CPTM symmetry and cosmological constant in formalism of extended manifold

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CPTM symmetry: doubling of degrees of freedom

- Consider two manifolds, A-manifold and B-manifold, with coordinates x and $\tilde{x}$ related by CPTM symmetry:

$$g_{\mu\nu}(x) = g_{\mu\nu}(\tilde{x}) = \tilde{g}_{\mu\nu}(\tilde{x})$$

provided by CPTM transform:

$$q \to -\tilde{q}\,, r \to -\tilde{r}\, t \to -\tilde{t}\,, m_{grav} \to -\tilde{m}_{grav}\,, m_{inertial} \to \tilde{m}_{inertial}$$
$$\tilde{q}\,,\, \tilde{r}\,,\, \tilde{t}\,,\, \tilde{m}_{grav} > 0$$
$$CPTM(g_{\mu\nu}(x)) = \tilde{g}_{\mu\nu}(\tilde{x}) = g_{\mu\nu}(\tilde{x})$$

The CC arises as a result of interaction between the manifolds, it's value can be different for two manifolds but related by the CPTM symmetry:

$$CPTM(\Lambda) = \tilde{\Lambda}\,,\;\; CPTM(g_{\mu\nu}(x,\Lambda)) = \tilde{g}_{\mu\nu}(\tilde{x},\tilde{\Lambda})$$

$$\begin{aligned} U &= -\,e^{-u/4M} \to \tilde{U} = e^{-\tilde{u}/4\tilde{M}} = -\,U\,,\;\; V = e^{v/4M} \to \tilde{V} = -\,e^{\tilde{v}/4\tilde{M}} = -\,V \\ T &= \frac{1}{2}\,(\,V + U\,) \to -\,T\,,\;\;\; R = \frac{1}{2}\,(\,V - U\,) \to -\,R \end{aligned}$$

Quantized scalar field: short example

- Consider a scalar field undergoes the symmetry transform:

$$\begin{aligned} CPTM(\phi(x)) &= CPTM\left(\int \frac{d^3\,k}{(2\pi)^{3/2}\sqrt{2\,\omega_k}}\left(\phi^-(k)\,e^{-\imath\,k\,x} + \phi^+(k)\,e^{\imath\,k\,x}\right)\right) = \\ &= \tilde{\phi}(\tilde{x}) = \int \frac{d^3\,k}{(2\pi)^{3/2}\sqrt{2\,\tilde{\omega}_k}}\left(\tilde{\phi}^-(k)\,e^{\imath\,k\,\tilde{x}} + \tilde{\phi}^+(k)\,e^{-\imath\,k\,\tilde{x}}\right) \end{aligned}$$

and

$$\left\{\begin{array}{l} \phi^-(k) \leftrightarrow \tilde{\phi}^-(k) \\ \phi^+(k) \leftrightarrow \tilde{\phi}^+(k) \end{array}\right. \rightarrow \left\{\begin{array}{c} [\tilde{\phi}^-(k)\,\tilde{\phi}^+(k^{'})] = \delta^3_{k\,k'} \\ < \tilde{\phi}^+(k)\,\tilde{\phi}^-(k^{'}) >= -\,\delta^3_{k\,k'} \end{array}\right.$$

The results:

$$\begin{aligned} < P^\mu > &= \int d^3\,k\,k^{\,\mu}\left(< \phi^+(k)\,\phi^-(k) > + < \tilde{\phi}^-(k)\,\tilde{\phi}^+(k) >\right) = \\ &= < P^\mu_A > + < P^\mu_B > = 0 \end{aligned}$$

$$CPTM(< P^\mu_A >) = < P^\mu_B >;$$

$$CPTM(G_F(x,y)) = -\,G_D(\tilde{x},\tilde{y})$$

A and B spinors in an external gravity field

- Lagrangian of extended manifold:

$$\begin{aligned}\mathcal{L} &= \mathcal{L}_A + \mathcal{L}_B = \mathcal{L}_A + \mathcal{CPTM}(\mathcal{L}_A) = \mathcal{L}_A + \overline{\psi}_B \left(\imath\gamma^a(-E^\mu_a)\partial_\mu + m\right)\psi_B = \\ &= \mathcal{L}_A - \overline{\psi}_B \left(\imath\gamma^a(E^\mu_a)\partial_\mu - m\right)\psi_B\end{aligned}$$

Gravity field is included with "negative" vierbein transform $(e,E)_A \rightarrow -(e,E)_B$:

$$\omega_{cab} \rightarrow \omega_{cab}\,,\quad D_\mu \rightarrow D_\mu = \partial_\mu + \frac{1}{8}\,\omega_{\mu ab}\,[\gamma^a\gamma^b]$$

$$\begin{aligned}S &= S_A + S_B = \int d^4x_A\, e_A\, \overline{\psi}_A \left(\imath\, E^\mu_c\, \gamma^c\, D_\mu - m\right)\psi_A - \\ &- \int d^4x_B\, e_B\, \overline{\psi}_B \left(\imath\, E^\mu_c\, \gamma^c\, D_\mu - m\right)\psi_B\end{aligned}$$

We consider the linearized theory with symmetrical graviton:

$$\omega_{cab} = \partial_c\,(e_{1\,ab} - e_{1\,ba}) - \partial_a\,(e_{1\,cb} + e_{1\,bc}) + \partial_b\,(e_{1\,ca} + e_{1\,ac})$$

$$s_{cb} = \frac{1}{2}\,(e_{1\,cb} + e_{1\,bc})\,,\quad s_{cb} = s_{bc}$$

Quantization of B-spinor field

- The B-spinor field in this case is a replica of the A-field:

$$\psi(x)_{2B} = \int \frac{d^3p}{(2\pi)^{3/2}} \frac{1}{\sqrt{2\mathcal{E}p}} \sum_s \left(\left(\hat{\mathcal{M}} a^s_{\mathbf{p}} \right) u^s(p)\, e^{-\imath\, px} + \left(\hat{\mathcal{M}} b^{s\,\dagger}_{\mathbf{p}} \right) v^s(p)\, e^{\imath\, px} \right)$$

with

$$\begin{cases} \hat{\mathcal{M}}\, a^s_{\mathbf{p}} = c^s_{\mathbf{p}} \leftrightarrow a^s_{\mathbf{p}} \\ \hat{\mathcal{M}}\, b^s_{\mathbf{p}} = d^s_{\mathbf{p}} \leftrightarrow b^s_{\mathbf{p}} \end{cases} \rightarrow \begin{cases} \{ a^r_{\mathbf{p}}\, a^{s\dagger}_{\mathbf{k}} \} \rightarrow \{ c^r_{\mathbf{p}}\, c^{s\dagger}_{\mathbf{k}} \} = -\,\delta^3_{p\,k}\, \delta^{rs}, \quad < 0 | c^r_{\mathbf{p}} = 0 \\ \{ b^r_{\mathbf{p}}\, b^{s\dagger}_{\mathbf{k}} \} \rightarrow \{ d^r_{\mathbf{p}}\, d^{s\dagger}_{\mathbf{k}} \} = -\,\delta^3_{p\,k}\, \delta^{rs}, \quad < 0 | d^r_{\mathbf{p}} = 0 \end{cases}$$

and

$$P^\mu = \sum_s \int d^3k\, k^\mu \left(a^{s\dagger}_{\mathbf{p}} a^s_{\mathbf{p}} + b^{s\dagger}_{\mathbf{p}} b^s_{\mathbf{p}} + c^s_{\mathbf{p}} c^{s\dagger}_{\mathbf{p}} + d^s_{\mathbf{p}} d^{s\dagger}_{\mathbf{p}} \right), \quad < 0 |\, P^\mu \,| 0 > = 0$$

Feynman propagator for B-spinor field is a Dyson's one:

$$\tilde{S}_F(x-y) = -\left(\imath \hat{\partial}_x + m \right) \int \frac{d^4k}{(2\pi)^4} \frac{e^{-\imath\, k\,(x-y)}}{k^2 - m^2 - \imath\varepsilon}$$

$$\left(\imath\, \hat{\partial}_x - m \right) \tilde{S}_F(x,y) = -\,\delta^4(x-y)$$

One loop effective action for A,B-manifolds

- The effective action construction:

$$\psi_{A,B} \rightarrow \psi_{A,B\,cl} + \chi_{A,B}\,.$$

Tadpole contributions to Γ effective action or vacuum contributions to momentum-energy tensor (Euclidean space):

$$\Gamma_1(p_f) = -\,4\,\imath\,m^2\,G^E_{FR}(0)\int d^4x\,s(x)\,,\;\; \Gamma_{1A} + \Gamma_{1B} = 0$$

Two-legs contributions to Γ or tadpole contributions to momentum-energy tensor

$$\Gamma_{2A} + \Gamma_{2B} = 0$$

We will use further for the weak gravity limit:

$$s_{ab} = \overline{s}_{ab} - \frac{1}{2}\,\eta_{ab}\,\overline{s}\,,\;\; \partial_a\,\overline{s}^{a}_{b} = 0$$

$$M_1(x) = -\,\imath\,\gamma^c\,\overline{s}^{\mu}_{c}\,\partial_\mu + \frac{1}{2}\,m\,\overline{s} = \overline{s}_{\mu\nu}\left(J^{\mu\nu}_1 + \frac{1}{2}\,m\,\eta^{\mu\nu}\right) = \overline{s}_{\mu\nu}\,J^{\mu\nu}$$

One-loop spinor and gravity actions together:

- One-loop spinor action:

$$\Gamma(\overline{\psi},\psi,s) = \Gamma_A(\overline{\psi}_A,\psi_A,s) + \Gamma_B(\overline{\psi}_B,\psi_B,s) =$$

$$= \int d^4x_A\,\overline{\psi}_A\,M_1(x_A)\,\psi_A - \int d^4x_B\,\overline{\psi}_B\,M_1(x_B)\,\psi_B -$$

$$- \int d^4x_A\,d^4y_A\,\overline{\psi}_A(x_A)\,M_1(x_A)\,S_F(x_A,y_A)\,M_1(y_A)\,\psi_A(y_A) -$$

$$- \int d^4x_B\,d^4y_B\,\overline{\psi}_B(x_B)\,M_1(x_B)\,S_D(x_B,y_B)\,M_1(y_B)\,\psi_B(y_B)$$

Gravity action:

$$S_{gr} = -m_p^2\int_{-\infty}^{\infty} dt_A \int d^3x\,\sqrt{-g_A}\,R(x) - m_p^2\int_{-\infty}^{\infty} dt_B \int d^3x\,\sqrt{-g_B}\,R(x)$$

with

$$m_p^2 = \frac{1}{16\pi G} = \frac{2}{\kappa^2}\,, \quad g_B(x_B) = CPTM\,(g_A(x_A))$$

General action:

$$S = \Gamma(\overline{\psi},\psi,s) + S_{gr}$$

General set-up for the gravity field:

- General form of the gravity action:

$$g^{A}_{\mu\nu}(x) = g^{A\,0}_{\mu\nu}(x) + h^{A}_{\mu\nu}(x)\,;$$
$$g^{B}_{\mu\nu}(y) = g^{B\,0}_{\mu\nu}(y) + h^{B}_{\mu\nu}(y)\,;\,.$$

$$h_{\mu\nu} = \overline{h}_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}\,\overline{h}\,,\;\; \partial_{\mu}\,\overline{h}^{\mu}_{\nu} = 0\,,$$

$$\begin{aligned}
\Gamma \;=\; & \frac{m_p^2}{4}\int d^4x\,\overline{h}^{\mu\nu}_{A}\,G^{-1}_{A}\,\overline{h}^{A}_{\mu\nu} + \frac{m_p^2}{4}\int d^4x\,\overline{h}^{\mu\nu}_{B}\,G^{-1}_{B}\,\overline{h}^{B}_{\mu\nu} + \int d^4x\,\overline{h}^{\mu\nu}_{A}\,T_{\mu\nu\,A} + \\
+ & \int d^4x\,\overline{h}^{\mu\nu}_{B}\,T_{\mu\nu\,B} + \eta_{\mu\nu}\int d^4x\,\overline{h}^{\mu\nu}_{A}\,\Lambda_{0\,A} + \eta_{\mu\nu}\int d^4x\,\overline{h}^{\mu\nu}_{B}\,\Lambda_{0\,B} - \\
- & \frac{1}{2}\int d^4x\int d^4y\,\overline{h}^{\mu\nu}_{A}(x)\,M^{1\,AA}_{\mu\nu\,\rho\sigma}\,\overline{h}^{\rho\sigma}_{A}(y) - \frac{1}{2}\int d^4x\int d^4y\,\overline{h}^{\mu\nu}_{B}(x)\,M^{1\,BB}_{\mu\nu\,\rho\sigma}\,\overline{h}^{\rho\sigma}_{B}(y) - \\
- & \frac{1}{2}\int d^4x\int d^4y\,\overline{h}^{\mu\nu}_{A}(x)\,M^{1\,AB}_{\mu\nu\,\rho\sigma}\,\overline{h}^{\rho\sigma}_{B}(y) - \frac{1}{2}\int d^4x\int d^4y\,\overline{h}^{\mu\nu}_{B}(x)\,M^{1\,BA}_{\mu\nu\,\rho\sigma}\,\overline{h}^{\rho\sigma}_{A}(y)
\end{aligned}$$

The $M^{1\,IJ}_{\mu\nu\,\rho\sigma}(\overline{\psi},\psi)$ here are vertices of effective interaction between $I = A, B$ and $J = A, B$ gravity fields. The cosmological constants $\Lambda_{A,B}$ appears here as some terms in the effective action.

General set-up: propagators and dark matter

- Green's function of the framework:

$$\frac{m_p^2}{2}\begin{pmatrix} G_A^{-1} - \frac{2}{m_p^2}\, M_1^{AA} & -\frac{2}{m_p^2}\, M_1^{AB} \\ -\frac{2}{m_p^2}\, M_1^{BA} & G_B^{-1} - \frac{2}{m_p^2}\, M_1^{BB} \end{pmatrix}\begin{pmatrix} G_{AA} & G_{AB} \\ G_{BA} & G_{BB} \end{pmatrix} = I$$

The G_{AB} and G_{BA} propagators here are analog of the Wightman propagators $S_>$ and $S_<$ in the Schwinger-Keldysh technique. The Green's function for A-manifold:

$$G_A^{-1}\, G_{0\,AA} \,=\, \frac{2}{m_p^2}\,\delta_{AA}\,,\;\; G_B^{-1}\, G_{0\,BA} \,=\, 0\,,\;\; G_A^{-1}\, G_{0\,AB} \,=\, 0\,;$$

$$G_{AA} \,=\, G_{0\,AA} + \int G_{0\,AA}\, M^{1\,AA}\, G_{AA} + \int G_{0\,AA}\, M^{1\,AB}\, G_{BA} +$$

$$+ \int G_{0\,AB}\, M^{1\,BA}\, G_{AA} + \int G_{0\,AB}\, M^{1\,BB}\, G_{BA}\,.$$

The propagator is modified-"dark" matter effect. The gravitational field:

$$h_I \,=\, h_{0\,I} \,-\, \frac{2}{m_p^2}\int G_{IJ}\,\frac{\delta\,\Gamma_{int}}{\delta h_J} + \xi_I\,;\;\; G_I^{-1} h_{0\,I} \,=\, 0\,;\;\; I, J = A, B\,.$$

Cosmological constant: first variant

- We have to define the connection of s and h fields. In the case of the Schwinger-Keldysh like formulation we define:

$$g_{\mu\nu}^{A,B}(x) = g_{\mu\nu}^{A,B\,0}(x) + h_{\mu\nu}^{A,B}(x)\,, \quad s_A = \frac{h_A}{2}\,, \quad s_B = \frac{h_B}{2}$$

To leading order precision CC is:

$$\Lambda_A = \frac{1}{m_p^2}\,\frac{\delta\,\Gamma}{\delta\,\overline{h}_A}\bigg|_{\overline{h}_A=0} = \frac{m}{4\,m_p^2}\,\overline{\psi}_A\,\psi_A\,, \quad \Lambda_B = \frac{1}{m_p^2}\,\frac{\delta\,\Gamma}{\delta\,\overline{h}_B}\bigg|_{\overline{h}_B=0} = -\frac{m}{4\,m_p^2}\,\overline{\psi}_B\,\psi_B$$

$$m\,\overline{\psi}_{A,B}\,\psi_{A,B} = \left(T_{0\,\mu}^{\mu}\right)_{A,B}$$

The one loop-contributions in this case are not fully canceled:

$$\begin{aligned} s_A &= \frac{h_A}{2} = \frac{1}{2}\,h_{0\,A} - \int G_{AA}\,\Lambda_{0\,A} + \cdots \\ s_B &= \frac{h_B}{2} = \frac{1}{2}\,h_{0\,B} - \int G_{BB}\,\Lambda_{0\,B} + \cdots \end{aligned}$$

even for $h_{0\,A} = h_{0\,B}$, to next order the fields are not the same.

Cosmological constant: second variant

- Vierbein gravity fields are the same for the matter fields:

$$g^{A,B}_{\mu\nu}(x) = g^{A,B\,0}_{\mu\nu}(x) + h^{A,B}_{\mu\nu}(x)\,, \quad \bar{s}_{\mu\nu} = \frac{1}{2}\,\bar{h}_{\mu\nu} = \frac{1}{4}\left(\bar{h}^{A}_{\mu\nu} + \bar{h}^{B}_{\mu\nu}\right)$$

with action:

$$\begin{aligned}
\Gamma \; = \; & \frac{m_p^2}{4}\int d^4x\,\bar{h}^{\mu\nu}_{A}\,G^{-1}_{AA}\,\bar{h}^{A}_{\mu\nu} + \frac{m_p^2}{4}\int d^4x\,\bar{h}^{\mu\nu}_{B}\,G^{-1}_{BB}\,\bar{h}^{B}_{\mu\nu} + \int d^4x\,\bar{h}^{\mu\nu}_{A}\,T_{\mu\nu\,A} + \\
+ \; & \int d^4x\,\bar{h}^{\mu\nu}_{B}\,T_{\mu\nu\,B} + \eta_{\mu\nu}\int d^4x\,\bar{h}^{\mu\nu}_{A}\,\Lambda_{0\,A} + \eta_{\mu\nu}\int d^4x\,\bar{h}^{\mu\nu}_{B}\,\Lambda_{0\,B} - \\
- \; & \frac{1}{2}\int d^4x\int d^4y\,\bar{h}^{\mu\nu}_{A}(x)\left(M^{1\,AA}_{\mu\nu\,\rho\sigma} + M^{1\,BB}_{\mu\nu\,\rho\sigma}\right)_{xy}\,\bar{h}^{\rho\sigma}_{A}(y) - \\
- \; & \frac{1}{2}\int d^4x\int d^4y\,\bar{h}^{\mu\nu}_{B}(x)\left(M^{1\,AA}_{\mu\nu\,\rho\sigma} + M^{1\,BB}_{\mu\nu\,\rho\sigma}\right)_{xy}\,\bar{h}^{\rho\sigma}_{B}(y) - \\
- \; & \frac{1}{2}\int d^4x\int d^4y\,\bar{h}^{\mu\nu}_{A}(x)\left(M^{1\,AA}_{\mu\nu\,\rho\sigma} + M^{1\,BB}_{\mu\nu\,\rho\sigma}\right)_{xy}\,\bar{h}^{\rho\sigma}_{B}(y) - \\
- \; & \frac{1}{2}\int d^4x\int d^4y\,\bar{h}^{\mu\nu}_{B}(x)\left(M^{1\,AA}_{\mu\nu\,\rho\sigma} + M^{1\,BB}_{\mu\nu\,\rho\sigma}\right)_{xy}\,\bar{h}^{\rho\sigma}_{A}(y) - \\
- \; & \frac{1}{2}\int d^4x\int d^4y\,\bar{h}^{\mu\nu}_{A}(x)\,M^{1\,AB}_{\mu\nu\,\rho\sigma}\,\bar{h}^{\rho\sigma}_{B}(y) - \frac{1}{2}\int d^4x\int d^4y\,\bar{h}^{\mu\nu}_{B}(x)\,M^{1\,BA}_{\mu\nu\,\rho\sigma}\,\bar{h}^{\rho\sigma}_{A}(y)
\end{aligned}$$

Cosmological constant: second variant

- CC we have in this case:

$$\Lambda_{0A} = \Lambda_{0B} = \frac{1}{8}\,\frac{m}{m_p^2}\,\left(\overline{\psi}_A(z)\,\psi_A(z) - \overline{\psi}_B(z)\,\psi_B(z)\right) = \frac{1}{8\,m_p^2}\,\left(T^{\mu}_{A\,\mu} - T^{\mu}_{B\,\mu}\right)$$

There are two possibilities, the trivial one with parralel time axis

$$T^{\mu}_{B\,\mu} = T^{\mu}_{A\,\mu}$$

and with opposite time directions for the A, B manifolds

$$t_{A,B} = \frac{T}{2} \pm t\,;\quad \zeta = t/T$$

$$\Lambda_{0A} = \frac{1}{8m_p^2}\left(T^{\mu}_{A\,\mu}(\frac{T}{2}+t) - T^{\mu}_{B\,\mu}(\frac{T}{2}-t)\right) \approx \frac{1}{4Tm_p^2}\left(\frac{\partial T^{\mu}_{0A\,\mu}}{\partial\zeta} + \frac{\partial T^{\mu}_{0B\,\mu}}{\partial\zeta}\right)t$$

The cosmological constant is changing with time and rate of the the change is defined by the change of the trace of the energy-momentum tensor, which is due a new matter creation and/or annihilation in our Universe.

Cosmological constant: third variant

- We can consider the following possibility as well:

$$g^{A,B}_{\mu\nu}(x) = g^{A,B\,0}_{\mu\nu}(x) + \frac{1}{2}\left(h^{A}_{\mu\nu}(x) + h^{B}_{\mu\nu}(x)\right)\,,\;\; \bar{s}_{\mu\nu} = \frac{1}{2}\,\bar{h}_{\mu\nu} \;=\; \frac{1}{4}\left(\bar{h}^{A}_{\mu\nu} + \bar{h}^{B}_{\mu\nu}\right)$$

with action

$$\begin{aligned}\Gamma \;\; &= \;\; \frac{m_p^2}{16}\int d^4x\,\bar{h}^{\mu\nu}_{A}\left(G^{-1}_{AA} + G^{-1}_{BB}\right)\bar{h}^{A}_{\mu\nu} + \frac{m_p^2}{16}\int d^4x\,\bar{h}^{\mu\nu}_{B}\left(G^{-1}_{BB} + G^{-1}_{AA}\right)\bar{h}^{B}_{\mu\nu} + \\ &+ \;\; \frac{m_p^2}{8}\int d^4x\,\bar{h}^{\mu\nu}_{A}\left(G^{-1}_{AA} + G^{-1}_{BB}\right)\bar{h}^{B}_{\mu\nu} + \int d^4x\,\bar{h}^{\mu\nu}_{A}\,T_{\mu\nu\;A} + \cdots\end{aligned}$$

There is a special free fields propagator, for the particular types of G^{-1}_{AA} and G^{-1}_{BB} it can describes a theory without free asymptotic gravitons, similarly to Wheeler-Feynman propagator. The cosmological constant is this case is the same (to LO) as in the second variant, but propagator's structure ("dark" matter issue) is different from the previous case.

Conclusion:

- The CPTM symmetry defines an additional manifold populated by negative mass (gravitational) matter, the number of matter fields is doubling (at least).
- For the same external gravity field legs attached to the loop diagrams, a cancellations of the particular, at least, one-loop contributions to the general effective action (momentum-energy tensor) of both manifolds occurs. For the full cancellation, the mechanism requires a justification of the unified gravity field for A and B manifolds in the Schwinger-Keldysh like construction of the formalism, otherwise the only particular cancellation takes place.
- Without special "mixing" mechanisms, the A and B manifolds do not interact. The interactions are due the Schwinger-Keldysh non-diagonal Green's functions or/and introduction of the interactions of the matter of both separated manifolds with two weak gravity fields in Dirac equations. There is the single unified gravity field for both manifolds as option as well of course.
- On the classical level the CC is small and equal or to the trace of the matter's momentum-energy tensor for each manifold separately or to the difference of the A,B manifolds tensors.

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Conclusion:

- The dark matter appears in the approach inevitably in the form of the gravity propagator modification due the B manifold influence.
- The approach is falsifiable, namely each from the variants provides different values of cosmological constant and different ways of propagators modifications The cosmological constant and propagators can be calculated at least to one-loop precision.
- The interesting issue is about the renormalizability properties of the model-can also help to choose the particular scheme.

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