Quantum torsion with non-zero standard deviation: non-perturbative approach for cosmology

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# Gravity quantizationTorsion

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#### Feynman diagrams



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Nonperturbative quantization for gravity

#### Operator equations

$$\begin{aligned} \hat{\Gamma}^{\rho}{}_{\mu\nu} &= \hat{G}^{\rho}{}_{\mu\nu} + \hat{K}^{\rho}{}_{\mu\nu}, \\ \hat{R}_{\mu\nu} - \frac{1}{2}\hat{g}_{\mu\nu}\hat{R} &= \varkappa \hat{T}_{\mu\nu}, \\ \hat{G}^{\rho}{}_{\mu\nu} &= \frac{1}{2}\hat{g}^{\rho\sigma}\left(\frac{\partial \hat{g}_{\mu\sigma}}{\partial x^{\nu}} + \frac{\partial \hat{g}_{\nu\sigma}}{\partial x^{\mu}} - \frac{\partial \hat{g}_{\mu\nu}}{\partial x^{\sigma}}\right) \end{aligned}$$

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Let us note that all quantities in Eqs are operators. This leads to a difficult problem because now one has to solve the operator differential equations. Actually this is the main problem of nonperturbative quantization (that is well known.)

The non-perturbative quantization for Einstein gravity means that the quantum operators of metrics  $\hat{g}_{\mu
u}$ , Christoffel symbols  $\hat{G}^{
ho}_{\mu
u}$  and torsion  $\hat{Q}_{\mu
u}{}^{
ho}$  obey the operator Einstein -Cartan equations.

Vector field approximation for non-perturbative quantization of torsion

In our approach we consider the torsion with zero expectation value



but with non-zero dispersion

$$\left\langle \left( \hat{Q}^{
ho}_{\ \mu
u} 
ight)^2 
ight
angle 
eq 0.$$

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### Vector field approximation for non-perturbative quantization of torsion

$$\left\langle \hat{Q}_{
ho_1\mu_1
u_1}(\mathbf{x}_1)\hat{Q}_{
ho_2\mu_2
u_2}(\mathbf{x}_2) \right
angle pprox \ \epsilon_{
ho_1\mu_1
u_1lpha}\epsilon_{
ho_2\mu_2
u_2eta} A^{lpha}(\mathbf{x}_1) A^{eta}(\mathbf{x}_2).$$

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## The expectation values of the Ricci and scalar curvature operators

$$egin{aligned} \left\langle \hat{R}_{\mu
u} 
ight
angle &= ilde{R}_{\mu
u} + 2 \left( g_{\mu
u} A_{lpha} A^{lpha} - A_{\mu} A_{
u} 
ight), \ \left\langle \hat{R} 
ight
angle &= ilde{R} + 6 A^{\mu} A_{\mu}, \end{aligned}$$

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#### Einstein equations

$$egin{aligned} & ilde{R}_{\mu
u}-rac{1}{2}g_{\mu
u} ilde{R}-(g_{\mu
u}A_{lpha}A^{lpha}+2A_{\mu}A_{
u})=\ &arkappa T_{\mu
u}, \end{aligned}$$

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In order that the Einstein equations are not overdetermined we demand that

 $\left\langle \left( \hat{R}^{\mu}_{\nu} - \frac{1}{2} \delta^{\mu}_{\nu} \hat{R} \right) \right\rangle_{\mu} = 0$ 

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The desired equation for the vector field  $A_{\mu}$ 

 $(\delta^{\mu}_{
u}A^{lpha}A_{lpha}+2A^{\mu}A_{
u})_{;\mu}=0$ 

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Non-perturbative quantum torsion in cosmology

Now we would like to consider cosmology with quantum corrections coming from the torsion.

$$ds^{2} = a^{2}(\eta) \left\{ d\chi^{2} - \left[ d\chi^{2} + \left( \frac{\sin \sqrt{k}\chi}{\sqrt{k}} \right)^{2} \left( d\theta^{2} + \sin^{2}\theta d\varphi^{2} \right) \right] \right\}$$

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## We take the vector field $A_{\mu}$ as follows $A_{\mu} = (\phi(\eta), 0, 0, 0)$ .

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The averaged Einstein equations in the presence of matter in the form of dust are



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Quantum torsion may lead to a qualitative change of the evolution of the Universe. For example, a closed Universe with fluctuating quantum torsion may have an evolution similar to a closed, open or flat (non-torsion) Universe, depending on the value of the quantum fluctuation dispersion of the torsion

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