma_{\varsigma\tau\mu\nu}^{\alpha\beta\gamma\rho\sigma} \\
&\left| \sum_{\alpha\beta\mu\nu} g_{\mu\nu} g_{\alpha\beta} g^{\mu\nu\alpha\beta} \right| \cdot \left\| d\xi_{\mu\nu} d\xi_{\alpha\beta} d\xi^{\mu\nu\alpha\beta} \right\| \cdot \langle \delta_{\mu\nu} \delta_{\alpha\beta} \delta^{\nu\alpha\beta} \rangle = 1 \\
|g_{\mu\nu}| &= \left| \sum_{\sigma} (\alpha_{\sigma\mu} \alpha_{\sigma\nu}) \right| = (\alpha_{\mu\nu\sigma})^2 - \sqrt{g \delta_{\varepsilon\zeta\theta\iota\kappa} d\tau} \cdot \frac{d\tau_0}{\sum_{\alpha\beta\lambda\mu} C_{\alpha\beta\lambda\mu}} \cdot g^{\mu\nu} g^{\rho\sigma} g^{\sigma\zeta} \\
&= C_{\mu\nu\rho\sigma\varsigma} \cdot \sqrt{gV} / d\mathbf{x}_{\sigma\varsigma\tau\rho}^{\eta\mu\nu\lambda\kappa} \\
C_{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa} &_{\mu\nu\rho\sigma\varsigma} \\
&= \sum_{\substack{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa \\ \mu\nu\rho\sigma\varsigma}} \sqrt{g \delta_{\mu\nu\rho\sigma\varsigma} g^{\mu\nu\rho\sigma\varsigma} g^{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa}} \\
&= \sum_{\substack{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa \\ \mu\nu\rho\sigma\varsigma}} 1 / \sqrt{g \delta_{\mu\nu\rho\sigma\varsigma} g^{\mu\nu\rho\sigma\varsigma} g^{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa}} = \Gamma_{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa}^{\mu\nu\rho\sigma\varsigma} \\
\Gamma_{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa}^{\mu\nu\rho\sigma\varsigma} &= \sum_{\substack{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa \\ \mu\nu\rho\sigma\varsigma}} \Gamma_{\mu\nu\rho\sigma\varsigma}^{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa} g^{\mu\nu\rho\sigma\varsigma} g^{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa} \\
F^{\mu\nu} &= \frac{1}{2\hbar \sum_{\alpha\beta} \mathfrak{G}_{\alpha\beta}^{\mu\nu} F^{\alpha\beta}} = \frac{1}{2 \sum_{\mu\nu\alpha\beta} \mathfrak{G}_{\alpha\beta}^{\mu\nu} F^{\mu\nu}} \\
&= \frac{1}{4\omega\psi\phi \sum_{\alpha\beta\mu\nu} \mathfrak{G}_{\alpha\beta\sigma}^{\mu\nu\lambda} \mathfrak{G}_{\kappa\lambda\xi\rho\sigma\varrho}^{\delta\epsilon\zeta\tau\omega}} \\
&\frac{\sum_{\mu\nu} \mathfrak{G}_{\alpha\beta\sigma}^{\mu\nu\lambda} \mathfrak{G}_{\kappa\lambda\xi\rho\sigma\varrho}^{\delta\epsilon\zeta\tau\omega}}{\sqrt{g \delta_{\mu\nu\rho\sigma\varsigma} g^{\mu\nu\rho\sigma\varsigma} g^{\alpha\beta\gamma\epsilon\zeta\theta\iota\kappa}} \cdot 1} \\
&= 2(\delta^{\mu\nu\lambda} \delta_{\alpha\beta\hbar\sigma\tau} - \delta^{\alpha\beta\hbar} \delta_{\mu\nu\lambda\sigma\tau}) \\
\delta\omega &= 1/\omega \left\| \frac{1}{2 \sum_{\mu\nu\sigma} \frac{\partial g_{\mu\nu}}{\partial x_{\sigma}} \cdot dx_{\mu\nu}} \cdot \frac{dx_{\alpha\beta}}{d\lambda} + \sum_{\mu\nu} g_{\mu\nu} \cdot \frac{dx_{\mu\nu}}{d\lambda} \delta \left( \frac{dx_{\nu\mu}}{d\lambda} \right) \right\| \\
&\frac{\sum_{\mu\nu} g_{\mu\nu\sigma} \cdot d^2 x_{\mu\nu}}{ds^2} + \frac{\sum_{\mu\nu} \frac{\mu\nu}{\sigma} dx_{\mu\nu}}{ds} \cdot \frac{dx_{\alpha\beta\sigma}}{ds} \\
\frac{\mu\nu}{\sigma} &= 1/2 \left( \frac{\partial x_{\mu\sigma}}{\partial x_{\mu\nu}} + \frac{\partial x_{\nu\sigma}}{\partial x_{\mu\nu}} - \frac{\partial g_{\mu\nu\sigma}}{\partial x_{\sigma}} - \frac{\partial g_{\mu\nu\tau}}{\partial x_{\tau\sigma}} \right) = \partial\phi \int \mathfrak{I}\psi\phi d\omega \cdot d\phi \\
\frac{d^2\phi}{ds^2} &= \frac{\sum_{\mu\nu} \frac{\partial^2\phi}{\partial x_{\mu} \partial x_{\nu}} \cdot dx_{\mu}}{ds} \cdot \frac{dx_{\nu}}{ds} + \frac{\sum_{\tau} \partial\phi}{\partial\chi_{\tau}} \cdot d^2\chi_{\tau}/ds^2 \\
\frac{d^2\phi}{ds^2} &= \sum_{\mu\nu} \left( \frac{\partial^2\phi}{\partial x_{\mu} \partial x_{\nu}} - \sum_{\tau} \frac{\mu\nu}{\tau} \partial\phi/\partial\chi_{\tau} \right) \cdot dx_{\mu}/ds \cdot \frac{dx_{\nu}}{ds}
\end{aligned}$$

$$\begin{aligned} & \frac{\partial}{\partial \mathbf{x}_\nu} \left( \psi \cdot \frac{\partial \phi}{\partial \mathbf{x}_\mu} \right) - \sum_\tau \frac{\mu\nu}{\tau} \left( \psi \cdot \frac{\partial \phi}{\partial \mathbf{x}_\tau} \right) \\ & \frac{1}{\mathcal{G}} \cdot \frac{\partial \mathcal{G}}{\partial \mathbf{x}_\alpha} = \sum_{\mu\nu} \frac{\partial g_{\mu\nu}}{\partial \mathbf{x}_\alpha} - g^{\mu\nu} = \frac{2}{\sqrt{\mathcal{G}}} \cdot \frac{\partial \sqrt{\mathcal{G}}}{\partial \mathbf{x}_\alpha} \\ & \sum_\tau \frac{\mu\nu}{\tau} = \sum_\tau \frac{\tau}{\mu\nu} = \frac{1}{2} \sum_{\tau\alpha} g^{\tau\alpha} \frac{\partial g_{\tau\alpha}}{\partial \mathbf{x}_{\mu\nu}} = \frac{1}{\sqrt{\mathcal{G}}} \cdot \frac{\partial \sqrt{\mathcal{G}}}{\partial \mathbf{x}_\mu} \\ A_\sigma &= \frac{1}{\sqrt{\mathcal{G}}} \left( \sum_{\mu\nu} g_{\mu\nu\sigma} \cdot \frac{\partial (A_{\mu\nu} \sqrt{\mathcal{G}})}{\partial \mathbf{x}_\nu} + \sqrt{\mathcal{G}} \sum_{\tau\mu\nu} \frac{\tau\nu}{\sigma} A^{\tau\nu} \right) \\ &= 1/\sqrt{\mathcal{G}} \left( \sum_{\mu\nu} \partial \left( \frac{g_{\mu\nu\sigma} A^{\mu\nu} \sqrt{\mathcal{G}}}{\partial \mathbf{x}_\nu} + \frac{1}{2\sqrt{\mathcal{G}}} \sum_{\mu\nu} \left( \frac{\partial g_{\mu\nu\sigma}}{\partial \mathbf{x}_\mu} + \frac{\partial g_{\nu\mu\sigma}}{\partial \mathbf{x}_\nu} - \frac{\partial g_{\mu\nu}}{\partial \mathbf{x}_\sigma} \right) A^{\mu\nu} \right) \right) \\ A_\sigma &= \frac{1}{\sqrt{\mathcal{G}}} \left( \sum_{\mu\nu} g_{\mu\nu\sigma} \cdot \frac{\partial (A_{\mu\nu} \sqrt{\mathcal{G}})}{\partial \mathbf{x}_\nu} - \sqrt{\mathcal{G}} \sum_{\tau\mu\nu} \frac{\tau\nu}{\sigma} A^{\tau\nu} \right) \\ &= 1/\sqrt{\mathcal{G}} \left( \sum_{\mu\nu} \partial \left( \frac{g_{\mu\nu\sigma} A^{\mu\nu} \sqrt{\mathcal{G}}}{\partial \mathbf{x}_\nu} - \frac{1}{2\sqrt{\mathcal{G}}} \sum_{\mu\nu} \left( \frac{\partial g_{\mu\nu\sigma}}{\partial \mathbf{x}_\mu} + \frac{\partial g_{\nu\mu\sigma}}{\partial \mathbf{x}_\nu} - \frac{\partial g_{\mu\nu}}{\partial \mathbf{x}_\sigma} \right) A^{\mu\nu} \right) \right) \\ A_{\mu\nu\lambda} &= \frac{\partial^2 A_\mu}{\partial \mathbf{x}_\mu \partial \mathbf{x}_\lambda} - \frac{\sum_\tau \frac{\mu\lambda}{\tau} \partial A_\tau}{\partial \mathbf{x}_\nu} + \frac{\mu\nu}{\tau} \frac{\partial A_\tau}{\partial \mathbf{x}_\lambda} - \sum_\tau \frac{\nu\lambda}{\tau} \frac{\partial A_\mu}{\partial \mathbf{x}_\tau} + \sum_{\sigma\tau} \frac{\nu\lambda\tau\mu}{\tau\sigma} \frac{\partial A_\sigma}{\partial \mathbf{x}_{\sigma\tau\lambda\nu}} - \sum_\sigma \frac{\mu\nu}{\sigma} \frac{\partial}{\partial \mathbf{x}_\lambda} - \sum_\tau \frac{\mu\lambda\nu\tau}{\tau\sigma} \frac{\partial A_\sigma}{\partial \mathbf{x}_{\sigma\tau\lambda\nu}} \\ \mathfrak{E}_\sigma &= \sum_{\mu\nu} \frac{\partial \mathfrak{E}_\sigma^{\mu\nu}}{\partial \mathbf{x}_\mu} - \frac{1}{2 \sum_{\mu\tau\nu} g^{\tau\mu} \partial g_{\mu\nu}} \mathfrak{E}_\sigma^{\mu\nu} \\ \sum_{\mu\nu} \partial \mathfrak{S}_{\lambda\sigma}^{\mu\nu} / \partial \mathfrak{S}_\mu &= \frac{1}{2\hbar \sum_{\mu\tau\nu} g^{\tau\mu} \partial g_{\mu\nu}} \cdot \mathfrak{S}_{\lambda\sigma}^{\mu\nu} + \mathfrak{R}_{\lambda\sigma} \\ & \begin{matrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{matrix} \\ \sum_{\mu\nu} \partial (\mathfrak{S}_{\lambda\sigma}^{\mu\nu} + \mathfrak{t}_{\lambda\sigma}^{\mu\nu}) & \frac{\partial \mathfrak{x}_\lambda}{\mathbb{R}_{\alpha\beta\gamma\delta\epsilon\zeta\eta\kappa\lambda\mu\nu\xi}} = 0 \\ \Gamma^\Lambda &= \int \frac{\tau\nu\sigma}{d\omega^2} \left( \frac{1}{2dl^2} \triangleq \frac{\sum_{\mu\nu} \mathcal{G} \Delta^{\mu\nu} \partial g_{\mu\nu}}{\partial \mathbf{x}_\sigma} \cdot d\tau^2 / ds^2 \right) \end{aligned}$$

$$\begin{aligned} ds^2 &= \sum_{\mu\nu} \int g_{\mu\nu} d\chi_\mu d\chi_\nu = -d\xi_1^2 - d\xi_2^2 - d\xi_3^2 - d\xi_\eta^2 / \sqrt{-g} \\ \frac{d}{d\chi_4} &= \left( m \sum_{\mu\nu} g_{\mu\nu\sigma} \cdot \frac{d\chi_\mu}{ds} \right) = \sum_{\nu\tau} \Gamma_{\nu\sigma}^\tau \cdot \frac{d\chi_\nu}{d\chi_4} m \sum_{\mu\nu} g_{\tau\nu} \cdot \frac{d\chi_\mu}{ds} + \int d\nabla \mathfrak{R}_{\lambda\sigma} dv \end{aligned}$$



$$-\delta_{\sigma\lambda}^{\mu\nu}\sqrt{-g}\cdot\frac{\partial\rho}{\partial\chi_\sigma}+\frac{\rho}{\rho_{0\text{med}}}+\mathfrak{T}_{\lambda\sigma}^{\mu\nu}+\sum_{\mu\nu}\frac{\partial}{\partial\chi_\nu}\left(\rho^*g_{\dagger\sigma\nu}\cdot\frac{d\chi_\omega}{ds}\cdot\frac{d\chi_\psi}{ds}\right)$$

$$=\frac{1}{2\sum_{\mu\nu}\rho^*\partial g_{\mu\nu\sigma}}\partial\chi_\sigma\frac{d\chi_\omega}{ds}\cdot\frac{d\chi_\psi}{ds}+\mathfrak{R}_{\lambda\sigma}=1$$

$$\sum_{\mu\nu}\partial(\mathfrak{T}_{\lambda\sigma}^{\mu\nu}-\mathfrak{B}_\epsilon^{\mu\nu})/\partial\chi_\sigma=\rho_\epsilon\cdot d\chi_\mu/ds+\mathfrak{T}^{\mu\nu}$$

$$\sum_{\mu\nu}\partial(\mathfrak{T}_{\lambda\sigma}^{\mu\nu\dagger}-\mathfrak{B}_{(m)}^{\mu\nu*})/\partial\chi_\sigma=\rho_{(m)}\cdot d\chi_\mu/ds+\mathfrak{T}^{\mu\nu}$$

$$\left(\mathfrak{B}_\epsilon^{\mu\nu}=\sigma_\epsilon\sum_{\alpha\beta}\mathfrak{B}_{\epsilon\dagger}^{\mu\nu*}=\mathfrak{B}_\epsilon^{\mu\nu}\sum_{\alpha\beta}\mathfrak{B}_\epsilon^{\mu\nu*}\frac{g_{\alpha\beta}\mathfrak{F}^{\mu\nu}d\chi_{\mu\nu}}{e^{-i\omega t}}\right)\left(\mathfrak{B}_{(m)}^{\mu\nu}=\sigma_{(m)}\sum_{\alpha\beta}\mathfrak{B}_{(m)\dagger}^{\mu\nu*}=\mathfrak{B}_{(m)}^{\mu\nu}\sum_{\alpha\beta}\mathfrak{B}_{(m)}^{\mu\nu*}\frac{g_{\alpha\beta}\mathfrak{F}^{\mu\nu}d\chi_{\mu\nu}}{e^{-i\omega t}}\right)\left(\mathfrak{Q}^{\mu\nu}=-\lambda\sum_{\alpha\beta}g_{\alpha\beta}\mathfrak{F}^{\mu\nu\sigma\lambda}\cdot\frac{d\chi_\beta}{ds}\right)$$

$$\Delta\mathfrak{G}_\sigma^{\mu\nu}=\sum_\alpha\frac{\partial}{\partial\chi_\sigma}\left(\mathfrak{G}^{\mu\sigma}\cdot\frac{\partial\Delta\chi_\mu}{\partial\chi_\alpha}+\mathfrak{G}^{\nu\sigma}\cdot\frac{\partial\Delta\chi_\nu}{\partial\chi_\alpha}\right)-\frac{\partial\mathfrak{G}^{\mu\nu}}{\partial\chi_\alpha}\frac{\partial\Delta\chi_\alpha}{\partial\chi_\sigma}$$

$$-\frac{1}{2\Delta\mathcal{H}}\sum_{\mu\nu\sigma\alpha}\frac{\mathfrak{G}_{\mu\nu}^{\sigma\tau}}{\partial^2}\Delta\mathfrak{G}_\sigma^{\mu\nu}\int d\tau\cdot\partial\mathcal{H}\sqrt{-g}\cdot\partial^2\Delta\chi_\nu$$

$$\mathfrak{F}=\int d\tau\sum_{\mu\nu\alpha\sigma}\frac{\partial^2}{\partial\mathfrak{f}_\alpha}\partial\chi_\sigma\left(\frac{g^{\nu\alpha}\partial\mathcal{H}\sqrt{-g}}{\partial\mathfrak{G}_\sigma^{\mu\nu}}\partial\Delta\chi_{\mu\nu}-\frac{\partial}{\partial\chi_\tau}\left(\frac{g^{\nu\sigma}\partial\mathcal{H}\sqrt{-g}}{\partial\mathfrak{G}_\alpha^{\mu\nu}}\right)\Delta\chi_\tau\right)$$

$$\mathfrak{d}\mathfrak{S}=\delta\left(\int\mathcal{H}\sqrt{-g}d\tau\right)=\frac{\int d\tau\sum_{\mu\nu\sigma}(\partial\mathcal{H}\sqrt{-g})}{\partial\mathfrak{G}^{\mu\nu}}\delta\mathfrak{G}^{\mu\nu}+\partial(\mathcal{H}\sqrt{-g})/\partial\mathfrak{G}_\sigma^{\mu\nu}\delta\mathfrak{G}_\sigma^{\mu\nu}$$

$$\mathfrak{G}_{\mu\nu}=\frac{\partial\mathcal{H}\sqrt{-g}}{\partial\mathfrak{G}^{\mu\nu}}-\sum_{\mu\nu\sigma}\frac{\partial^2}{\partial\chi_\sigma}\left(\frac{\partial\mathcal{H}\sqrt{-g}S_{\sigma\tau}^{\mu\nu}}{\partial\mathfrak{G}_{\sigma\tau}^{\mu\nu}}-\frac{\partial\mathcal{H}\sqrt{-g}}{\partial\mathfrak{G}_{\alpha\beta}^{\mu\nu}}-\frac{\partial\mathcal{H}\sqrt{-g}}{\partial\mathfrak{G}^\kappa}\right)$$

$$S_\sigma^{\mu\nu}=\frac{\partial}{\partial\chi_\nu}\left(\mathfrak{G}^{\nu\tau}\mathfrak{G}_{\sigma\tau}\right)+\frac{1}{2\sum_{\mu\nu}\partial\mathfrak{G}^{\mu\nu}}\cdot\mathfrak{G}_{\mu\nu}$$

$$=\frac{\sum_{\mu\nu\tau}(g^{\nu\tau}\cdot\partial\mathcal{H}\sqrt{-g})}{\partial\mathfrak{G}_{\sigma\tau}^{\mu\nu}}+g_{\sigma\tau}^{\mu\nu}\cdot\frac{\partial\mathcal{H}\sqrt{-g}}{\partial\mathfrak{G}_{\mu\nu}^{\sigma\tau}}+g_{\alpha\beta}^{\mu\nu}\cdot\frac{\partial\mathcal{H}\sqrt{-g}}{\partial\mathfrak{G}_{\mu\nu}^{\alpha\beta}}+\frac{1}{2S_{\sigma\tau}^{\mu\nu}\mathcal{H}\sqrt{-g}}$$

$$-\frac{1}{4g_{\sigma\tau}^{\mu\nu}}\cdot\frac{\partial\mathcal{H}\sqrt{-g}}{dg^{\mu\nu}}\cdot\mathfrak{G}_{\rho\alpha\beta}^{\mu\nu}-\frac{\partial g_\kappa}{\partial\chi_\rho}\cdot\frac{1}{\sigma\mathfrak{Q}^\kappa_{\sigma\tau\rho\alpha\beta\gamma\delta\epsilon\zeta\eta\theta\iota\lambda\mu\nu\xi}}-\frac{\sqrt{-g}}{4\kappa}+\frac{1}{2S_{\sigma\tau}^{\mu\nu}g_{\mu\nu}^{\sigma\tau}\Gamma_{\rho\omega}^{\alpha\beta}}$$

$$\boxplus\frac{\hbar_{\sigma\tau}^{\mu\nu}\cdot\kappa\rho_\sigma}{\rho\kappa}-\frac{1}{\partial\chi_\tau}$$

$$\begin{matrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{matrix}$$



**17.4. Ecuaciones relativistas aplicables a campos cuánticos curvos o con deformación geométrica.**

$$\mathfrak{G}_{ijkl} = \mathfrak{G}^{ijkl} = \frac{1}{2\sqrt{-g}} \cdot \delta_{ijkl}$$

$$\mathfrak{G}_{ijkl} = \mathfrak{G}^{ijkl} = \frac{1}{2\sqrt{-g'}} \cdot \delta_{ijkl}$$

$$\mathcal{A}^{\alpha_i \dots \alpha_j} = \frac{\sum_s \partial \mathcal{A}^{\alpha_i \dots \alpha_j^s}}{\partial \tau_s} + \sum_{s\bar{1}} \binom{\mathbb{Z}\bar{1}}{\lambda} \mathcal{A}^{\lambda_i \dots \alpha_j^{\bar{1}}}$$

$$\sum_{\tau\bar{1}} \binom{s\bar{1}}{\lambda} = \frac{1}{2\hbar \sum_{\alpha s} \mathfrak{g}^{\delta\alpha} \left( \frac{\partial \mathfrak{g}^{\alpha s}}{\partial \tau_\lambda} + \frac{\partial \mathfrak{g}^{\alpha \lambda}}{\partial \tau_s} - \frac{\partial \mathfrak{g}^{\alpha \delta}}{\partial \tau_\alpha} \right)} = \frac{1}{2 \sum_s \mathfrak{g}^{\alpha s}} \cdot \frac{\partial \mathfrak{g}^{\alpha s}}{\partial \tau_\lambda} = \partial \left( \frac{\ell \mathfrak{g}^{\alpha s}}{\partial \tau_s} \right)$$

$$\Phi = 1/\sqrt{-g} \sum_{\mu\nu} \partial/\partial \tau_{\mu\nu} (\sqrt{-g} A^{\mu\nu})$$

$$A_\sigma = \sum_{\mu\nu} \partial A_\sigma^{\mu\nu} / \partial \mathfrak{R}_{\mu\nu} - \frac{1}{2 \sum_{\mu\nu\tau} \mathfrak{g}^{\tau\mu\nu}} \cdot \frac{\partial \mathfrak{g}^{\mu\nu}}{\partial \mathfrak{R}_\sigma} \cdot A_\sigma^{\mu\nu}$$

$$(ik, lm) = \frac{1}{2} \left( \frac{\partial^2 \mathfrak{g}_{im}}{\partial \tau_{ik} \partial \tau_{lm}} + \frac{\partial^2 \mathfrak{g}_{ik}}{\partial \tau_{il} \partial \tau_{kl}} - \frac{\partial^2 \mathfrak{g}_{il}}{\partial \tau_{im} \partial \tau_{il}} - \frac{\partial^2 \mathfrak{g}_{kl}}{\partial \tau_{lm} \partial \tau_{kl}} \right) + \sum_{\rho\sigma} \mathfrak{g}^{\rho\sigma} \left( \left\| \begin{matrix} im \\ \rho \end{matrix} \right\| \left\| \begin{matrix} kl \\ \sigma \end{matrix} \right\| - \left\| \begin{matrix} il \\ \rho \end{matrix} \right\| \left\| \begin{matrix} km \\ \sigma \end{matrix} \right\| \right)$$

$$(ik, lm) = \sum_\rho \mathfrak{g}^{\kappa\rho} (i\rho, lm) = \frac{\partial \left\| \begin{matrix} il \\ \kappa \end{matrix} \right\|}{\partial \tau_m} - \frac{\partial \left\| \begin{matrix} im \\ \kappa \end{matrix} \right\|}{\partial \tau_i} + \sum_{\rho\sigma} \mathfrak{g}^{\rho\sigma} \left( \left\| \begin{matrix} im \\ \rho \end{matrix} \right\| \left\| \begin{matrix} kl \\ \sigma \end{matrix} \right\| - \left\| \begin{matrix} il \\ \rho \end{matrix} \right\| \left\| \begin{matrix} km \\ \sigma \end{matrix} \right\| \right)$$

$$\sum_{\mu\nu} \partial \Lambda_{\rho\sigma}^{\mu\nu} = \frac{1}{2 \sum_{\mu\nu\tau} \mathfrak{g}^{\mu\nu\tau}} \cdot \frac{\partial \mathfrak{g}^{\mu\nu}}{\partial \mathfrak{R}_\sigma} \Gamma_{\rho\sigma}^{\mu\nu} + K_\Lambda$$

$$\Gamma_{\rho\sigma}^{\mu\nu} = - \left\| \begin{matrix} \mu\nu \\ \sigma \end{matrix} \right\| = - \sum_\alpha \mathfrak{g}^{\sigma\alpha} \left\| \begin{matrix} \mu\nu \\ \alpha \end{matrix} \right\| = -1/2 \sum_\alpha \mathfrak{g}^{\sigma\alpha} \left( \frac{\partial \mathfrak{g}_{\mu\alpha}}{\partial \mathfrak{R}_{\mu\nu}} + \frac{\partial \mathfrak{g}_{\nu\alpha}}{\partial \mathfrak{R}_{\nu\mu}} - \frac{\partial \mathfrak{g}_{\mu\nu}}{\partial \mathfrak{R}_\alpha} \right)$$

$$\frac{\sum_\alpha \partial \Lambda_\sigma^\alpha}{\partial \mathfrak{R}_\alpha} = - \sum_{\alpha\beta} \Gamma_{\sigma\beta}^\alpha \Gamma_\alpha^\beta$$

$$\frac{d^2 \chi_\tau}{ds^2} = \sum_{\mu\nu} \Gamma_{\mu\nu}^\tau \cdot \frac{d\chi_\mu}{ds} \frac{d\chi_\nu}{ds}$$

$$\mathfrak{R}_{\mu\nu} = -\kappa \tau_{\mu\nu} = \frac{\sum_\alpha \partial \Gamma_{\mu\nu}^{\alpha\sigma}}{\partial \mathfrak{R}_\alpha} + \sum_{\alpha\beta} \Gamma_{\mu\beta}^\alpha \Gamma_{\nu\alpha}^\beta = -\kappa \tau_{\mu\nu}$$

$$\delta \left\| \int \mathfrak{G} - \kappa \sum_{\mu\nu} \mathfrak{g}^{\mu\nu} \tau_{\mu\nu} \right\| d\tau$$



$$\begin{aligned} \mathfrak{G} &= \sum_{\sigma\tau\alpha\beta} \mathfrak{g}^{\sigma\tau} \Gamma_{\sigma\beta}^{\alpha} \Gamma_{\tau\alpha}^{\beta} \\ \sum_{\alpha} \frac{\partial}{\partial \mathfrak{R}_{\alpha}} \left( \frac{\partial \mathfrak{G}}{\partial \mathfrak{g}^{\alpha\sigma}} \right) - \frac{\partial \mathfrak{G}}{\partial \mathfrak{g}^{\alpha\sigma}} &= -\kappa \gamma_{\mu\nu} \frac{\partial \mathfrak{G}}{\partial \mathfrak{g}^{\alpha\sigma}} = -\sum_{\alpha\beta} \Gamma_{\mu\beta}^{\alpha} \Gamma_{\nu\alpha}^{\beta} - \frac{\partial \mathfrak{G}}{\partial \mathfrak{g}^{\alpha\sigma}} = \Gamma_{\mu\nu}^{\alpha} \\ \sum_{\sigma\mu\nu} \frac{\partial}{\partial \mathfrak{R}_{\alpha}} \mathfrak{R}_{\alpha} \left( \mathfrak{g}^{\alpha\sigma} \cdot \frac{\partial \mathfrak{G}}{\partial \mathfrak{g}^{\mu\nu}} \right) - \frac{\partial \mathfrak{G}}{\partial \mathfrak{R}_{\sigma}} &= -\kappa \sum_{\mu\nu} \gamma_{\mu\nu} \mathfrak{g}^{\alpha\sigma} \\ \sum_{\lambda} \frac{\partial \gamma_{\sigma}^{\lambda}}{\partial \mathfrak{R}_{\lambda}} &= \frac{1}{2 \sum_{\mu\nu} \mathfrak{g}^{\mu\nu}} \\ \sum_{\lambda} \frac{\partial \gamma_{\sigma}^{\lambda}}{\partial \mathfrak{R}_{\lambda}} &= \sum_{\mu\nu} \Gamma_{\sigma\nu}^{\mu} \gamma_{\mu}^{\nu} \\ \sum_{\lambda} \frac{\partial}{\partial \mathfrak{R}_{\lambda}} (\gamma_{\sigma}^{\lambda} + t_{\sigma}^{\lambda}) \\ \kappa t_{\sigma}^{\lambda} &= \frac{1}{2} \delta_{\sigma}^{\lambda} \sum_{\mu\nu\alpha\beta} \mathfrak{g}^{\mu\nu} \Gamma_{\mu\beta}^{\alpha} \Gamma_{\nu\alpha}^{\beta} - \sum_{\mu\nu\alpha} \mathfrak{g}^{\mu\nu} \Gamma_{\mu\sigma}^{\alpha} \Gamma_{\nu\alpha}^{\lambda} \\ t_{\sigma}^{\lambda} &= \frac{1}{2\kappa \left( \mathfrak{G} \delta_{\sigma}^{\lambda} - \sum_{\mu\nu} \mathfrak{g}^{\mu\nu} \frac{\partial \mathfrak{G}}{\partial \mathfrak{g}^{\mu\nu}} \right)} \\ \gamma_{\sigma}^{\lambda} &= \frac{1}{2\delta_{\sigma}^{\lambda} \sum_{\mu\nu\alpha\beta} \mathfrak{g}^{\mu\nu} \Gamma_{\mu\beta}^{\alpha} \Gamma_{\nu\alpha}^{\beta}} - \sum_{\mu\nu\alpha} \mathfrak{g}^{\mu\nu} \Gamma_{\mu\sigma}^{\alpha} \Gamma_{\nu\alpha}^{\lambda} \\ \frac{\sum_{\alpha\beta} \partial^2 \mathfrak{g}^{\alpha\beta}}{\partial \mathfrak{R}_{\alpha} \partial \mathfrak{R}_{\beta}} - \sum_{\sigma\tau\alpha\beta} \mathfrak{g}^{\sigma\tau} \Gamma_{\sigma\beta}^{\alpha} \Gamma_{\tau\alpha}^{\beta} + \sum_{\alpha\beta} \frac{\partial}{\partial \mathfrak{R}_{\alpha}} (\mathfrak{g}^{\alpha\beta} \partial \lg \sqrt{-g} / \partial \mathfrak{R}_{\beta}) &= -\kappa \sum_{\sigma} \gamma_{\sigma}^{\rho} \\ \sum_{\alpha\nu} \frac{\partial}{\partial \mathfrak{R}_{\alpha}} (\mathfrak{g}^{\nu\lambda} \Gamma_{\mu\nu}^{\alpha}) - \sum_{\alpha\beta\nu} \mathfrak{g}^{\nu\beta} \Gamma_{\nu\mu}^{\alpha} \Gamma_{\beta\alpha}^{\lambda} &= -\kappa \gamma_{\mu\nu}^{\tau} \\ \sum_{\alpha\nu} \frac{\partial}{\partial \mathfrak{R}_{\alpha}} (\mathfrak{g}^{\nu\lambda} \Gamma_{\mu\nu}^{\alpha}) - 1/2 \delta_{\mu}^{\lambda} \sum_{\alpha\beta\mu\nu} \mathfrak{g}^{\mu\nu} \Gamma_{\mu\beta}^{\alpha} \Gamma_{\nu\alpha}^{\beta} &= -\kappa (\gamma_{\mu}^{\lambda} + t_{\mu}^{\lambda}) \\ \frac{\partial}{\partial \mathfrak{R}_{\mu\nu}} \left\| \sum_{\alpha\beta} \frac{\partial^2 \mathfrak{g}^{\alpha\beta}}{\partial \mathfrak{R}_{\alpha} \partial \mathfrak{R}_{\beta}} - \sum_{\sigma\tau\alpha\beta} \mathfrak{g}^{\sigma\tau} \Gamma_{\sigma\beta}^{\alpha} \Gamma_{\tau\alpha}^{\beta} \right\| &= \frac{\sum_{\alpha\beta} \partial}{\partial \mathfrak{R}_{\alpha}} \left( \mathfrak{g}^{\alpha\beta} \frac{\partial \lg \sqrt{-g}}{\partial \mathfrak{R}_{\beta}} \right) = -\kappa \sum_{\sigma} \gamma_{\sigma}^{\rho} \\ \gamma^{\mu\nu} &= \sqrt{-g} \rho_0 \cdot \frac{d\chi_{\mu}}{ds} \frac{d\chi_{\nu}}{ds} \\ \sum_{\mu} \gamma_{\nu}^{\mu} &= \sum_{\mu\nu} \mathfrak{g}_{\mu\nu} \gamma^{\mu\nu} = \rho_0 \sqrt{-g} \\ \mathfrak{G}_{im} &= \sum_l (il, lm) = \mathfrak{R}_{im} + \mathfrak{S}_{im} \\ \mathfrak{R}_{im} &= -\sum_l \frac{\partial \|il\|}{\partial \mathfrak{R}_l} + \sum_{\rho l} |il| |\rho m| \\ \mathfrak{R}_{im} &= \frac{\sum_l \partial \Gamma_{im}^l}{\partial \mathfrak{R}_l} + \sum_{\rho l} \Gamma_{i\rho}^l \Gamma_{ml}^{\rho} \end{aligned}$$



$$\mathfrak{R}_{im} = \sum_l \partial \Gamma_{im}^l / \partial \mathfrak{R}_l + \sum_{\rho l} \Gamma_{i\rho}^l \Gamma_{ml}^\rho = -\kappa \left( \gamma_{im} - \frac{1}{2g_{im}\mathfrak{S}} \right)$$

$$\mathfrak{S}_{im} = \sum_l \frac{\partial \left\| \frac{im}{l} \right\|}{\partial \mathfrak{R}_m} - \sum_{\rho l} \left| \frac{im}{\rho} \right| \left| \frac{\rho l}{l} \right|$$

$$\mathfrak{S}_{im} = -\kappa \left( \gamma_{im} - \frac{1}{2g_{im}\mathfrak{S}} \right)$$

$$\sum_{\rho\sigma} g^{\rho\sigma} \gamma_{\rho\sigma} = \sum_{\sigma} \gamma_{\sigma}^{\rho} = T$$

$$\mathfrak{G}_{\mu\nu} = -\kappa \gamma_{\mu\nu}$$

$$\mathfrak{R}_{\mu\nu} = -\kappa \gamma_{\mu\nu}$$

$$\sum_{\alpha\beta} \frac{\partial}{\partial \mathfrak{R}_\alpha} \left( \frac{g^{\alpha\beta} \partial l g \sqrt{-g}}{\partial \mathfrak{R}_\beta} \right) = -\kappa \sum_{\sigma} \gamma_{\sigma}^{\rho}$$

$$\frac{1}{2 \sum_{im} g_{im}} = \frac{\partial g^{im}}{\partial \mathfrak{R}_\sigma} = -\frac{\partial l g \sqrt{-g}}{\partial \mathfrak{R}_\sigma}$$

$$\partial / \partial \mathfrak{R}_{\mu\nu} \left[ \sum_{\alpha\beta} \frac{\partial^2 g^{\alpha\beta}}{\partial \mathfrak{R}_\alpha \partial \mathfrak{R}_\beta} - \kappa(\gamma + t) \right]$$

$$A'^{\sigma\tau} = \frac{\partial \mathfrak{R}'_\sigma}{\partial \mathfrak{R}_\mu} \frac{\partial \mathfrak{R}'_\tau}{\partial \mathfrak{R}_\nu} A^{\mu\nu} = \frac{\partial \mathfrak{R}'_\sigma}{\partial \mathfrak{R}_\mu} \frac{\partial \mathfrak{R}'_\tau}{\partial \mathfrak{R}_\nu} A^{\nu\mu} = \frac{\partial \mathfrak{R}'_\sigma}{\partial \mathfrak{R}_\nu} \frac{\partial \mathfrak{R}'_\tau}{\partial \mathfrak{R}_\mu} A^{\mu\nu} = A'^{\tau\sigma}$$

$$\mathfrak{G} = \left| \frac{\partial \mathfrak{R}_\mu}{\partial \mathfrak{R}'_\sigma} \right| \cdot \left| \frac{\partial \mathfrak{R}_\nu}{\partial \mathfrak{R}'_\tau} \right| \cdot |\mathfrak{G}_{\mu\nu}| = \left( \frac{\partial \mathfrak{R}_\mu}{\partial \mathfrak{R}'_\sigma} \right)^2 \mathfrak{G} \sqrt{-g'} = \left| \frac{\partial \mathfrak{R}_\mu}{\partial \mathfrak{R}'_\sigma} \right| \sqrt{-g}$$

$$d\tau' = \left| \frac{\partial \mathfrak{R}_\mu}{\partial \mathfrak{R}'_\sigma} \right| \cdot d\tau$$

$$\delta\omega = 1/\omega \left| \frac{\frac{1}{2} \frac{\partial g^{\mu\nu}}{\partial \mathfrak{R}_\sigma} d\chi_\mu}{\frac{d\lambda}{d\lambda} d\chi_\nu} \delta\chi_\sigma + \frac{g^{\mu\nu} d\chi_\mu}{d\lambda} \delta \left( \frac{d\chi_\nu}{d\lambda} \right) = \frac{d}{d\lambda} (\delta\chi_\nu) \right|$$

$$\kappa\omega = \frac{d}{d\lambda} \left( \frac{g^{\mu\nu} d\chi_\mu}{\omega} \frac{d\chi_\nu}{d\lambda} \right) - \frac{1}{2\omega} \frac{\partial g^{\mu\nu}}{\partial \mathfrak{R}_\sigma} \frac{d\chi_\mu}{d\lambda} \frac{d\chi_\nu}{d\lambda}$$

$$g^{\mu\nu} = \frac{d^2 \chi_\mu}{ds^2} + \frac{\partial g^{\mu\nu}}{\partial \mathfrak{R}_\sigma} \frac{d\chi_\sigma}{ds} \frac{d\chi_\mu}{ds} - \frac{1}{2} \frac{\partial g^{\mu\nu}}{\partial \mathfrak{R}_\sigma} \frac{d\chi_\mu}{ds} \frac{d\chi_\nu}{ds}$$

$$[\mu\nu, \sigma] = \frac{1}{2} \left( \frac{\partial g_{\mu\sigma}}{\partial \mathfrak{R}_\nu} + \frac{\partial g_{\nu\sigma}}{\partial \mathfrak{R}_\mu} - \frac{\partial g_{\mu\nu}}{\partial \mathfrak{R}_\sigma} \right)$$

$$\frac{d\phi}{ds} = \frac{\partial \phi}{\partial \mathfrak{R}_\mu} \frac{d\chi_\mu}{ds}$$

$$\psi = \frac{\frac{\partial \phi}{d\chi_\mu} \frac{d\chi_\mu}{ds}}{d\psi}$$

$$\chi = \frac{\partial^2 \phi}{\partial \mathfrak{R}_\mu \partial \mathfrak{R}_\nu} \frac{d\chi_\mu}{ds} \frac{d\chi_\nu}{ds} + \frac{\partial \phi}{\partial \mathfrak{R}_\mu} \frac{d^2 \chi_\mu}{ds^2} \left( \frac{\partial^2 \phi}{\partial \mathfrak{R}_\mu \partial \mathfrak{R}_\nu} - [\mu\nu, \sigma] \frac{\partial \phi}{\partial \mathfrak{R}_\tau} \right) \frac{d\chi_\mu}{ds} \frac{d\chi_\nu}{ds}$$

$$\psi \frac{\partial^2 \phi}{\partial \mathfrak{R}_\mu \partial \mathfrak{R}_\nu} - [\mu\nu, \tau] \psi \frac{\partial \phi}{\partial \mathfrak{R}_\tau}$$

$$\frac{\partial}{\partial \mathfrak{R}_\nu} \left( \psi \frac{\partial \phi}{\partial \mathfrak{R}_\mu} \right) - [\mu\nu, \tau] \left( \psi \frac{\partial \phi}{\partial \mathfrak{R}_\tau} \right)$$



$$\begin{aligned}
A_{\mu\nu\sigma} &= \frac{\partial A_{\mu\nu}}{\partial \mathfrak{R}_\sigma} - [\sigma\mu, \tau]A_{\tau\nu} - [\sigma\nu, \tau]A_{\mu\tau} \\
\frac{1}{\sqrt{-g}} \frac{\partial \sqrt{-g}}{\partial \mathfrak{R}_\sigma} &= \frac{1}{2} \frac{\partial \log(-g)}{\partial \mathfrak{R}_\sigma} = \frac{\frac{1}{2g^{\mu\nu}}}{\frac{\partial g^{\mu\nu}}{\partial \mathfrak{R}_\sigma}} = \frac{1}{2g^{\mu\nu}} \frac{\partial g^{\mu\nu}}{\partial \mathfrak{R}_\sigma} \\
&\left\{ \begin{aligned} g_{\mu\sigma} dg^{\nu\sigma} &= -g^{\nu\sigma} dg_{\mu\sigma} \\ \frac{g_{\mu\sigma} \partial g^{\nu\sigma}}{\partial \mathfrak{R}_\lambda} &= \frac{-g^{\nu\sigma} \partial g_{\mu\sigma}}{\partial \mathfrak{R}_\lambda} \end{aligned} \right\} \\
&\left\{ \begin{aligned} dg^{\mu\nu} &= -g^{\mu\alpha} g^{\nu\beta} dg_{\alpha\beta} \\ \frac{\partial g^{\mu\nu}}{\partial \mathfrak{R}_\sigma} &= \frac{-g^{\mu\alpha} g^{\nu\beta} \partial g_{\alpha\beta}}{\partial \mathfrak{R}_\sigma} \end{aligned} \right\} \\
\frac{\partial g_{\alpha\beta}}{\partial \mathfrak{R}_\sigma} &= [\alpha\sigma, \beta] + [\beta\sigma, \alpha] \\
\frac{\partial g^{\mu\nu}}{\partial \mathfrak{R}_\sigma} &= -g^{\mu\tau} [\tau\sigma, \nu] - g^{\nu\tau} [\tau\sigma, \mu] \\
\frac{1}{\sqrt{-g}} \frac{\partial \sqrt{-g}}{\partial \mathfrak{R}_\sigma} &= [\mu\sigma, \mu] \\
\frac{\partial}{\partial \mathfrak{R}_\nu} (g^{\mu\nu} A_{\mu\nu}) &- \frac{A_{\mu\nu} \partial g^{\mu\nu}}{\partial \mathfrak{R}_\nu} - \frac{1}{2} g^{\tau\alpha} \left( \frac{\partial g_{\mu\alpha}}{\partial \mathfrak{R}_\nu} + \frac{\partial g_{\nu\alpha}}{\partial \mathfrak{R}_\mu} - \frac{\partial g_{\mu\nu}}{\partial \mathfrak{R}_\alpha} \right) g^{\mu\nu} A_{\mu\nu} \\
&\frac{1}{2} \frac{\partial g^{\tau\nu}}{\partial \mathfrak{R}_\nu} A_\tau + \frac{1}{2 \partial g^{\tau\mu}} \frac{1}{\partial \mathfrak{R}_\mu} A_\tau + \frac{1}{\sqrt{-g}} \frac{\partial \sqrt{-g}}{\partial \mathfrak{R}_\sigma} g^{\mu\nu} A_\tau \\
\Phi &= \frac{\frac{1}{\sqrt{-g}} \partial}{\partial \mathfrak{R}_\nu (\sqrt{-g} A^{\mu\nu})} \\
\mathbb{B}_{\mu\nu\sigma} &= A_{\mu\nu\sigma} + A_{\nu\sigma\mu} + A_{\sigma\mu\nu} = \frac{\partial A_{\mu\nu}}{\partial \mathfrak{R}_\sigma} + \frac{\partial A_{\nu\sigma}}{\partial \mathfrak{R}_\mu} + \frac{\partial A_{\mu\sigma}}{\partial \mathfrak{R}_\nu} \\
\frac{\partial}{\partial \mathfrak{R}_\sigma} (g^{\mu\alpha} g^{\nu\beta} A_{\mu\nu}) &- \frac{g^{\mu\alpha} \partial g^{\nu\beta}}{\partial \mathfrak{R}_\sigma} A_{\mu\nu} - \frac{g^{\nu\beta} \partial g^{\mu\alpha}}{\partial \mathfrak{R}_\sigma} A_{\mu\nu} \\
\sqrt{-g} A_\mu &= \frac{\partial (\sqrt{-g} A_\mu^\sigma)}{\partial \mathfrak{R}_\sigma} - \frac{1}{2} \frac{\partial g_{\rho\sigma}}{\partial \mathfrak{R}_\mu} \sqrt{-g} A^{\rho\sigma} \\
\sqrt{-g} A_\mu &= \frac{\partial (\sqrt{-g} A_\mu^\sigma)}{\partial \mathfrak{R}_\sigma} + \frac{1}{2} \frac{\partial g^{\rho\sigma}}{\partial \mathfrak{R}_\mu} \sqrt{-g} A_{\rho\sigma} \\
A_{\mu\sigma\tau} &= \frac{\partial^2 A_\mu}{\partial \mathfrak{R}_\sigma \partial \mathfrak{R}_\tau} - \frac{[\mu\sigma, \rho] \partial A_\rho}{\partial \mathfrak{R}_\tau} - \frac{[\mu\tau, \rho] \partial A_\rho}{\partial \mathfrak{R}_\sigma} - \frac{[\sigma\tau, \rho] \partial A_\mu}{\partial \mathfrak{R}_\rho} \\
&+ \left[ \frac{\partial}{\partial \mathfrak{R}_\tau} [\mu\sigma, \rho] + [\mu\tau, \alpha] [\alpha\sigma, \rho] + [\sigma\tau, \alpha] [\sigma\mu, \rho] \right] A_\rho \\
\mathbb{B}_{\mu\sigma\tau}^\rho &= \frac{\partial}{\partial \mathfrak{R}_\tau} [\mu\sigma, \rho] + \frac{\partial}{\partial \mathfrak{R}_\sigma} [\mu\tau, \rho] - [\mu\sigma, \alpha] [\alpha\tau, \rho] + [\mu\tau, \alpha] [\alpha\sigma, \rho] \\
\mathcal{R}_{\mu\nu} &= -\frac{\partial}{\partial \mathfrak{R}_\alpha} [\mu\nu, \alpha] + [\mu\alpha, \beta] [\nu\beta, \alpha] \\
S_{\mu\nu} &= \partial^2 \log \frac{\sqrt{-g}}{\partial \mathfrak{R}_\mu \partial \mathfrak{R}_\nu} - \frac{[\mu\nu, \alpha] \partial \log \sqrt{-g}}{\partial \mathfrak{R}_\alpha} \\
\langle \delta \int \mathcal{H} &= \mathcal{H} d\tau = 0 \\
&= g^{\mu\nu} \Gamma_{\mu\beta}^\alpha \Gamma_{\nu\alpha}^\beta \sqrt{-g} = 1 \rangle \\
\delta \mathcal{H} &= \Gamma_{\mu\beta}^\alpha \Gamma_{\nu\alpha}^\beta \delta g^{\mu\nu} + 2g^{\mu\nu} \Gamma_{\mu\beta}^\alpha \Gamma_{\nu\alpha}^\beta = -\Gamma_{\mu\beta}^\alpha \Gamma_{\nu\alpha}^\beta + 2\Gamma_{\mu\beta}^\alpha \Gamma_{\nu\alpha}^\beta \delta (\Gamma_{\mu\beta}^\alpha \Gamma_{\nu\alpha}^\beta)
\end{aligned}$$

$$\begin{aligned}
\delta(\mathcal{G}^{\mu\nu}\Gamma_{\mu\beta}^\alpha\Gamma_{\nu\alpha}^\beta) &= \frac{1}{2}\delta\left(\mathcal{G}^{\mu\nu}\mathcal{G}^{\beta\lambda}\left(\frac{\partial\mathcal{G}_{\nu\lambda}}{\partial\mathfrak{R}_\alpha} + \frac{\partial\mathcal{G}_{\alpha\lambda}}{\partial\mathfrak{R}_\nu} + \frac{\partial\mathcal{G}_{\alpha\nu}}{\partial\mathfrak{R}_\lambda}\right)\right) \\
\delta\mathcal{H} &= -\Gamma_{\mu\beta}^\alpha\Gamma_{\nu\alpha}^\beta\delta\mathcal{G}^{\mu\nu} - \Gamma_{\mu\beta}^\alpha\Gamma_{\nu\alpha}^\beta\delta\mathcal{G}_\alpha^{\mu\beta} \\
&\quad \left\{ \begin{array}{l} \frac{\partial\mathcal{H}}{\partial\mathcal{G}^{\mu\nu}} = -\Gamma_{\mu\beta}^\alpha\Gamma_{\nu\alpha}^\beta \\ \frac{\partial\mathcal{H}}{\partial\mathcal{G}_\sigma^{\mu\nu}} = \Gamma_{\mu\nu}^\sigma \end{array} \right\} \\
\frac{\partial}{\partial\mathfrak{R}_\alpha}\left(\frac{\partial\mathcal{H}}{\partial\mathcal{G}_\alpha^{\mu\nu}}\right) - \frac{\partial\mathcal{H}}{\partial\mathcal{G}^{\mu\nu}} &= \mathcal{G}_\sigma^{\mu\nu}\frac{\partial}{\partial\mathfrak{R}_\alpha}\left(\frac{\partial\mathcal{H}}{\partial\mathcal{G}_\alpha^{\mu\nu}}\right) = \frac{\partial}{\partial\mathfrak{R}_\alpha}\left(\mathcal{G}_\sigma^{\mu\nu}\frac{\partial\mathcal{H}}{\partial\mathcal{G}_\alpha^{\mu\nu}}\right) - \frac{\partial\mathcal{H}}{\partial\mathcal{G}_\alpha^{\mu\nu}}\frac{\partial\mathcal{G}_\alpha^{\mu\nu}}{\partial\mathfrak{R}_\sigma} - 2\kappa t_\sigma^\alpha\frac{\partial\mathcal{H}}{\partial\mathcal{G}_\alpha^{\mu\nu}} - \delta_\sigma^\alpha\mathcal{H} \\
\kappa t_\sigma^\alpha &= \frac{1}{2\delta_\sigma^\alpha\mathcal{G}^{\mu\nu}\Gamma_{\mu\beta}^\lambda\Gamma_{\nu\lambda}^\beta} - \mathcal{G}^{\mu\nu}\Gamma_{\mu\beta}^\alpha\Gamma_{\nu\alpha}^\beta \\
\frac{\mathcal{G}^{\nu\sigma}\partial\Gamma_{\mu\nu}^\alpha}{\partial\mathfrak{R}_\alpha} &= \frac{\partial}{\partial\mathfrak{R}_\alpha}(\mathcal{G}^{\nu\sigma}\mathcal{G}^{\nu\beta}\partial\Gamma_{\mu\nu}^\alpha\Gamma_{\alpha\beta}^\sigma) - \frac{\partial\mathcal{G}^{\nu\sigma}\mathcal{G}^{\sigma\beta}}{\partial\mathfrak{R}_\alpha}\Gamma_{\mu\nu}^\alpha\Gamma_{\alpha\beta}^\sigma \\
\frac{\partial}{\partial\mathfrak{R}_\alpha}(\mathcal{G}^{\sigma\beta}\Gamma_{\mu\beta}^\alpha) &= -\kappa\left(t_\mu^\sigma - \frac{1}{2\delta_\mu^\sigma t}\right)\sqrt{-g} = 1 \\
\frac{\partial}{\partial\mathfrak{R}_\alpha}(\mathcal{G}^{\sigma\beta}\Gamma_{\mu\beta}^\alpha) &= -\kappa\left(\left(t_\mu^\sigma - \frac{1}{2\delta_\mu^\sigma t}\right) - \frac{1}{2}\delta_\mu^\sigma(t+\tau)\right)\sqrt{-g} = 1 \\
\frac{\partial}{\partial\mathfrak{R}_\alpha}\Gamma_{\mu\nu}^\alpha + \Gamma_{\mu\beta}^\alpha\Gamma_{\nu\alpha}^\beta &= -\kappa\left(\tau_{\mu\nu} - \frac{1}{2\mathcal{G}_{\mu\nu}\tau}\right)\sqrt{-g} = 1 \\
\frac{\partial}{\partial\mathfrak{R}_\alpha}\left(\mathcal{G}^{\sigma\beta}\Gamma_{\mu\beta}^\alpha - \frac{1}{2\delta_\mu^\sigma\mathcal{G}^{\lambda\beta}\Gamma_{\lambda\beta}^\alpha}\right) &= -\kappa(t_\mu^\sigma + \tau_\mu^\sigma) \\
\frac{\partial^2}{\partial\mathfrak{R}_\alpha\partial\mathfrak{R}_\sigma}(\mathcal{G}^\sigma\Gamma_{\beta\mu}^\alpha) &= -\frac{1}{2}\frac{\partial^2}{\partial\mathfrak{R}_\alpha\partial\mathfrak{R}_\sigma}\left(\mathcal{G}^{\sigma\beta}\mathcal{G}^{\alpha\lambda}\left(\frac{\partial\mathcal{G}_{\mu\lambda}}{\partial\mathfrak{R}_\beta} + \frac{\partial\mathcal{G}_{\beta\lambda}}{\partial\mathfrak{R}_\mu} + \frac{\partial\mathcal{G}_{\mu\beta}}{\partial\mathfrak{R}_\lambda}\right)\right) \\
\mathfrak{R}_{\mu\nu} + \mathfrak{S}_{\mu\nu} &= -\kappa\left(\tau_{\mu\nu} + \frac{1}{2\mathcal{G}_{\mu\nu}\tau}\right) \\
\mathfrak{R}_{\mu\nu} &= -\sum_\alpha\frac{\partial}{\partial\mathfrak{R}_\alpha}\left|\frac{\mu\nu}{\alpha}\right| + \sum_{\alpha\beta}\left|\frac{\mu\alpha}{\beta}\right|\left|\frac{\nu\beta}{\alpha}\right| \\
\mathfrak{S}_{\mu\nu} &= \frac{\partial^2\log\sqrt{g}}{\partial\mathfrak{R}_\mu\partial\mathfrak{R}_\nu} - \frac{\sum_\alpha\left|\frac{\mu\nu}{\alpha}\right|\partial\log\sqrt{g}}{\partial\mathfrak{R}_\alpha} \\
\sum_\alpha\frac{\partial^2\gamma_{\mu\omega}}{\partial\mathfrak{R}_\nu\partial\mathfrak{R}_\alpha} + \sum_\alpha\frac{\partial^2\gamma_{\nu\alpha}}{\partial\mathfrak{R}_\mu\partial\mathfrak{R}_\alpha}\partial\mathfrak{R}_\mu\partial\mathfrak{R}_\alpha - \sum_\alpha\frac{\partial^2\gamma_{\mu\nu}}{\partial\mathfrak{R}_\alpha^2} - \frac{\partial^2}{\partial\mathfrak{R}_\mu\partial\mathfrak{R}_\nu}\left(\sum_\alpha\gamma_{\alpha\alpha}\right) \\
&= -2\kappa\left(\tau_{\mu\nu} - \frac{1}{2\delta_{\mu\nu}\sum_\alpha\tau_{\alpha\alpha}} + \frac{2\partial^2\psi}{\partial\mathfrak{R}_\mu\partial\mathfrak{R}_\nu} - \delta_{\mu\nu}\sum_\alpha\frac{\partial^2\psi}{\partial\mathfrak{R}_\alpha^2} - 4\frac{\partial^2\psi}{\partial\mathfrak{R}_\mu\partial\mathfrak{R}_\nu} + \frac{\partial\mathcal{G}^{\rho\sigma}}{\partial\mathfrak{R}_\alpha}\right) \\
&\quad - \frac{\partial\sqrt{-g}\tau_\rho^\sigma}{\partial\mathfrak{R}_\mu\partial\mathfrak{R}_\nu} = \frac{\sum_{\alpha\beta\tau}\frac{\partial\gamma_{\alpha\beta}^\dagger}{\partial\mathfrak{R}_\Lambda d\tau}}{\partial\mathfrak{R}_\mu\partial\mathfrak{R}_\nu} - \frac{\partial^2\Delta\mathfrak{R}_\Lambda}{\sqrt{-g}\Delta} - \int\frac{1}{2}\delta\mathfrak{R}^* - \int-\frac{1}{4}\otimes\mathcal{G}_{\alpha\beta}^{\mu\nu}\cdot\delta\Delta\mathcal{G}^{\mu\nu}
\end{aligned}$$



**17.5. Perturbaciones de los campos cuánticos curvos por el movimiento acelerado de partículas masivas (ondas a escala cuántica).**

$$g_{\mu\nu} = -\delta_{\mu\nu} + \gamma_{\mu\nu}$$

$$-\sum_{\alpha} \frac{\partial}{\partial \chi_{\alpha}} \frac{\mu\nu}{\alpha} + \sum_{\alpha} \frac{\partial}{\partial \chi_{\nu}} \frac{\mu\alpha}{\alpha} + \sum_{\alpha\beta} \frac{\mu\alpha}{\beta} \frac{\nu\beta}{\alpha} - \sum_{\alpha\beta} \frac{\mu\nu}{\alpha} \frac{\alpha\beta}{\beta} = -\kappa \left( \mathfrak{T}_{\mu\nu} - \frac{1}{2g_{\mu\nu}} \mathfrak{T} \right)$$

$$\frac{\sum_{\alpha} \left( \frac{\partial^2 \gamma_{\mu\nu}}{\partial \chi_{\alpha}^2} + \frac{\partial^2 \gamma_{\alpha\alpha}}{\partial \chi_{\mu} \partial \chi_{\nu}} - \frac{\partial^2 \gamma_{\mu\alpha}}{\partial \chi_{\nu} \partial \chi_{\alpha}} - \partial^2 \gamma_{\nu\alpha} \right)}{\partial \chi_{\mu} \partial \chi_{\alpha}} = 2\kappa \left( \mathfrak{T}_{\mu\nu} - \frac{1}{2g_{\mu\nu}} \sum_{\alpha} \mathfrak{T}_{\alpha\alpha} \right)$$

$$\frac{\sum_{\alpha} \left( \frac{\partial^2 \gamma'_{\mu\nu}}{\partial \chi_{\alpha}^2} + \frac{\partial^2 \gamma'_{\alpha\beta}}{\partial \chi_{\nu} \partial \chi_{\alpha}} - \frac{\partial^2 \gamma'_{\mu\alpha}}{\partial \chi_{\mu} \partial \chi_{\alpha}} - \partial^2 \gamma'_{\nu\alpha} \right)}{\partial \chi_{\alpha} \partial \chi_{\beta}} = 2\kappa \left( \mathfrak{T}_{\mu\nu} - \frac{1}{2g_{\mu\nu}} \sum_{\alpha} \mathfrak{T}_{\alpha\alpha} \right)$$

$$\gamma'_{\mu\nu} = -\kappa/2\pi \int \frac{\mathfrak{T}_{\mu\nu}(\chi_0, y_0, z_0, t-r)}{r} d\mathfrak{B}_0$$

$$\frac{\sum_{\sigma} \partial \mathfrak{T}_{\mu}^{\sigma}}{\partial \chi_{\sigma}} + \frac{1}{2 \sum_{\rho\sigma} \frac{\partial g^{\rho\sigma}}{\partial \chi_{\mu}} \mathfrak{T}_{\rho\sigma}}$$

$$\gamma_{\mu\nu} = \gamma'_{\mu\nu} - \frac{1}{2\delta_{\mu\nu} \sum_{\alpha} \gamma'_{\alpha\alpha}} = \gamma'_{\mu\nu} - \frac{1}{2\delta_{\mu\nu} \gamma'}$$

$$\sum_{\alpha} \partial t_{\mu\sigma} / \partial \chi_{\sigma} = \sum_{\alpha} \partial / \partial \chi_{\sigma} \left( \frac{1}{4\kappa} \left( \sum_{\alpha\beta} \left( \frac{\partial \gamma'_{\alpha\beta}}{\partial \chi_{\mu} \partial \chi_{\sigma}} \right) - \frac{1}{2} \frac{\partial \gamma'}{\partial \chi_{\mu}} \frac{\partial \gamma'}{\partial \chi_{\sigma}} \right) \right)$$

$$\frac{1}{8\kappa \delta_{\mu\sigma} \left( \sum_{\alpha\beta\lambda} \left( \frac{\partial \gamma'_{\alpha\beta}}{\partial \chi_{\lambda}} \right)^2 - \frac{1}{2 \sum_{\lambda} (\partial \gamma' / \frac{\hbar}{\mathfrak{S}} / \partial \chi_{\lambda})^2} \right)}$$

$$4\kappa \gamma_{\mu\sigma} = \left( \frac{\sum_{\alpha\beta} \left( \frac{\partial \gamma'_{\alpha\beta}}{\partial \chi_{\mu} \partial \chi_{\sigma}} \right) - 1}{2 \frac{\partial \gamma'}{\partial \chi_{\mu}} \frac{\partial \gamma'}{\partial \chi_{\sigma}}} \right) - \frac{1}{2\delta_{\mu\sigma} \left( \sum_{\alpha\beta\lambda} \left( \frac{\partial \gamma'_{\alpha\beta}}{\partial \chi_{\lambda}} \right)^2 - \frac{1}{\frac{\hbar}{\mathfrak{S}} 2 \sum_{\lambda} (\partial \gamma' / \frac{\kappa}{\mathcal{R}} / \partial \chi_{\lambda})^2} \right)}$$



$$\kappa \mathfrak{S}_\sigma^\alpha = \frac{1}{2\delta_\sigma^\alpha \sum_{\mu\nu\lambda\beta} g^{\mu\nu} \frac{\mu\lambda\nu\sigma}{\beta \lambda}} - \sum_{\mu\nu\lambda} g^{\mu\nu} \frac{\mu\lambda\nu\sigma}{\alpha \lambda}$$

$$S = -1/4 \left( \sum_\mu A_{\mu\mu} \right)^2 + \frac{1}{2 \sum_\mu A_{\mu\mu}} \sum_{\rho\sigma} A_{\rho\sigma} \alpha_\rho \alpha_\sigma + \frac{1}{4} \left( \sum_{\rho\sigma} A_{\rho\sigma} \alpha_\rho \alpha_\sigma \right)^2 + \frac{1}{2 \sum_{\mu\nu} A_{\mu\nu}^2} - \sum_{\mu\sigma\tau} A_{\mu\sigma} A_{\mu\tau} \alpha_\sigma \alpha_\tau$$

**17.6. Puente Einstein – Rosen en un campo cuántico geoméricamente deformado o curvo, generado por una partícula masiva acelerada, explica (1) la superposición cuántica; (2) la aniquilación de partículas y antipartículas; y, (3) el entrelazamiento cuántico.**

$$\begin{aligned} ds^2 &= d\chi_1^2 - d\chi_2^2 - d\chi_3^2 + \alpha^2 \chi_1^2 d\chi_4^2 \\ \mathcal{R}_{lm}^{ik} &= g^2 \mathcal{R}^{kl} \mathfrak{R}_{kl} = \mathbb{R}_{ik} - \frac{1}{2g_{ik}} \mathfrak{T} = -\mathfrak{S}_{ik} \\ \mathfrak{S}_{ik} &= \frac{1}{4g_{ik} \varphi_{\alpha\beta} \varphi^{\alpha\beta}} - \varphi_{i\alpha} \varphi_{\lambda/\sigma}^{\alpha/\mu} \varrho^{\nu\sigma} \\ ds^2 &= -d\chi_1^2 - d\chi_2^2 - d\chi_3^2 + (\alpha^2 \chi_1^2 + \sigma) d\chi_4^2 \\ ds^2 &= -\frac{1}{1} - \frac{2m}{r} dr^2 - r^2(d\theta^2 + \sin^2\theta d\phi^2) + \left(1 - \frac{2m}{r}\right) dt^2 \\ ds^2 &= -4(\mu^2 + 2m)d\mu^2 + (\mu^2 + 2m)^2 (d\theta^2 + \sin^2\theta d\phi^2) + \frac{\mu^2}{\mu^2 + 2m} dt^2 \\ ds^2 &= -\frac{1}{1} - \frac{2m}{r - \varepsilon^2/2r^2} dr^2 - r^2(d\theta^2 + \sin^2\theta d\phi^2) + \left(1 - \frac{2m}{r} - \varepsilon^2/2r^2\right) dt^2 \\ \varphi_{\mu\nu} &= \varphi_{\mu,\nu} - \varphi_{\nu,\mu} + g^2 \varphi_{\mu\nu\sigma}^{\mu} \varrho^{\nu\sigma} = g^2 (\mathfrak{R}_{ik} + \varphi_{\alpha\beta} \varphi^{\alpha\beta}) \\ \frac{\sum_\alpha \partial^2}{\partial \mathfrak{R}_\alpha^2 \left( \gamma'_{\mu\nu} - \frac{1}{2} \delta_{\mu\nu} \sum_\alpha \gamma'_{\alpha\alpha} \right)} &= 2\kappa \mathfrak{S}_{\mu\nu} \left( \mathfrak{S}_{\mu\nu} - \frac{1}{2} \delta_{\mu\nu} \sum_\alpha \mathfrak{T}_{\alpha\alpha} \right) \\ \gamma_{\mu\nu} &= \gamma'_{\mu\nu} - \frac{1}{2} \delta_{\mu\nu} \sum_\alpha \gamma'_{\alpha\alpha} \\ \gamma'_{\mu\nu} &= \gamma_{\mu\nu} - \frac{1}{2} \delta_{\mu\nu} \sum_\alpha \gamma_{\alpha\alpha} \\ \gamma'_{\mu\nu} &= -\frac{\kappa}{2\pi \int \mathfrak{S}_{\mu\nu} (\chi_0 y_0 z_0, t-r)} \cdot d\mathfrak{B}_0 \\ \sum_\alpha \frac{\partial}{\partial \mathfrak{R}_\alpha} \left( \frac{\partial \gamma'_{\mu\nu}}{\partial \mathfrak{R}_\sigma} \frac{\partial \gamma'_{\mu\nu}}{\partial \mathfrak{R}_\alpha} \frac{1}{2} \delta_{\alpha\sigma} \sum_{\mu\nu\beta} \left( \frac{\partial \gamma'_{\mu\nu}}{\partial \mathfrak{R}_\beta} \right)^2 \right) & \end{aligned}$$



$$\sum_{\sigma} \frac{\partial \sqrt{-g} \mathfrak{S}_{\mu}^{\sigma}}{\partial \mathfrak{R}_{\sigma}} + \frac{1}{2 \sum_{\rho\sigma} \partial g^{\rho\sigma}} \sqrt{-g} \mathfrak{S}_{\sigma}^{\rho} \mathfrak{S}^{\rho\sigma} \mathfrak{S}_{\rho\sigma} - 4\kappa \sum_{\nu} \frac{\partial \mathfrak{S}_{\rho\sigma}}{\partial \mathfrak{R}_{\nu}}$$

$$t_{\mu\nu} = \frac{1}{4\kappa} \left( \frac{\sum_{\alpha\beta} \frac{\partial \gamma'_{\alpha\beta}}{\partial \mathfrak{R}_{\mu}} \partial \gamma'_{\alpha\beta}}{\partial \mathfrak{R}_{\nu}} - \frac{1}{2} \frac{\delta_{\mu\nu} \sum_{\alpha\beta\tau} (\partial \gamma'_{\alpha\beta})}{\partial \mathfrak{R}_{\tau}^2} \right)$$

$$\frac{\partial}{\partial \mathfrak{R}_{\alpha}} \left( \frac{\partial \mathfrak{G}^*}{\partial g_{\alpha}^{\mu\nu}} \right) - \frac{\partial \mathfrak{G}^*}{\partial g^{\mu\nu}} = \frac{\partial \mathfrak{M}}{\partial g^{\mu\nu}} = \frac{\partial}{\partial \mathfrak{R}_{\alpha}} \left( \frac{\partial \mathfrak{M}}{\partial q_{(p)\alpha}} \right) - \partial \mathfrak{M} \partial q_{(p)\beta}$$

$$\mathfrak{G}^* = \sqrt{-g} g^{\mu\nu} \left( \begin{pmatrix} \mu\alpha \\ \beta \end{pmatrix} \begin{pmatrix} \mu\beta \\ \alpha \end{pmatrix} - \begin{pmatrix} \mu\nu \\ \alpha \end{pmatrix} \begin{pmatrix} \alpha\beta \end{pmatrix} \right)$$

$$\Delta g^{\mu\nu} = \frac{g^{\mu\alpha} \partial \Delta \chi_{\nu}}{\partial \mathfrak{R}_{\alpha}} + \frac{g^{\nu\alpha} \partial \Delta \chi_{\mu}}{\partial \mathfrak{R}_{\alpha}} + \Delta g_{\sigma}^{\mu\nu\rho} = \frac{\partial \Delta g^{\mu\nu}}{\partial \mathfrak{R}_{\sigma}} - \frac{g_{\sigma}^{\mu\nu\rho} \partial \Delta \chi_{\alpha}}{\partial \mathfrak{R}_{\sigma}}$$

$$\sqrt{-g} \Delta \left( \frac{\mathfrak{G}^*}{\sqrt{-g}} \right) = \delta_{\sigma}^{\nu} \frac{\partial \Delta \chi_{\sigma}}{\partial \mathfrak{R}_{\nu}} + 2 \frac{\partial \mathfrak{G}^*}{\partial g_{\alpha}^{\mu\nu}} + \mathfrak{G}^* \frac{g^{\mu\nu} \partial^2 \Delta \chi_{\sigma}}{\partial \mathfrak{R}_{\nu} \partial \mathfrak{R}_{\alpha}} + \delta_{\sigma}^{\nu}$$

$$= \frac{2 \partial \mathfrak{G}^*}{\partial g^{\mu\sigma} g^{\mu\nu}} + \frac{2 \partial \mathfrak{G}^*}{\partial g_{\alpha}^{\mu\sigma}} + \frac{1}{2} \mathfrak{G}^* \delta_{\sigma}^{\nu} - \partial \mathfrak{G}^* / \partial g_{\nu}^{\mu\alpha} g_{\sigma}^{\mu\alpha}$$

$$\mathfrak{G}_{\mu\nu} = -\kappa \left( \mathfrak{T}_{\mu\nu} - \frac{1}{2g^{\mu\nu}\mathfrak{T}} \right)$$

$$\mathfrak{G}_{\mu\nu} = -\frac{\partial}{\partial \mathfrak{R}_{\alpha}} (\mu\nu, \alpha) + (\mu\alpha, \beta)(\nu\beta, \alpha) + \partial^2 \log \frac{\sqrt{-g}}{\partial \mathfrak{R}_{\mu} \partial \mathfrak{R}_{\nu}} - \frac{(\mu\nu, \alpha) \partial \log \sqrt{-g}}{\partial \mathfrak{R}_{\alpha}} \lambda_{g_{\mu\nu}}$$