the WINNOWER

PHYSICS

Black Hole Entropy and dynamics of quantum fluctuations predicted by E-gravity theory

PATRICK LINKER

Quantum gravity theories are relevant for very high energies that occurred e.g. during the Big Bang. These theories also make statements for the entropy of a Black hole. This papers shows how the entropy of a Black Hole is computed approximately by E-gravity theory. Also quantum fluctuations affected by gravity are discussed.

CORRESPONDENCE:
patrick.linker@t-online.de

DATE RECEIVED:
March 30, 2016

DOI:
10.15200/winn.145934.43470

ARCHIVED:
March 30, 2016

KEYWORDS:
black hole, Entropy, quantum physics, quantum gravity, quantum field theory

CITATION:
Patrick Linker, Black Hole Entropy and dynamics of quantum fluctuations predicted by E-gravity theory, The Winnower 3:e145934.43470 , 2016 , DOI: 10.15200/winn.145934.43470

INTRODUCTION

Einstein's theory of General Relativity was proven successful for gravitational phenomena on large length and time scales. However, there are still no experimental proofs for gravity acting on quantum-mechanical length and time scales. Only a couple of different approaches to quantum gravity are existing. Such theories differ in predictions and mathematical concepts. Also the entropy produced by a Black Hole is computed by such theories. It turns out that a non-rotating and uncharged Black Hole with the surface of the event horizon A carries the entropy

$$S \propto A. \qquad (1)$$

Various computations of Black Hole entropy are performed in physics literature. For example, the entropy formula (1) is derived from Loop Quantum Gravity (Rovelli 1996). Other computations of the Black Hole entropy are performed by considering all possible spacetime geometries (Ashtekar et al. 1998). String theory leads to the same result for Black Hole Entropy (Carlip 1999). An open question is, whether other theories of quantum gravity lead to the same result for the Black Hole entropy given by equation (1).

This research paper focuses on the most recent theory of quantum gravity called "E-gravity theory" (Linker 2016). E-gravity theory is a theory similar to Causal Dynamical Triangulation, where different discrete spacetime geometries are considered. Black Hole entropy will be derived from the partition function of E-gravity theory in this paper. Moreover, the effect of gravity to quantum fluctuations and its experimental validation is examined.

THEORY

The Lagrangian density of the gravitational field in E-gravity in 4 dimensions has the form

$$L_{grav} = v\delta^2 I(s_0 \dots s_4) \quad (2)$$

with the generators of the E-semigroup $s_0, \dots, s_4 \in S$ (S denotes the E-semigroup set), the equalizer indicator function I that is zero for any equalizers in the function argument and 1 in all other cases, the gravitational coupling constant ν and the coboundary map δ. Equation (2) can be reformulated to (a quantity with hat is omitted)

$$L_{grav} = \nu\delta\left(\sum_{i=0}^{4}(-1)^i I(s_0 \dots \hat{s_i} \dots s_4)\right). \quad (3)$$

Only if the product $s_0 \dots \hat{s_i} \dots s_4$ is nonvanishing, the second coboundary map of the indicator function can exist. From (3) one arrives at:

$$L_{grav} = \nu \sum_{i=0}^{4}\sum_{j=0}^{4}(-1)^j I\left(s_0 \dots \hat{s_i} \dots \hat{s_j} \dots s_4\right)(-1)^i I\left(s_0 \dots \hat{s_i} \dots s_4\right). \quad (4)$$

From (4) it turns out that if any product of four E-semigroup generators is equal to the empty set, it holds $L_{grav} = 0$. In other words, if there is a region, where only 2-dimensional surfaces can exist, there will be no gravitational potential density. Now the partition function of a Black Hole reads

$$Z = \sum_{\cup_i Eq(S_i)} exp(i\sum_{S_i}(L_{grav})_i), \qquad (5)$$

where the sum over all S_i denotes the sum of all spacetime simplices and $(\dots)_i$ denotes the evaluation of a function on the i-th spacetime simplex.

Due to the large value of ν, it holds $exp(i\sum_{S_i}(L_{grav})_i \ll 1$ for $(L_{grav})_i \neq 0$. Approximately, (5) can be regarded as a sum over all 2-dimensional surfaces. On every spacetime point the same number of these 2-dimensional surfaces exist. May be n_2 the number of 2-dimensional surfaces and N the number of spacetime simplices that can carry these surfaces, it holds

$$Z \approx n_2^N. \qquad (6)$$

Now the entropy can be set to $S = klnZ$ due to Boltzmann's entropy formula with the constant k. All 2-dimensional surfaces build up the event horizon of a Black Hole (they have no gravitational energy density). Finally, by using $N \propto A$ one obtains:

$$S \approx kNln(n_2) \propto A. \quad (7)$$

Equation (7) states that E-gravity theory predicts that a Black Hole has an entropy that is approximately proportional to the event horizon area.

The main criticism on E-gravity theory was the prediction of non-elastic elementary particle scattering (i.e. no conservation of energy and momentum). However, E-theory is not a theory that predicts the existence of a perpetuum mobile of first kind. On macroscopic scales it can be approximated to General Relativity, where energy, momentum and angular momentum are conserved covariantly.

The effect of real non-elastic scattering takes place on scales in orders of Planck-lengths. On the other hand, on small length and time scales one has a very large uncertainty in energy and momentum due to Heisenberg's uncertainty relation. Even a violation of energy and momentum conservation in processes on these scales would be "blurred out" by ordinary quantum uncertainty. Therefore, E-gravity theory would only modify the fluctuations in energy, momentum and angular momentum. The total energy of a system will still be conserved in space and time average.

As an example, quantum electrodynamics in inhomogenous spacetimes is considered briefly. Here, the partition function of gravity-affected quantum electrodynamics has the form:

$$Z = \sum_{\cup_i Eq(S_i)} \int d[A] \int d[\psi] exp(i \sum_{S_i} (L_{grav} + L_{QED})_i). \quad (8)$$

Perturbative expansion of the quantum electrodynamics term formulated on the

i-th simplex $(L_{QED})_i$ lead to all possible electromagnetic processes. There are processes, where two particles (including gauge bosons) can come extremely close together for a longer period of time. These processes are the self-energy contributions and the Loop contributions. Gravitational effects play a role if the electron-positron pair in a Loop contribution or an electron-photon pair in a self-energy contribution is only a few Planck length separated. In this case, the incoming energy required for producing such quantum corrections is much lower than in the non-gravitational case, because momentum is not conserved. Such processes cannot be detected experimentally even because of the high significance of measurement uncertainty on these length and time scales. Only for very dense quantum systems (e.g. the Big Bang) quantum-gravitational effects can be measured since particles are coming very close.

Experimental validation of E-gravity theory is possible in experiments with dense matter. For example, collider experiments with protons can be performed to measure E-gravity corrections. Protons are composite particles (consisting on three quarks) where quark-gluon interactions become very frequent. Also gravity-modified Loop contributions are a lot more frequent than in pure quantum electrodynamics systems. Hence, a possible explaination of the higher accuracy of quantum electrodynamics in comparison with quantum chromodynamics lies in the corrections predicted by E-gravity theory.

CONCLUSIONS

E-gravity theory is a plausible approach to quantum gravity, because it predicts an approximately correct value for the Black Hole entropy. Moreover, it is a candidate explaination of the accuracy differences in various other quantum field theories. Therefore, experimental verification of E-gravity theory is also possible by performing accelerator experiments. The physics of very dense systems can be understood more precisely when the predictions of E-gravity theory are proven.

REFERENCES

Rovelli, C. "Black Hole Entropy from Loop Quantum Gravity." Physical Review Letters, 1996, 77 (16) : 3288-3291. doi: 10.1103/PhysRevLett.77.3288

Ashtekar, A. et al. "Quantum Geometry and Black Hole Entropy" Physical Review Letters, 1998, 80 (5): 904-907. doi: 10.1103/PhysRevLett.80.904

Carlip, S. "Entropy from Conformal Field Theory at Killing Horizons"Class.Quant.Grav., 1999, 16: 3327-3348.

Linker, P. "E-gravity theory.", The Winnower, 2016, 3:e145441.18359. doi:10.15200/winn.145441.18359