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Using "Particle Density" of "Graviton Gas", to Obtain Value of Cosmological Constant

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Abstract

We use the work of de Vega, Sanchez, and Comes (1997), to approximate the "particle density" of a "graviton gas". This "particle density" derivation is compared with Dolgov's (1997) expression of the Vacuum energy in terms of a phase transition. The idea is to have a quartic potential, and then to utilize the Bogomol'nyi inequality to refine what the phase transition states. We utilize Ng, Infinite quantum information procedures to link our work with initial entropy and other issues and close with a variation in the HUP: at the start of the expansion of the universe.

Keywords

Graviton Gas, Partition Function, Modified HUP, Symmetry Breaking Potential

1. Introduction

We first state the summary findings of the de Vega, Sanchez, and Comes [1] self interacting gravitational gas. The piece, authored in 1997 gives a partition function, then a net "particle density" argument. This construction will form the basis of the subsequent evaluation. We for the sake of the gas, reference a bosonic Spin 2 "graviton gas" similar in part to what was done by [1] but adopting the conventions of Infinite quantum statistics by Ng [2] to conflate particle count with entropy, makes the case that what we are doing is to conclusively argue for a nonzero initial entropy.

The rest of the manuscript, borrows from Doldov's [3] 1997 discussion of the variation of the "cosmological constant" and its inter relationship to a potential congruent with the mechanism of symmetry breaking. What we do is to equate the variation of the "cosmological constant" and from there ask what it portends if there is no variation in the cosmological "constant" from its inception to [3] to its present value. We should also note that we use Padmanbhan's arguments [4] as to scalar fields, which will be used to confirm some of the details in [3]. This is the plan of the manuscript. Now let us proceed.

2. Reviewing the Implementation of Reference [1]

In [1], there is the use of a partition function which was initially planned for a "cold interstellar gas" but which we apply for a bosonic graviton gas, partly in the spirit of [5] but assuming in conjunction with the authors work in applying [2], and the idea of massive gravitons as given in [6]. To begin, look at the partition function [1], as given by

$$\begin{aligned} Z &= \iint \wp\,\phi \exp\left(-S(\phi)\right) \\ &= \iint \wp\,\phi \exp\left(-\frac{1}{T_{eff}} \int \mathrm{d}^3 x \left[\frac{(\nabla\phi)^2 - 2\mu^2 \exp\left(\phi(x)\right)}{2}\right]\right) \end{aligned} \tag{1}$$

Then, if T is a temperature, and z is the fugacity, and m is the mass, which we will decompose:

$$T_{eff} = 4\pi G m^2 T^{-1}; \mu^2 = \sqrt{2\pi^{-1}} \cdot z \cdot G \cdot m^{7/2} \cdot \sqrt{T} \tag{2}$$

The key element which we will be working with is, a particle density expression of [1] as

$$\left\langle \rho(r) \right\rangle = \mu^2 T_{eff}^{-1} \cdot \left\langle \exp\left(\phi(r)\right)\right\rangle \tag{3}$$

If we use the following from Padmanabhan, [4], using the approximation of $a(t) \sim t^{\tilde{n}}$, then

$$\phi\left(r(t)\right) \sim \phi(t) \approx \sqrt{2\tilde{n} \cdot m_{Pl}} \cdot \ln(t) \simeq \ln\left(t^{\sqrt{2\tilde{n} \cdot m_{Pl}}}\right) \tag{4}$$

$$\left\langle \rho(r) \right\rangle = \mu^2 T_{eff}^{-1} \cdot t^{\sqrt{2\tilde{n} \cdot m_{Pl}}} \propto \mu^2 T_{eff}^{-1} \cdot t^{\sqrt{2\tilde{n}}} \tag{5}$$

We will be utilizing these first five equations, with Equation (5) compared against results from [3], next.

3. Isolating m Value in Equation (2) and Equation (5) and Its Relevance to Reference [3]

Comparing Equations (2) and (5) get us a mass term of the proportional value

$$m \sim \left(\frac{\lambda}{\sqrt{2\pi^3}} T^{3/2} t^{\sqrt{2\tilde{n}}}\right)^{2/5} \tag{6}$$

Dolgov, in [3] has an emergent value of the vacuum energy density which he gives as follows with our subsequent valuation.

$$\rho_{\text{Vacuum}} \sim \frac{m^4}{2\lambda} \sim \frac{\lambda^{8/5}}{2\lambda \cdot \left(\sqrt{2\pi^3}\right)^{8/5}} \cdot \left(T^{3/2} \cdot t^{\sqrt{2\tilde{n}}}\right)^{8/5} \tag{7}$$

Then the given by [3] value for subsequent emergent fluctuation of the "cosmological constant" is

$$\Lambda_{\text{cos.const}} \sim 8\pi \cdot \rho_{\text{Vacuum}} / m_{\text{Planck}}^2 \sim \left[\frac{4\pi \cdot \lambda^{3/5}}{\left(\sqrt{2\pi^3}\right)^{8/5} \cdot m_{\text{Planck}}^2} \right] \cdot \left(T^{3/2} \cdot t^{\sqrt{2\tilde{n}}} \right)^{8/5} \tag{8}$$

Our subsequent point of evaluation will compare Equation (8) with a present day value of the cosmological constant of

$$\Lambda_{\text{cos.const}}\Big|_{\text{today's}} \sim \left(2.4 \times 10^{-11}\,\text{GeV}/c^2\right)^4 \tag{9}$$

Comparison of Equations (8) and (9) leads to $\tilde{n} \sim 25/32$, and

$$\left(2.4 \times 10^{-11}\,\text{GeV}/c^2\right)^4 \cdot \left(1.2009^2 \times 10^{38}\,(\text{GeV})^2/c^4\right) \sim \left[\frac{4\pi \cdot \lambda^{3/5}}{\left(\sqrt{2\pi^3}\right)^{8/5}} \right] \cdot \left(T^{3/2} \cdot t^{\sqrt{50/32}} \right)^{8/5} \tag{10}$$

And using [2]

$$\phi(r(t)) \sim \phi(t) \approx \sqrt{(50/32) \cdot m_{Pl}} \cdot \ln(t) \tag{11}$$

Then according to [3] we should look at the spontaneous symmetry breaking potential, given by

$$U(\phi) \sim -m^2\phi^2 + \lambda\phi^4 \tag{12}$$

Setting the temperature, T, and the time, t as Planck temperature and Planck time, and specifying we are still adhering to Equation (10) leads to a spontaneous symmetry breaking potential of the form which has λ

$$\left(2.4 \times 10^{-11}\,\text{GeV}/c^2\right)^4 \cdot \left(1.2009^2 \times 10^{38}\,(\text{GeV})^2/c^4\right) \sim \left[\frac{4\pi \cdot \lambda^{3/5}}{\left(\sqrt{2\pi^3}\right)^{8/5}} \right] \cdot \left(T_{\text{Planck}}^{3/2} \cdot t_{\text{Planck}}^{\sqrt{50/32}} \right)^{8/5} \tag{13}$$

We shall next, then proceed to discuss the idea of a graviton gas (bosonic), and the spontaneous symmetry breaking potential.

4. Conclusion: Existence of Graviton Gas? Non Zero Initial Entropy?

We acknowledge that Glinka, [5] pursued this idea in 2007. Our approach is fundamentally different from his, and we make use of using Equation (13) to set the λ. As well as specify the mass of a graviton as 10^{-62} grams as given in [6]. Following up upon the Ng "infinite quantum statitistics" as given by [2] so we then write, S(entropy) as $\sim N$(counting number), and we specify N, via

$$\begin{aligned} & m \sim \left(\frac{\lambda}{\sqrt{2\pi^3}} T_{\text{Planck}}^{3/2} t_{\text{Planck}}^{\sqrt{50/32}} \right)^{2/5} \sim N_{\text{graviton}} \cdot m_{\text{graviton}} \\ & \Rightarrow N_{\text{graviton}} \sim S(\text{Initial entropy}) \sim \left(\frac{\lambda}{\sqrt{2\pi^3}} T_{\text{Planck}}^{3/2} t_{\text{Planck}}^{\sqrt{50/32}} \right)^{2/5} \Big/ m_{\text{graviton}} \end{aligned} \tag{14}$$

The value of the initial graviton mass is specified as being 10^{-62} grams, meaning that this puts a premium upon the fine tuning of the initial parameters in the numerator of Equation (14). We hope that, if this is conclusively non zero, that it will enable CMBR style studies as alluded to in [7] and [8], as well as looking at non zero vacuum energy as given by non linear electrodynamics as in [9] and also the issue of the nature of gravity as up by Corda [10], as far as future studies and investigations, See Appendix A as to further elaborations as to the Infinite Quantum statistics brought up in this document. In addition, we argue that further understanding of Equation (14) will add more definition to the fluctuations of the metric tensor as alluded to in [6] and [7] and [8] as a compliment to Equations (6) and (7), *i.e.* further developments should specifically investigate the symmetry breaking potential as written up as enabling the metric tensor approach given in [8].

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] de Vega, H.J., Sanchez, N. and Combes, F. (1998) Fractal Dimensions and Scaling Law as in the Interstellar Medium and Galaxy Distributions: A New Field Theory Approach. In: De Vega, H. and Sanchez, N., eds., *Fourth Paris Cosmology Colloquium*: *Phase Transitions in Cosmology EuroConference*: *Within the International School of Astrophysics* "*Daniel Chalonge*", World Scientific Publishing Company, Singapore, 230-272.

[2] Ng, Y.J. (2008) Spacetime Foam: From Entropy and Holography to Infinite Statistics and Nonlocality. *Entropy,* **10**, 441-461. https://doi.org/10.3390/e10040441

[3] Dolgov, A.D (1997) The Problem of Vacuum Energy and Cosmology. In: De Vega, H. and Sanchez, N., eds., *Fourth Paris Cosmology Colloquium*: *Phase Transitions in Cosmology EuroConference*: *Within the International School of Astrophysics* "*Daniel Chalonge*", World Scientific Publishing Company, Singapore, 161-195.

[4] Padmanabhan, T. (2005) Understanding Our Universe: Current Status and Open Issues. In: Ashtekar, A., ed., 100 *Years of Relativity Space-Time Structure*: *Einstein and Beyond*, World Press Scientific, Singapore, 175-204.
http://arxiv.org/abs/gr-qc/0503107
https://doi.org/10.1142/9789812700988_0007

[5] Glinka, L. (2007) Quantum Information from a Graviton-Matter Gas. *Symmetry, Integrability and Geometry*: *Methods and Applications*, **87**, 13 p.
http://arxiv.org/pdf/0707.3341.pdf
https://doi.org/10.3842/SIGMA.2007.087

[6] Beckwith, A. (2016) Gedanken Experiment for Fluctuation of Mass of a Graviton, Based on the Trace of GR Stress Energy Tensor-Pre Planckian Conditions that Lead to Gaining of Graviton Mass, and Planckian Conditions That Lead to Graviton Mass Shrinking to 10^{-62} Grams. *Journal of High Energy Physics*, *Gravitation and Cosmology*, **2**, 19-24. https://doi.org/10.4236/jhepgc.2016.21002

[7] Beckwith, A. (2016) Non Linear Electrodynamics Contributing to a Minimum Vacuum Energy ("Cosmological Constant") Allowed in Early Universe Cosmology. *Journal of High Energy Physics*, *Gravitation and Cosmology*, **2**, 25-32. https://doi.org/10.4236/jhepgc.2016.21003

[8] Beckwith, A. (2016) Gedanken Experiment for Refining the Unruh Metric Tensor Uncertainty Principle via Schwartz Shield Geometry and Planckian Space-Time with Initial Nonzero Entropy and Applying the Riemannian-Penrose Inequality and Initial Kinetic Energy for a Lower Bound to Graviton Mass (Massive Gravity). *Journal of High Energy Physics*, *Gravitation and Cosmology*, **2**, 106-124. https://doi.org/10.4236/jhepgc.2016.21012

[9] Camara, C.S., de Garcia Maia, M.R., Carvalho, J.C. and Lima, J.A.S. (2004) Nonsingular FRW Cosmology and Non Linear Dynamics. *Physical Review D*: *Particles and Fields*, **69**, Article ID: 063501. https://doi.org/10.1103/PhysRevD.69.123504

[10] Corda, C. (2007) A Longitudinal Component in Massive Gravitational Waves Arising from a Bimetric Theory of Gravity. *Astroparticle Physics*, **28**, 247-250. http://arxiv.org/abs/0811.0985 https://doi.org/10.1016/j.astropartphys.2007.05.009

Appendix, a Review of Ng [2] with Comments

First of all, Ng [2] refers to the Margolus-Levitin theorem with the rate of operations $< E/\hbar \Rightarrow \#\text{operations} < E/\hbar \times \text{time} = \frac{Mc^2}{\hbar} \cdot \frac{l}{c}$. Ng wishes to avoid black-hole formation $\Rightarrow M \le \frac{lc^2}{G}$. This last step is not important to our view point, but we refer to it to keep fidelity to what Ng brought up in his presentation. Later on, Ng refers to the $\#\text{operations} \le \left(R_H / l_P\right)^2 \sim 10^{123}$ with R_H the Hubble radius. Next Ng refers to the $\#\text{bits} \propto \left[\#\text{operations}\right]^{3/4}$. Each bit energy is $1/R_H$ with $R_H \sim l_P \cdot 10^{123/2}$

The key point as seen by Ng [2] and the author is in, if M is the "space-time" mass

$$\#\text{bits} \sim \left[\frac{E}{\hbar} \cdot \frac{l}{c}\right]^{3/4} \approx \left[\frac{Mc^2}{\hbar} \cdot \frac{l}{c}\right]^{3/4} \tag{1}$$

Assuming that the initial energy E of the universe is not set equal to zero, which the author views as impossible, the above equation says that the number of available bits goes down dramatically if one sets $R_{\text{initial}} \sim \frac{1}{\#} \ell_{\text{Ng}} < l_{\text{Planck}}$? Also Ng writes entropy S as proportional to a particle count via N.

$$S \sim N \cong \left[R_H / l_P\right]^2 \tag{2}$$

We rescale R_H to be

$$R_H\big|_{\text{rescale}} \sim \frac{l_{\text{Ng}}}{\#} \cdot 10^{123/2} \tag{3}$$

The upshot is that the entropy, in terms of the number of available particles drops dramatically if $\#$ becomes larger.

So, as $R_{\text{initial}} \sim \frac{1}{\#} \ell_{\text{Ng}} < l_{\text{Planck}}$ grows smaller, as $\#$ becomes larger.

1) The initial entropy drops.

2) The nunber of bits initially available also drops.

The limiting case of Equations (2) and (3) in a closed universe, with no higher dimensional embedding is that both would almost vanish, *i.e.* appear to go to zero if $\#$ becomes very much larger. The question we have to ask is would the number of bits in computational evolution actually vanish?