GRUPO DE PRINCIPIOS PRINCIPIOS FUNDAMENTALES

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De una manera muy general los temas considerados se pueden agrupar de la siguiente manera:

(1) **Problemas fundamentales de la mecánica cuántica y su relación con la gravitación:** (Y. Bonder, C. Chryssomalakos, T. Koslowski, E. Okon, C. Ramirez, M. Salgado, D. Sudarsky).

(2) **Estudio de simetrías espacio temporales:** (Y. Bonder, D. Delepine, P. Hess, E. Martinez, H Martínez L. Nellen, J. Toscano, L. Urrutia, D. Vergara).

(3) **Teorías no conmutativas:** (C. Chryssomalakos, D. Vergara)

(4) **Violación de CP:** (R. Juárez, P. Kielanowski, D. Delepine)

(5) **Gravedad clásica y cuántica:** **(T. Koslowski, C. Ramirez, P. Hess, B. Juárez).**

(6) **Dimensiones extras:** **(E. Martínez, J. Toscano, H. Novales).**

(7) **Teoría de Cuerdas:** **(E. Cáceres, M. Chernicoff, H. García-Compeán, J. A. García Zenteno, A. Güijosa, O. Loaiza-Brito, L. Patiño, S. Ramos-Sánchez, M. Sabido).**

(8) **Grafeno y Aislantes topológicos:** **(A. Raya, L. Urrutia).**

(9) **Espines Altos y Métodos Espinoriales:** **(M. Kirchbach, B. Larios).**

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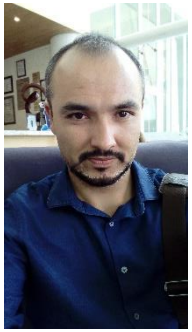
• TEORIAS DE KK Y EL MODELO ESTÁNDAR EN DIMESIONES EXTRAS



La acción... $S[\mathcal{A}^a_M] = \int d^dx\left(-\frac{1}{4}\mathcal{F}^a_{MN}(x,\bar{x})\mathcal{F}^{MN}_a(x,\bar{x})\right)$

- Curvaturas: $\mathcal{F}^a_{MN} = \partial_M \mathcal{A}^a_N - \partial_N \mathcal{A}^a_M + g_{(4+n)} f^{abc}\mathcal{A}^b_M\mathcal{A}^c_N$
- Conexiones de $SU(N,\mathcal{M}^{4+n})$: $\mathcal{A}^a_M(x,\bar{x})$
- Constante de acoplamiento: $g_{(4+n)} \longrightarrow$ unidades de inverso de masa

$$S = -\frac{1}{4}\int d^dx\left(\mathcal{F}^a_{\mu\nu}\mathcal{F}^{\mu\nu}_a - 2\mathcal{F}^a_{\mu\bar{\nu}}\mathcal{F}^{\mu}_{a\ \bar{\nu}} + \mathcal{F}^a_{\bar{\mu}\bar{\nu}}\mathcal{F}^{\bar{\mu}\bar{\nu}}_a\right)$$

Las torres de KK:

$$\mathcal{A}^a_\mu(x,\bar{x}) = \sum\nolimits_{(m)} f^{(m)}(\bar{x})A^{(m)a}_\mu(x)$$

$$\mathcal{A}^a_{\bar{\mu}}(x,\bar{x}) = \sum\nolimits_{(m)} f^{(m)}(\bar{x})A^{(m)a}_{\bar{\mu}}(x)$$

$$\alpha^a(x,\bar{x}) = \sum\nolimits_{(m)} f^{(m)}(\bar{x})\alpha^{(m)a}(x)$$

Masas de norma: $\sum_{(m)}\frac{1}{2}m^2_{(m)}A^{(m)a}_\mu A^{(m)a\mu}$

Masas escalares: $-\sum_{(m)}\frac{1}{2}A^{(m)a}_{\bar{\mu}}\underbrace{\mathfrak{M}^{(m)}_{\bar{\mu}\bar{\nu}}}A^{(m)a}_{\bar{\nu}}$

$\mathcal{L}^{(0)}_{\text{eff}} = \mathcal{L}^{(0)}_{\text{SM}} + \mathcal{L}^{(0)}_{\mathbf{d>4}} \longrightarrow$ Sólo modos cero; contiene al ME

$\mathcal{L}^{(0)(m)}_{\text{eff}} = \mathcal{L}^{(0)(m)}_{\mathbf{d=4}} + \mathcal{L}^{(0)(m)}_{\mathbf{d>4}} \longrightarrow$ Modos cero y excitados; primeras contribuciones de DEs a observables del ME

$\mathcal{L}^{(m)}_{\text{eff}} = \mathcal{L}^{(m)}_{\mathbf{d=4}} + \mathcal{L}^{(m)}_{\mathbf{d>4}} \longrightarrow$ Sólo modos excitados

- **Renormalización de las teorías de Kaluza-Klein en un sentido amplio**
- **Fenomenología: estudio de contribuciones de Kaluza-Klein a observables**

PROBLEMAS Y AVANCES EN LA DESCRIPCION DE ESPINES SUPERIORES

$$\mathcal{L}: \quad [S_{\mu\nu}, S_{\rho\sigma}] = i(g_{\mu\rho}S_{\nu\sigma} - g_{\nu\rho}S_{\mu\sigma} + g_{\mu\sigma}S_{\rho\nu} - g_{\nu\sigma}S_{\rho\mu}),$$

$$\mathcal{T}_4: \quad [P_\mu, P_\nu] = 0, \qquad F_{AB} = \frac{1}{4}[S^{\mu\nu}]_{AD}[S_{\mu\nu}]_{DB},$$

$$[S_{\mu\nu}, P_\lambda] = 0, \qquad G_{AB} = \frac{1}{8}\epsilon_{\mu\nu\alpha\beta}[S^{\mu\nu}]_{AC}[S_{\alpha\beta}]_{CB}, \quad A, B, C, D, ... = 1, ..., d.$$

$$F\, D^{(j_1,j_2)\oplus(j_2,j_1)} = c_{(j_1,j_2)} D^{(j_1,j_2)\oplus(j_2,j_1)},$$

$$c_{(j_1,j_2)} = \frac{1}{2}\left(K(K+2) + M^2\right), \quad K = j_1 + j_2, \quad M = |j_1 - j_2|,$$

$$\Psi^{(n)}{}_{a_1 a_2 \dots a_n}, \quad a_i = 1, 2, 3, 4,$$

$D^{(n/2,0)\oplus(0,n/2)}$ irrep.

$$\mathcal{P}_F^{(n/2,0)} = \Pi_{kl} \times \left(\frac{F - c_{(j_k,j_l)}}{c_{(n/2,0)} - c_{(j_k,j_l)}}\right),$$

$$\left(\partial_\mu \partial^\mu \left[\mathcal{P}_F^{(n/2,0)}\right]_{a_1 a_2 \dots a_n}{}^{b_1 b_2 \dots b_n} + m^2\right)\Psi^{(n)}_{b_1 b_2 \dots b_n} = 0, \quad n = 2j.$$

$$\Psi^{(2)}_{a_1 a_2} \simeq D^{(1/2,0)\oplus(0,1/2)} \otimes D^{(1/2,0)\oplus(0,1/2)} = D^{(1,0)\oplus(0,1)} \oplus 2D^{(0,0)} \oplus 2D^{(1/2,1/2)},$$

$$\mathcal{P}_F^{(1,0)} = \frac{1}{2}\left(2F^2 - 3F\right).$$

$$\left[\mathcal{P}_F^{(1,0)}\right]^{a_1 a_2}{}_{b_1 b_2} = \frac{1}{4}(\sigma_{\mu\nu})^{a_1}{}_{b'_1}(\sigma_{\mu\nu})^{a_2}{}_{b'_2} F^{b'_1 b'_2}{}_{b_1 b_2}$$

First calculation of the Compton scattering off $(3/2, 0) \oplus (0, 3/2)$

g factor =2/3

$$c_{(0,0)} = 0 \quad \text{for} \quad (0,0),$$

$$c_{(1,0)} = 2 \quad \text{for} \quad (1,0) \oplus (0,1),$$

$$c_{(1/2,1/2)} = \frac{3}{2} \quad \text{for} \quad (1/2, 1/2).$$

TEORIA DE LA RELATIVIDAD PSEUDO COMPLEJA

$$X = X_1 + IX_2 \quad , \quad I^2 = 1$$

Alternativa: $\sigma_\pm = \frac{1}{2}(1 \pm I) \quad \rightarrow \quad X = X_+\sigma_+ + X_-\sigma_-$

$$\sigma_\pm^{\ 2} = \sigma_\pm \qquad \sigma_+\sigma_- = 0 \qquad !$$

Solo una extensión pseudo-compleja no produce estados no-fisicos, como fantasmas y tachyones.

$$F(X)G(X) \; = \; F(X_+)G(X_+)\sigma_+ + F(X_-)G(X_-)\sigma_-$$

$$X^\mu = x^\mu + I\frac{\ell}{c}\frac{dx^\mu}{d\tau} \qquad \frac{D}{DX^\mu} = \frac{1}{2}(\partial_{1,\mu} + I\partial_{2,\mu})$$

$$\delta S \quad \epsilon \quad P^0$$

$$g_{\mu\nu} = g^+_{\mu\nu}\sigma_+ + g^-_{\mu\nu}\sigma_-$$

$$D_{+,\mu}\left(\frac{D_+\mathcal{L}_+}{D_+(D_{+,\mu}\Phi_{+,r})}\right) - \frac{D_+\mathcal{L}_+}{D_+\Phi_{+,r}} \; = \; 0$$

$$D_{-,\mu}\left(\frac{D_-\mathcal{L}_-}{D_-(D_{-,\mu}\Phi_{-,r})}\right) - \frac{D_-\mathcal{L}_-}{D_-\Phi_{-,r}} - A^r_-\sigma_- \; = \; 0$$

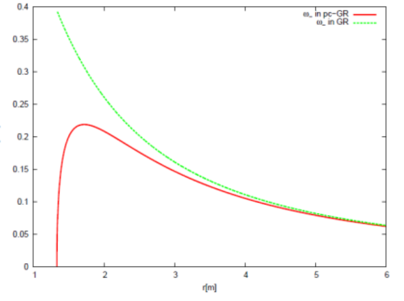
$$\mathcal{R}^{\mu\nu} - \frac{1}{2}g^{\mu\nu}\mathcal{R} = -\frac{8\pi\kappa}{c^2}T^{\mu\nu}_-\sigma_-$$

- **Al final uno debe proyectar reemplazando todas las variables pseudocomplejas por su parte pseudoreal y tomar** $\ell = 0$

$$\Omega_- = B / r^2$$

- **Schwarzschlid** $d\omega^2 = \left(1 - \frac{2m}{r} + \frac{\Omega_-}{2r}\right)e^{\frac{f_-}{2}}(dx^0)^2 - \left(1 - \frac{2m}{r} + \frac{\Omega_-}{2r}\right)^{-1}(dr)^2 - r^2\left((d\theta)^2 + \sin^2\theta(d\phi)^2\right)$

$$\omega_{\rm GR} = c\sqrt{\frac{m}{r^3}} \qquad\qquad \omega_{\rm pc-GR} = \sqrt{\frac{m}{r^3} - \frac{3B}{4r^5}}$$



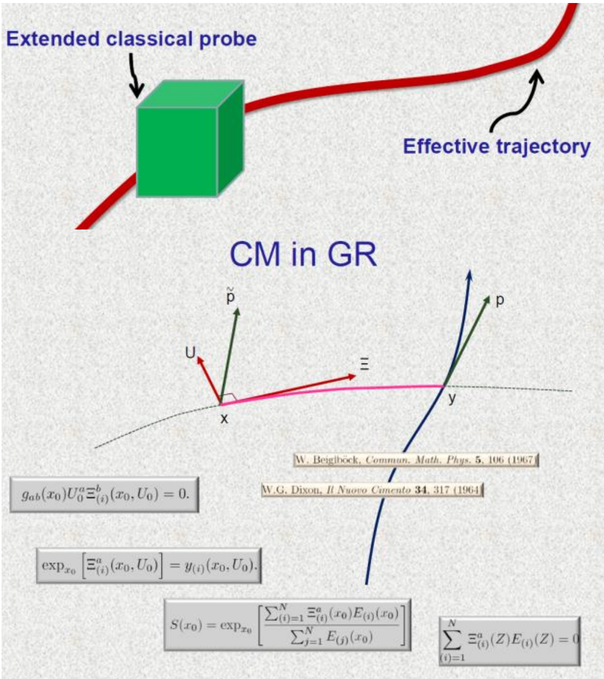
AN OVERVIEW OF QUANTUM FIELD THEORY IN CURVED SPACETIMES

- **Ecuación de Klein Gordon** $(\Box - m^2 + \xi R)\Phi = 0$
- **Campos** $A = \Phi(f)$ **forman un algebra** $\mathcal{A}$,
  1. $f \mapsto \Phi(f)$ is a linear map (linearity),
  2. $\Phi(f)^* = \Phi(f)$ (hermicity),
  3. $\Phi((\Box - m^2 + \xi R)f) = 0$ (field equation),
  4. $[\Phi(f), \Phi(g)] = -\mathrm{i}E(f,g)\mathbb{1}$, $g \in C_0^\infty(M)$ (covariant CCR).
- **Los estados** ω **son funcionales**
  1. $\omega : A \mapsto z \in \mathbb{C}$ is linear (linearity)
  2. $\omega(\mathbb{1}) = 1$ (normalisation),
  3. $\omega(A^* A) \geq 0$ (positivity).
- **Método de Gelfand-Neimark y Siegel**

  GNS: Given $\mathcal{A}$ and ω, construct the Hilbert space of the theory and have algebra elements represented on it.

- **Produce una representación de los campos como operadores lineales en el espacio de Hilbert y un producto interno.**

EXTRACTING GEOMETRY FROM QUANTUM SPACETIME: OBSTACLES DOWN THE ROAD



- Relativistic center of mass (Pryce, 1948)

Requirements:

1. Part of four-vector (worldline frame independent)
2. At rest in COMom frame
3. Move in straight line (no external forces)
4. X_i's commute (???)

Definitions:

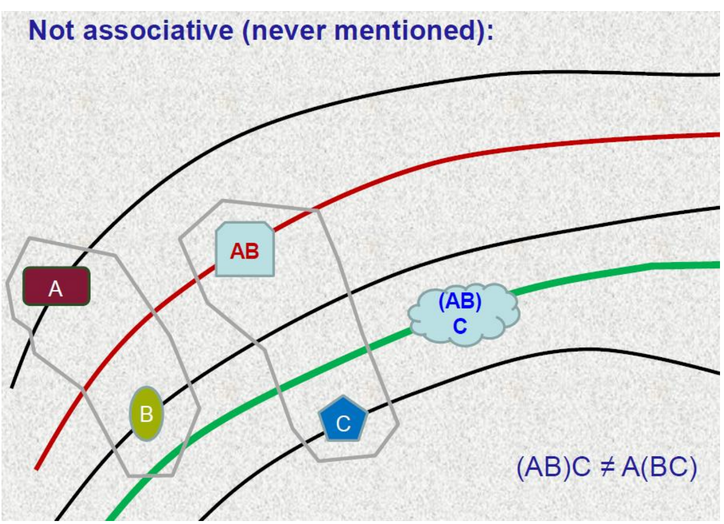
1. X_i's weighted by rest mass (Eddington, 1946)
2. Apply (1) in COMom, LT to other frames
3. X_i's weighted by energies (*centroid*)
4. Apply (3) in COMom, LT to other frames (*CM*)

Score

	1	2	3	4
1	-	-	-	x
2	x	-	-	x
3	-	x	x	-
4	x	x	x	-

3. $[q_i, q_j] = -\epsilon_{ijk} H^{-2} S_k$
4. $[X_i, X_j] = \epsilon_{ijk} M^{-2} S_k$

Is it an atom or is it a molecule?



CoM worldline not geodesic

Effective geometry?

No effective metric

QUANTUM COSMOLOGY OF QUADRATIC F(R) THEORIES WITH A FRW METRIC

$$A = \frac{1}{2\kappa^2}\int \sqrt{-g}\left(R + \alpha R^2\right) d^4x \quad , \quad A = \frac{1}{2\kappa^2}\int \sqrt{-g}\,[R + \phi(\beta\phi + R)]\, d^4x$$

$$3k^2 + a^2\left(6\dot{a}\dddot{a} - 3\ddot{a}^2 - 2k\beta\right) + \dot{a}^2\left(6a\ddot{a} - 9\dot{a}^2 - 2\beta a^2 - 6k\right) = 0$$

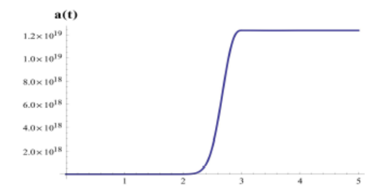


Figure: $a(t)$ with $\beta = -200$ $(k = 0)$

$$\pi_a = -\frac{6a}{N}\left[2(\phi + 1)\dot{a} + a\dot{\phi}\right] \quad \text{and} \quad \pi_\phi = -\frac{6a^2\dot{a}}{N}$$

$$\left[(\phi + 1)\frac{\partial^2}{\partial\phi^2} - a\frac{\partial^2}{\partial\phi\partial a} + 2\frac{\partial}{\partial\phi} + 6\beta\phi^2 a^6 + 36k(\phi + 1)a^4\right]\psi(a, \phi) = 0$$

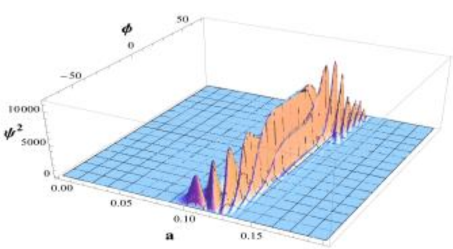


Figure: $\psi(a, \phi)$, $\beta = -200$.

$$\Psi(a, \tau) = \left.\frac{1}{\sqrt{\int_0^\infty da\,|\psi(a, \phi)|^2}}\,\psi(a, \phi)\right|_{\phi = \tau}$$

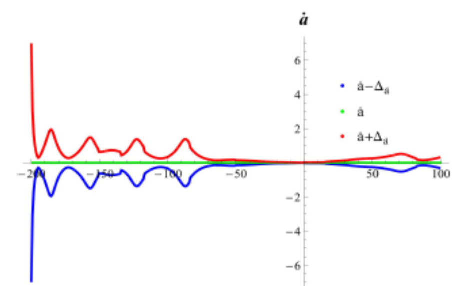


Figure: $\dot{a}(t)$ with fluctuations

GEOMETRY OF THE QUANTUM SPACE

$$\mathcal{F}(\lambda,\lambda+\delta\lambda) = |\langle\psi(\lambda+\delta\lambda)|\psi(\lambda)\rangle|,$$

$$\mathcal{F}(\lambda,\lambda+\delta\lambda) = 1+\frac{1}{2}G_{ab}\,\delta\lambda^a\delta\lambda^b+\cdots,$$

$$G_{ab} = \langle\partial_a\psi|\partial_b\psi\rangle - \langle\partial_a\psi|\psi\rangle\langle\psi|\partial_b\psi\rangle.$$

$$\langle\psi|\partial_a\psi\rangle \equiv -iA_a$$

$$\frac{1}{2}F_{ab} \equiv \mathbf{Im}\,G_{ab} = \frac{1}{2i}\left(\langle\partial_a\psi|\partial_b\psi\rangle - \langle\partial_b\psi|\partial_a\psi\rangle\right) = \frac{1}{2}\{\partial_a A_b - \partial_b A_a\}$$

A Lagrangian approach to the quantum information metric and Berry curvature

$-\infty < t < 0$ $\quad \mathcal{L}_0(\lambda^a)$ $\quad |\Omega_0\rangle$ $\quad\quad 0 < t < \infty$ $\quad \mathcal{L}_1 = \mathcal{L}_0 + \delta\lambda^a\mathcal{O}_a$ $\quad |\Omega_1\rangle$

$$\langle\Omega_1|\Omega_0\rangle = \frac{\left\langle \exp\left(-\int_0^\infty d\tau \int d^dx\, \delta\lambda^a\mathcal{O}_a\right)\right\rangle}{\left\langle \exp\left(-\int_{-\infty}^\infty d\tau \int d^dx\, \delta\lambda^a\mathcal{O}_a\right)\right\rangle^{1/2}},$$

$$g_{ab} = \int_{-\infty}^0 d\tau_1 \int_0^\infty d\tau_2 \left(\frac{1}{2}\langle\{\mathcal{O}_a(\tau_1),\mathcal{O}_b(\tau_2)\}\rangle - \langle\mathcal{O}_a(\tau_1)\rangle\langle\mathcal{O}_b(\tau_2)\rangle\right)$$

$$F_{ab} = \frac{1}{i}\int_{-\infty}^0 d\tau_1 \int_0^\infty d\tau_2\, \langle[\mathcal{O}_a(\tau_1),\mathcal{O}_b(\tau_2)]\rangle.$$

EJEMPLO

$$H = Zp^2 + Y\{p,q\} + Xq^2,$$

$$\{X,Y,Z\} \to \{X+\delta X, Y+\delta Y, Z+\delta Z\}$$

ASPECTOS MODERNOS DE LAS AMPLITUDES DE DISPERSION

- **Base de los resultados experimentales** $\frac{d\sigma}{d\Omega} \propto |\mathcal{A}|^2$
- **La idea básica es emplear la representacion espinorial**

$$p_{a\dot{a}} = p_\mu \sigma^\mu_{a\dot{a}} \qquad \gamma^\mu = \begin{pmatrix} 0 & \sigma^\mu \\ \bar{\sigma}^\mu & 0 \end{pmatrix} \qquad \sigma^\mu_{a\dot{a}} = (I, \vec{\sigma}),\ \bar{\sigma}^{\mu\dot{a}a} = (I, -\vec{\sigma}) \qquad u_-(\vec{p})\bar{u}_-(\vec{p}) = \frac{1}{2}(1-\gamma_5)(-\not{p}) = \begin{pmatrix} 0 & -p_{a\dot{a}} \\ 0 & 0 \end{pmatrix}$$

$$u_-(\vec{p}) = \begin{pmatrix} \phi_a \\ 0 \end{pmatrix} \qquad \bar{u}_-(\vec{p}) = (0, \phi^*_{\dot{a}}), \qquad p_{a\dot{a}} = -\phi_a \phi^*_{\dot{a}}$$

$$[pk] = \phi^a \kappa_a = \bar{u}_+(\vec{p}) u_-(\vec{k}) = -[kp] \qquad \langle pk\rangle = \phi^*_{\dot{a}} \kappa^{*\dot{a}} = \bar{u}_-(\vec{p}) u_+(\vec{k}) = -\langle kp\rangle$$

$$|p] = u_-(\mathbf{p}) = v_+(\mathbf{p})\,,$$
$$|p\rangle = u_+(\mathbf{p}) = v_-(\mathbf{p})\,,$$
$$[p| = \overline{u}_+(\mathbf{p}) = \overline{v}_-(\mathbf{p})\,,$$
$$\langle p| = \overline{u}_-(\mathbf{p}) = \overline{v}_+(\mathbf{p})\,.$$

Some of the most important formulas that are needed to compute scattering amplitudes :

$$[ij] = -[ji],$$
$$\langle ij\rangle = [ji]^*,$$
$$\langle ij\rangle[ji] = \langle ij\rangle\langle ij\rangle^* = |\langle ij\rangle|^2,$$
$$\langle ij\rangle[ji] = -2k_i \cdot k_j = s_{ij},$$
$$\langle i|\gamma_\mu|j] = [j|\gamma_\mu|i\rangle,$$
$$\langle i|\gamma_\mu|j]\langle k|\gamma^\mu|l] = 2\langle ik\rangle[lj],$$
$$\langle ab\rangle\langle cd\rangle = \langle ac\rangle\langle bd\rangle + \langle ad\rangle\langle cb\rangle,$$
$$\sum_{k=1}^{n} \langle ik\rangle[kj] = 0,$$

$$\langle pk] = [pk\rangle = 0$$

160 amplitudes, 132 son cero
Quedan 28, sólo 14 por simetría.

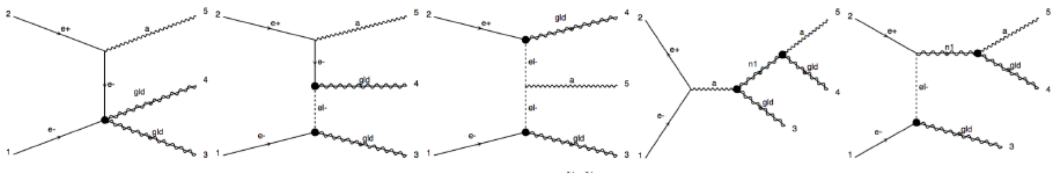


Figure: Feynman Diagrams for $e^+e^- \to \gamma \tilde{G}\tilde{G}$

MUCHAS GRACIAS