“Quantum Gravity corrections at the Planck time”

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Related references:

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- S. Das and ECV, Can.J.Phys.87:233-240,2009. e-Print: arXiv:0901.1768 [hep-th]
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Outline

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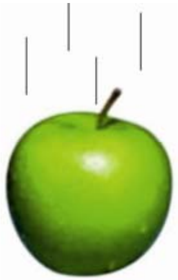
Motivation

Gravity is a universal and fundamental force.
Anything that has energy creates gravity and is affected by it.

Newton's constant G often means that associated classical effects are too weak to be measurable.

Prediction of candidate theories of QG (such as String Theory) and black hole physics : *minimum measurable length.*

Model-independent prediction and can be understood as follows:
HUP breaks down for energies close to Planck scale
(Schwarzschild radius is comparable to the Compton wavelength).



So at Planck scales the suggestion is that GUP holds:

$$\Delta x \geq \frac{\hbar}{\Delta p} + \alpha' \frac{\Delta p}{\hbar}$$

(E. Witten, Physics Today, 1996)

Recently it was shown that certain effects of QG are also universal and can affect almost any system with a well-defined Hamiltonian (*quantum effects are generically small to be observed in experiments but future experiments could make them measurable*).

(A.F. Ali, S. Das, ECV, Phys. Lett. B 678, 497 (2009))

The scope is to investigate in a cosmological setup if these GUP-corrections are assigned to physical quantities at Planck time.

Heisenberg Uncertainty Principle and Planck era

$$\Delta x \Delta p \geq \hbar$$

In order to derive the energy-time uncertainty principle, one employs the relations:

$$\Delta x \approx c\,\tau, \quad \Delta p \approx \frac{\Delta E}{c}$$

and thus the energy –time uncertainty principle reads:

$$\Delta E\,\tau \geq \hbar$$

At Planck era one can easily derive the energy-time uncertainty principle as follows:

$$E_{Pl} = M_{Pl}c^2,\ M_{Pl} = \rho_{Pl} l_{Pl}^3$$

$$\rho_{Pl} \approx \frac{1}{G t_{Pl}^2}$$ (1st Friedmann eqn)

Then set

$$\Delta E \approx E_{Pl} \qquad \tau \approx t_{Pl}$$

$$\rho_{Pl} l_{Pl}{}^{3} c^{2} t_{Pl} \geq \hbar$$

$$\Rightarrow \frac{l_{Pl}{}^{3}}{G t_{Pl}{}^{2}} c^{2} t_{Pl} \geq \hbar$$

$$\Rightarrow \frac{c^{5}}{G} t_{Pl}{}^{2} \geq \hbar$$

$$t_{Pl} = \sqrt{\frac{G\hbar}{c^{5}}}$$

(P. Coles, F. Lucchin, “Cosmology: The Origin and the Evolution of the Cosmic Structure”, 1995)

Generalized Uncertainty Principle (GUP)

Recently it was proposed (by Ahmed F Ali, Saurya Das and ECV) a new for of commutators that are consistent with String Theory, Black Hole Physics and DSR:

$$[x_i, p_j] = i\hbar\left(\delta_{ij} - (p\delta_{ij} + \frac{p_i p_j}{p}) + \alpha^2 (p^2 \delta_{ij} + 3 p_i p_j) \right)$$

$$\Delta x \Delta p \geq \frac{\hbar}{2}\left(1 - 2\alpha \langle p \rangle + 4\alpha^2 \langle p^2 \rangle \right)$$

$$\Delta x \geq (\Delta x)_{\min} \approx \alpha_0 l_{Pl}$$

$$\Delta p \leq (\Delta p)_{\max} \approx \frac{M_{Pl} c}{\alpha_0}$$

$$where \;\; \alpha = \frac{\alpha_0 l_{Pl}}{\hbar}$$

GUP at the Planck time

$$\Delta x \Delta p \geq \frac{\hbar}{2}\left(1 - 2\alpha\langle p\rangle + 4\alpha^{2}\langle p^{2}\rangle\right)$$

$$\Downarrow$$

$$\Delta E\,\tilde{t}_{Pl} \geq \frac{\hbar}{2}\left(1 - 2\alpha\frac{\Delta E}{c} + 4\alpha^{2}\frac{(\Delta E)^{2}}{c^{2}}\right)$$

$$\Delta E = \tilde{E}_{Pl} = \tilde{M}_{Pl} c^2,\ \tilde{M}_{Pl} = \tilde{\rho}_{Pl} \tilde{l}_{Pl}^{\,3}$$

$$\tilde{\rho}_{Pl} \approx \frac{1}{G \tilde{t}_{Pl}^{\,2}}$$

Finally one gets:

$$\tilde{t}_{Pl} = t_{Pl} f_{\pm}(\alpha_0)$$

$$f_{\pm}(\alpha_0) = \left[\frac{(1+\alpha_0) \pm \sqrt{(1-\alpha_0)(1+3\alpha_0)}}{4\alpha_0{}^2} \right]^{1/2}$$

$$f_{\pm}(1) = \frac{\sqrt{2}}{2} \quad , \quad f_{\pm}(-\frac{1}{3}) = \sqrt{\frac{3}{2}}$$

$$and \ \lim_{\alpha_0 \to 0} f_{-}(\alpha_0) = \frac{\sqrt{2}}{2}$$

so $f_{-}(\alpha_0)$ does not pay any significant role since

$$\tilde{t}_{Pl} \approx t_{Pl}$$

On the contrary, for the case of $f_{+}(\alpha_0)$

and for small values of α_0

$$f_{+}(\alpha_0) \approx \frac{1}{2\alpha_0}$$

goes rapidly to infinity!!

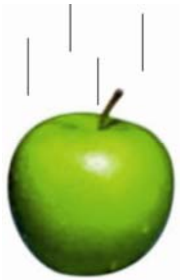
As an example

$\alpha_0 = \mathrm{O}(10^{-2} - 10^{-4})$

we find that $f_{+} \approx \dfrac{\tilde{t}_{Pl}}{t_{Pl}} \approx 10^{2} - 10^{4}$!!!

So $\dfrac{\tilde{\rho}_{Pl}}{\rho_{DE}} \approx \mathrm{O}(10^{115} - 10^{119})$

$\tilde{\sigma}_{Pl} \approx \sigma_{Pl}$!!!!



Conclusions

- Under specific circumstances the main Planck quantities in the context of GUP are LARGER than those defined in the context of HUP by a factor of

$$f_{+} \approx 10^{2} - 10^{4}$$

- Dimensionless entropy enclosed in the cosmological horizon does not "feel" the GUP effects and thus information remains the same.

- We expect modifications in the framework of Cosmology since changes in the Planck epoch will be inherited to late universe through QG.