POINCARE BREAKING AND GAUGE INVARIANCE:
A ROAD TO EMERGENT GRAVITY AND NEW PARTICLES

DURMUŞ A. DEMİR

Sabancı Üniversitesi

DICE2022 (Castiglioncello, 19-23 September 2022)
In effective QFTs with a UV cutoff $\Lambda$, all gauge bosons acquire masses in proportion to $\Lambda$.

- Gauge symmetries, broken explicitly by $\Lambda$, can be restored by invoking “Higgs mechanism”.

- The anticipated “Higgs field” must break Poincare symmetry since the cutoff $\Lambda$ does so.

- The “Higgs field” can be linked to curvature as they both break the Poincare symmetry.

- Gravity emerges then holographically as a completion of the flat spacetime effective QFT.

- Proper emergence of gravity brings in a plethora of new particles that do not have to couple to the known ones.
AN ILLUSTRATIVE CASE: SAKHAROV’S INDUCED GRAVITY

- Sakharov’s setup involves a flat spacetime QFT bordered in the UV by a UV cutoff $\Lambda$.

- Matter loops are assumed to have a curved metric $g_{\alpha\beta}$, and they can induce gravity therefore if $\Lambda$ lies at the Planck scale.

- ... and yet Sakharov’s induced gravity comes with all sort of UV sensitivity problems in the QFT sector:

$$S_{\text{ind}} = \int d^4x \sqrt{-g} \left\{ -a_R \Lambda^2 R(g) - a_O \Lambda^4 - \sum_m c_m m^2 \Lambda^2 - a_\phi \Lambda^2 \phi \phi^\dagger - a_V \Lambda^2 g_{\alpha\beta} \text{tr}[V^\alpha V^\beta] \right\}$$

  - Newton’s constant ($a_R \Lambda^2 \equiv \frac{1}{16\pi G_N}$)
  - Planckian vacuum energy (cosmological constant problem)
  - Planckian gauge boson masses (explicit gauge symmetry breaking)
  - Planckian scalar masses (gauge hierarchy problem)

Can gravity emerge in a way alleviating these problems?
We may restore gauge symmetries by invoking some sort of “Higgs mechanism”.

Quartic and quadratic corrections from matter loops in flat spacetime:

$$\delta S(\eta, \Lambda) = \int d^4x \sqrt{-\eta} \left\{ -c_O \Lambda^4 - \sum_m c_m m^2 \Lambda^2 - c_\phi \Lambda^2 \phi^\dagger \phi + c_V \Lambda^2 \eta_{\alpha\beta} \text{tr}[V^\alpha V^\beta] \right\}$$

$$c_{\text{Higgs}} \approx \frac{3h_t^2}{4\pi^2}$$

$$c_{g^a}^{(SM)} = \frac{21g_3^2}{16\pi^2}$$

$$c_{W^i}^{(SM)} = \frac{21g_2^2}{16\pi^2}$$

$$c_B^{(SM)} = \frac{39g_1^2}{32\pi^2}$$

$$c_O = \frac{n_b - n_f}{64\pi^2}$$

$$\sum_m c_m m^2 \propto \text{str}[M^2]$$

Flat metric $\eta_{\mu\nu}$

All the bosons ($n_b$) and fermions ($n_f$)

$$(\text{mass})^2 \text{ matrix of fields}$$
LOOP-INDUCED GAUGE BOSON MASS TERM

- Gauge boson anomalous mass term (flat metric): $\delta S_V(\eta, \Lambda) \equiv \int d^4x \sqrt{-\eta} c_V \text{tr}[V^\alpha \Lambda^2 \eta_{\alpha\beta} V^\beta]$

- Carrying gauge boson mass term to curved spacetime:

  - Consider these two kinetic structures:

    $I_V(\eta) = \int d^4x \sqrt{-\eta} c_V \text{tr}[V^{\alpha\beta} V_{\alpha\beta}] \quad \text{by-parts} \quad \tilde{I}_V(\eta) = \int d^4x \sqrt{-\eta} c_V \text{tr}[V^\alpha (-2^2 \eta_{\alpha\beta} + D_\alpha D_\beta + iV_{\alpha\beta}) V^\beta + \partial_\alpha (V_\beta V^\alpha\beta)]$

  - Their sensitivity to spacetime curvature enable us to regularize the gauge boson mass term:

    $-I_V(\eta) + \tilde{I}_V(\eta) = 0$

    $I_V(g) + \tilde{I}_V(g) = -\int d^4x \sqrt{-g} c_V \text{tr}[V^\alpha R_{\alpha\beta} (g^\Gamma) V^\beta]$

    $\delta \hat{S}_V(g, \Lambda) = -I_V(g) + \tilde{I}_V(g) + \delta S_J(g, \Lambda) = \int d^4x \sqrt{-g} c_V \text{tr}[V^\alpha (\Lambda^2 g_{\alpha\beta} - R_{\alpha\beta} (g^\Gamma)) V^\beta]$

    $\delta \hat{S}_V(\eta, \Lambda) = -I_V(\eta) + \tilde{I}_V(\eta) + \delta S_J(\eta, \Lambda) = \delta S_J(\eta, \Lambda)$

We proceed with this regularized gauge boson anomalous mass term.
RESTORATION OF GAUGE SYMMETRIES

- Mass term for a vector boson $V_\mu$ (Proca field):

$$ S_V(g, M_V) = \int d^4x \sqrt{-g} M_V^2 \eta_{\alpha\beta} \text{tr}[V^\alpha V^\beta] $$

<table>
<thead>
<tr>
<th></th>
<th>$M_V^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauge breaking</td>
<td>Yes</td>
</tr>
<tr>
<td>Poincare breaking</td>
<td>No</td>
</tr>
</tbody>
</table>

- Loop-induced anomalous mass term for a gauge boson $V_\mu$:

$$ \delta S_V(g, \Lambda) = \int d^4x \sqrt{-g} c_V \text{tr}[V^\alpha (\Lambda^2 g_{\alpha\beta} - R_{\alpha\beta(9\Gamma)}) V^\beta] $$

<table>
<thead>
<tr>
<th></th>
<th>$\Lambda^2 - R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauge breaking</td>
<td>Yes</td>
</tr>
<tr>
<td>Poincare breaking</td>
<td>Yes</td>
</tr>
</tbody>
</table>

E. Fermi, La Ricerca Scientifica 4, 491 (1933)

M. Peskin & D. Schroeder, Quantum Field Theory (1995)
RESTORATION OF GAUGE INVARIANCE

Higgsing massive gauge boson:

\[ S_V(g, M_V) = \int d^4x \sqrt{-g} \, M_V^2 g_{\alpha\beta} \text{tr}[V^\alpha V^\beta] \]

\[ M_V^2 \longrightarrow \text{“spurion } \phi \text{”} \]  
[Poincare-conserving]

\[ S_V(g, \phi) = \int d^4x \sqrt{-g} \, g_{\alpha\beta} \text{tr}[\phi^\dagger V^\alpha V^\beta \phi] \]

\[ \text{spurion } \longrightarrow \text{“Higgs”} \]

\[ S_V(g, \phi) = \int d^4x \sqrt{-g} \, g_{\alpha\beta} \text{tr}[(D^\alpha \phi)^\dagger D^\beta \phi] \]

P. Higgs, Phys. Rev. Lett. 13, 508 (1964)

Higgsing anomalously massive gauge boson:

\[ \delta S_V(g, \Lambda) = \int d^4x \sqrt{-g} c_V \, \text{tr}[V^\alpha (\Lambda^2 g_{\alpha\beta} - R_{\alpha\beta}(9\Gamma)) V^\beta] \]

\[ \Lambda^2 \longrightarrow \text{“spurion } \Sigma \text{”} \]  
[Poincare-breaking]

\[ \delta S_V(g, \Sigma) = \int d^4x \sqrt{-g} \, c_V \, \text{tr}[V^\alpha (\Sigma(x) g_{\alpha\beta} - R_{\alpha\beta}(9\Gamma)) V^\beta] \]

What is this spurion \( \Sigma \)? It cannot be \( \phi^\dagger \phi \) as it cannot break Poincare symmetry! Can it be related to spacetime curvature?
In an arbitrary second-quantized theory with no presumed properties, "... lack of translational invariance would just be interpreted as the effect of gravitational fields being present, which are not translational invariant."


Belonging inherently to the flat spacetime, QFTs have one natural Poincare (translation) breaking source: the UV cutoff $\Lambda$.

DD, Gen. Rel. Grav. 53, 22 (2021)

On physical grounds, therefore, there is a Poincare affinity between the UV cutoff $\Lambda$ in flat spacetime and curvature $\mathbb{R}$ in curved spacetime.

DD, Gen. Rel. Grav. 53, 22 (2021)
**RESTORATION OF GAUGE INVARIANCE**

**Higgsing massive gauge boson:**

\[ S_V(g, M_V) = \int d^4 x \sqrt{-g} \, M_V^2 g_{\alpha\beta} \text{tr}[V^\alpha V^\beta] \]

\[ M_V^2 \quad \text{“spurion } \phi \text{” (Poincare-conserving)} \]

\[ S_V(g, \phi) = \int d^4 x \sqrt{-g} \, g_{\alpha\beta} \text{tr}[\phi^\dagger V^\alpha V^\beta \phi] \]

\[ \text{spurion } \Rightarrow \text{“Higgs”} \]

\[ S_V(g, \phi) = \int d^4 x \sqrt{-g} \, g_{\alpha\beta} \text{tr}[(D^\alpha \phi)^\dagger D^\beta \phi] \]

**Higgsing anomalously massive gauge boson:**

\[ \delta \hat{S}_V(g, \Lambda) = \int d^4 x \sqrt{-g} c_V \text{tr}[V^\alpha (\Lambda^2 g_{\alpha\beta} - R_{\alpha\beta}(g \Gamma)) V^\beta] \]

\[ \Lambda^2 \quad \text{“spurion } \Sigma \text{” (Poincare-breaking)} \]

\[ \delta \hat{S}_V(g, \Sigma) = \int d^4 x \sqrt{-g} c_V \text{tr}[V^\alpha (\Sigma(x) g_{\alpha\beta} - R_{\alpha\beta}(g \Gamma)) V^\beta] \]

\[ \Sigma(x) \, g_{\mu\nu}(x) = R_{\mu\nu}(\Gamma(x)) \quad \text{(affine curvature } \mathbb{R}) \]

\[ \delta \hat{S}_V(g, \mathbb{R}) = \int d^4 x \quad \text{We can now form a symmetry-driven Palatini gravity (SPG) theory with the inclusion of non-gauge sectors.} \]
Equation of motion for the affine connection $\Gamma^\lambda_{\alpha\beta}$ (covariant derivative wrt $\Gamma^\lambda_{\alpha\beta}$):

\[ \Gamma^\lambda_{\alpha\beta} Q_{\lambda\beta} = 0 \]

Field metric:

\[ Q_{\alpha\beta} = \left( \frac{1}{16\pi G_N} + \frac{c_S}{4} g^{\alpha\beta} S^+ S + \frac{c_0}{8} g^{\mu\nu} R_{\mu\nu}(\Gamma) \right) g_{\alpha\beta} - c_V \text{tr}[V^\alpha V^\beta] \]

Newton's constant:

\[ G_N^{-1} = 4\pi \sum_m c_m m^2 \xrightarrow{\text{1-loop}} 4\pi \text{str}[M^2] \]
General solution for the affine connection:

\[ \Gamma^\lambda_{\alpha \beta} = g \Gamma^\lambda_{\alpha \beta} + \frac{1}{2} (Q^{-1})^{\lambda \rho} (\nabla_\alpha Q_{\beta \rho} + \nabla_\beta Q_{\rho \alpha} - \nabla_\rho Q_{\alpha \beta}) \]

Enormity of the Planck scale \( G_N^{-1/2} \) leads to:

- \[ \Gamma^\lambda_{\alpha \beta} = g \Gamma^\lambda_{\alpha \beta} + 8\pi G_N (\nabla_\alpha Q^\lambda_{\beta} + \nabla_\beta Q^\lambda_{\alpha} - \nabla^\lambda Q_{\alpha \beta}) + O(G_N^2) \]

- \[ \mathbb{R}^\alpha_{\beta \gamma} (\Gamma) = R_{\alpha \beta} (g \Gamma) + 8\pi G_N \left( \nabla^\mu \nabla_\alpha \delta^\nu_{\beta} + \nabla^\nu \nabla_\alpha \delta^\mu_{\beta} - \Box \delta^\mu_{\alpha} \delta^\nu_{\beta} - \nabla_\alpha \nabla_\beta g^{\mu \nu} + (\alpha \leftrightarrow \beta) \right) Q_{\mu \nu} + O(G_N^2) \]

Integrating-out the affine connection derivatives of the scalars \( \phi \) and gauge fields \( V_i^\alpha \).
EMERGENCE OF THE GR FROM RESTORATION OF GAUGE SYMMETRIES

Integration-out of $\mathbb{R}_{\alpha\beta}(\Gamma)$ reduces SPG to the GR ($R(g) = g^{\alpha\beta} R_{\alpha\beta}(g\Gamma)$):

$$\int d^4x \sqrt{-g} \left\{ \frac{1}{16\pi G_N} g^{\alpha\beta} \mathbb{R}_{\alpha\beta}(\Gamma) \right\} = \int d^4x \sqrt{-g} \left\{ -\frac{R(g)}{16\pi G_N} + O(G_N) \right\}$$

GR emerged!

$$\int d^4x \sqrt{-g} \left\{ -c_S g^{\alpha\beta} \mathbb{R}_{\alpha\beta}(\Gamma) S^\dagger S \right\} = \int d^4x \sqrt{-g} \left\{ -\frac{c_S}{4} R(g) \phi^\dagger \phi + O(G_N) \right\}$$

quadratic UV sensitivity of scalar masses gives cause to curvature-scalar fields couplings

$$\int d^4x \sqrt{-g} \left\{ -\frac{c_0}{16} \left( g^{\alpha\beta} \mathbb{R}_{\alpha\beta}(\Gamma) \right)^2 \right\} = \int d^4x \sqrt{-g} \left\{ -\frac{c_0}{16} (R(g))^2 + O(G_N) \right\}$$

quartic UV sensitivity in flat spacetime gives cause to quadratic curvature terms

gauge symmetries got restored!
Summary: Higgs Mechanism

\[ M_0^2 \eta^{\mu \nu} V_\mu V_\nu \]

\[ \phi^\dagger \phi \eta^{\mu \nu} V_\mu V_\nu \]

\[ \eta^{\mu \nu} (D_\mu \phi)^\dagger D_\nu \phi \]

spurion \( \phi \)

dynamical \( \phi \)

\[ \langle \phi \rangle = 0 \]
massless \( V_\mu \)

\[ \langle \phi \rangle \propto M_V \]
massive \( V_\mu \) and \( \phi - \langle \phi \rangle \) particle

Max of energy \( \Rightarrow \) massless \( V_\mu \) (exact gauge symmetry)

Min of energy \( \Rightarrow \) massive \( V_\mu \) (broken gauge symmetry)

Summary: Affine Curvature Mechanism

\[ c_V \Lambda^2 \eta^{\mu \nu} V_\mu V_\nu \]

\[ c_V V_\mu (\Lambda^2 g^{\mu \nu} - R^{\mu \nu} (g \Gamma)) V_\nu \]

\[ c_V V_\mu (\mathbb{R}^{\mu \nu} (\Gamma) - R^{\mu \nu} (g \Gamma)) V_\nu \]

general covariance

\( (\eta^{\mu \nu} \rightarrow g_{\mu \nu}, \partial_\mu \rightarrow V_\mu) \)

spurion \( \mathbb{R} (\Gamma) \)

\( \Lambda^2 g^{\mu \nu} \rightarrow \mathbb{R}^{\mu \nu} (\Gamma) \)

\[ \mathbb{R}_{\mu \nu} (\Gamma) = \Lambda^2 g_{\mu \nu} \]
massive \( V_\mu \)

\[ \Gamma \approx \sigma \Gamma \]

\[ \mathbb{R} (\Gamma) \approx R (\sigma \Gamma) \]

\[ M_0^2 \propto \text{str} [M^2] \]

massless \( V_\mu \),

natural scalars and general relativity (GR)

Non-extrema of SPG action \( \Rightarrow \) anom. massive \( V_\mu \) (broken gauge symmetry)

Extremum of SPG action \( \Rightarrow \) massless \( V_\mu \) (exact gauge symmetry and GR)
RENORMALIZED QFT + EMERGENT GRAVITY:

\[ S_{QFT+GR} = S(g, \psi) + \delta S(g, \psi) + \int d^4x \sqrt{-g} \left\{ -\frac{R(g)}{16\pi G_N} - \frac{c_0}{16} R(g)^2 - \frac{c_\phi}{4} R(g)\phi^\dagger \phi + \mathcal{O}(G_N) \right\} \]

QFT with

- dimensional-regularization in the classical curved background geometry,
- loop corrections computed in the flat spacetime QFT

\[ R + R^2 \] gravity with

- non-minimal coupling to scalars,
- \( \mathcal{O}(G_N) \) remainder involving derivatives of scalars and gauge fields,
- loop-induced coefficients computed in the flat spacetime QFT.

\textit{symmetry-restoring emergent gravity = "symmergent gravity"}
HOLOGRAPHIC STRUCTURE

Energy density in flat spacetime:

\[ c_o \Lambda^4 + c_m m^2 \Lambda^2 + c_\phi \Lambda^2 \phi^\dagger \phi + c_V \Lambda^2 \text{tr}[V^\alpha V_\alpha] \]

Curvature sector \((\Lambda^2_{IR} \propto R)\):

\[ \left( \frac{1}{8\pi G_N} + \cdots \right) R = \frac{c_o}{16} R^2 + \frac{R}{8\pi G_N} + \frac{c_\phi}{4} R \phi^\dagger \phi \]

new massive particles are a must for Newton’s constant to take right value

neutrinos must be Dirac for the Higgs mass to remain stable

black hole shadow, photon radius and quasiperiodic oscillations show distinctive features

dark matter must couple with a strength ≤ \( m_h^2 / m_{DM}^2 \) to known particles for the Higgs mass to remain stable

Higgs-curvature coupling is about 10% in the SM, and deviations indicate Higgs coupling to new particles

pure Einstein gravity is attained if bosons and fermions are equal in number

detection of new particles can wait for high-luminosity LHC

cosmic inflation is expected to be of Starobinsky type

DD, Gen. Rel. Grav. 53, 22 (2021)


DD, Galaxies 9, 2 (2021)

I. Çimdiker, Phys. Dark Universe 30, 100736 (2020)

DD, B. Puliçe & N. Sönmez, work in progress (2022)

I. Çimdiker, DD & A. Övgün, Phys. Dark Univ. 34, 100900 (2021)


GRAZIE MILLE !
BACK UP SLIDES 1
Ø Log $\Lambda$ corrections to particle masses can cause equivalence principle violation under the Poincare affinity $\Lambda^2 \Rightarrow \mathbb{R}(x)$.

Ø This violation can be prevented by detaching power-law and logarithmic corrections so that:

- **power-laws** involve $\Lambda$
- **logarithms** involve a different scale $\mu$

Ø The **detached regularization** can be constructed as an extension of the dimensional regularization:

- DimReg continues loop amplitudes from 4 to $D$ momentum space dimensions ($n = 0, 1, 2$)

$$I_n = \int \frac{d^4 p}{(2\pi)^4} \frac{1}{(p^2 - m^2 + i0)^n} \quad \Rightarrow \quad \mu^{4-D} \int \frac{d^D p}{(2\pi)^D} \frac{1}{(p^2 - m^2 + i0)^n}$$

and comprises logarithmic, quadratic and quartic divergences as $D \to 4$, $D \to 2$ and $D \to 0$.


- DimReg can be extended to form the **Detached Regularization**:

$$I_n = \mu^{4-D} \int \frac{d^D p}{(2\pi)^D} \frac{1}{(p^2 - m^2 + i0)^n} \quad \Rightarrow \quad f(\Lambda, \mu; D, n) \int \frac{d^D p}{(2\pi)^D} \frac{1}{(p^2 - m^2 + i0)^n}$$

What is the function $f(\Lambda, \mu; D, n)$?
If $\Lambda$-dependence is to reminisce the cutoff regularization and if DimReg results are to remain unchanged then the function $f(\Lambda, \mu; D, n)$ must have the form:

$$f(\Lambda, \mu; D, n) = \left(\frac{8 - 2D}{8 - D^2}\right)^2 \frac{1}{(8\pi)^{2-n}} \Lambda^{4-2n} \mu^{2n-D} + \left(\frac{D(D-2)(16-3D)}{32}\right)^2 \mu^{4-D}$$

vanishes as $D \to 4$

vanishes as $D \to 0$ and $D \to 2$

Then, in the $\overline{MS}$ renormalization scheme, the loop amplitudes take the detached form:

$$I_n = \begin{cases} 
\frac{i \Lambda^4}{32\pi^2} & \text{for } D = 0, n = 0 \\
-\frac{i\Lambda^2}{16\pi^2} \left(1 - \log \frac{\mu}{m}\right) & \text{for } D = 2, n = 1 \\
i \frac{m^2}{16\pi^2} \left(1 + 2 \log \frac{\mu}{m}\right) & \text{for } D = 4, n = 1 \\
\frac{i}{8\pi^2} \log \frac{\mu}{m} & \text{for } D = 4, n = 2 
\end{cases}$$

Detached regularization:
- $\Lambda$ for power-law corrections
- $\mu$ for logarithmic corrections

DD, talk at Gravitex21 (2021)
DD, talk at FFP16 (2022)
DD, C. Karahan & O. Sargin, submitted (2022)
BACK UP SLIDES 2
- SM is a renormalizable QFT of the strong, weak and electromagnetic interactions.
- SM agrees with all the existing experimental data.
- SM is a natural QFT in isolation.

- SM cannot account for empirical facts like galactic flat rotation curves, neutrino masses, baryon asymmetry, inflation, and neutron magnetic moment.
- SM Higgs sector is destabilized by high-scale physics. (e.g. Heavy RH neutrinos generating the neutrino Majorana masses destabilize the Higgs mass.)
- SM does not involve gravity. (Basically, GR is not a renormalizable QFT.)


Successes

1. Give priority to gravity.
2. Study other problems in the setup involving gravity.
THE SM DOESN’T ACCORD WITH GRAVITY BECAUSE ...

- GR is not a renormalizable QFT.
  M. Goroff & A. Sagnotti, NPB 266, 709 (1986)

- Classical GR is not eligible since QFTs (like the SM) are inherently specific to the flat spacetime with their Poincare-invariant vacuum states. They cannot thus be continued to curved spacetime.

- Strings, LQG, asymptotic safety, causal dynamical triangulations and others are currently “work in progress”.

  But the SM may accord with induced/emergent gravity as it arises from the matter loops.
Quantum corrections involve powers of $\Lambda$ with $\log \mu$ - dependent loop factors:

$$
\delta S = \int d^4 x \sqrt{-\eta} \left\{ -c_O \Lambda^4 - \sum_m c_m m^2 \Lambda^2 - c_\phi \Lambda^2 \phi \phi^\dagger + c_V \Lambda^2 \eta_{\alpha\beta} \text{tr}[V^\alpha V^\beta] + \delta L(\eta, \log \mu, \psi) \right\}
$$

- $c_O (\log \mu) = \frac{n_b - n_f}{64\pi^2}$, where $n_b$ are bosons and $n_f$ are fermions.
- $c_m (\log \mu) m^2 = \frac{1}{32\pi^2} \text{str} \left[ M^2 \left( 1 + \frac{1}{2} \log \frac{M^2}{\mu^2} \right) \right]$ for each mass squared $m^2$.
- $c_{\text{Higgs}} (\log \mu) \approx \frac{3h_t^2}{4\pi^2}$ for Higgs corrections.

**Table of Log $\mu$ Corrections**

<table>
<thead>
<tr>
<th>Term</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_g^{(\text{SM})} (\log \mu)$</td>
<td>$\frac{21g_3^2}{16\pi^2}$</td>
</tr>
<tr>
<td>$c_w^{(\text{SM})} (\log \mu)$</td>
<td>$\frac{21g_2^2}{16\pi^2}$</td>
</tr>
<tr>
<td>$c_B^{(\text{SM})} (\log \mu)$</td>
<td>$\frac{39g_1^2}{32\pi^2}$</td>
</tr>
</tbody>
</table>

**References**

- DD, talk at Gravitex21 (2021)
- DD, talk at FFP16 (2022)
- DD, C. Karahan & O. Sargin, submitted (2022)
In an arbitrary second-quantized theory with no presumed properties, “… lack of translational invariance would just be interpreted as the effect of gravitational fields being present, which are not translational invariant.”

Belonging inherently to the flat spacetime, QFTs have one natural Poincare (translation) breaking source: the UV cutoff $\Lambda$.
DD, Gen. Rel. Grav. 53, 22 (2021)

On physical grounds, therefore, there is a Poincare affinity between the UV cutoff $\Lambda$ in flat spacetime and curvature $\mathbb{R}$ in curved spacetime.
DD, Gen. Rel. Grav. 53, 22 (2021)