Can gravitation be expressed as information?

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Abstract

Erik Verlinde has proposed in 2010 that gravitation is related to entropy. He managed to derive Newton law from this assumption. His paper attracts many new papers around similar idea, for example there is proposal of entropic dark energy by Smoot et al. But deep behind the new entropic gravity approach, there is a question about whether gravitation can be expressed as information. This article is a summary of discussion about this question in researchgate.net. It is put here to stimulate further discussion. It is not yet conclusive.

Introduction

First, we can recall a phrase coined by the late John Archibald Wheeler: "It from bit." That phrase seems to indicate that physics has the origin in information bit, be it gravitation or particle physics.

Second, in 2010 a dutch physicist Erik Verlinde proposed that gravitation has an entropic origin. His paper is On the Origin of Gravity and the Laws of Newton (http://arxiv.org/pdf/1001.0785.pdf), and the abstract goes as follows: "Starting from first principles and general assumptions Newton's law of gravitation is shown to arise naturally and unavoidably in a theory in which space is emergent through a holographic scenario. Gravity is explained as an entropic force caused by changes in the information associated with the positions of material bodies."

I think there are other papers suggesting the plausible connection between gravitation and entropy, but Verlinde's paper seems one interesting example.

So, can gravitation be expressed as information? Is there evidence for it? And is there limitation for this relation? What is your opinion? Your comments are welcome.

Other source: http://www.science20.com/hammock_physicist/it_bit_case_gravity

Answers

[1] **Guoliang Liu**

I am supporting Erik Verlinde's thesis about the gravitational potential, because I have proposed a cosmological model with three fundamental constants turned into functions of the gravitational potential, and a gravitational field has a temperature associated with the gravitational potential as well. Even the gravitational waves essentially are black body radiations. The information is carried by the magnetic flux or neutrino flux associated with the gravitational potential.

[2] **Joachim Pimiskern**

In addition, here is an article about a derived paper.

http://www.technologyreview.com/view/418192/gravity-emerges-from-quantum-information-say-physicists/

http://arxiv.org/abs/1001.5445

Regards,
Joachim

[3] **Torsten Asselmeyer-Maluga**
Dear Victor,
you mentioned Wheelers "It from Bit". Because of that I recommend to look into the latest essay contest of the Foundational Questioning Institute (FQXi). Even the prize-winning essays are interesting for you.
Here is the link:
http://fqxi.org/community/essay/winners/2013.1
Best wishes
Torsten

[4] **V. Krasnoholovets**
Verlinde considers the canonical ensemble in which the statistical integral looks as follows

int int dE dx { S(E,x)/k_Boltzmann - (E+Fx)/)Tk_Boltzmann }

He examines the integrand assuming that an extreme point for variations E and x is associated with the saddle configuration. The variations change from to '-infinity' to 'infiity' and hence from the structure of the exponent one can see that it monotonically decreases with increase of x. No points of inflection or saddle points can be seen, which means that the hypothesis of an “entropic force” F= T dS/dx breaks downs.

It is also obvious from thermodynamics, as the conventional canonical ensemble describes particles weakly interacting with the heat bath that is found in an equilibrium state; the equilibrium state cannot generate any force inside of the system studied by definition. Besides, an introduction of an entropy with quantum overtones requires rigorous classical as well as quantum justification.

Similar consideration was done early by Padmanabhan. He rewrites the energy E via a force <dE> = F <dx> . Then he equates TdS = F<dx> . This simplest relationship was written for a very peculiar microscopic case of a small fluctuation.

The problem of thermodynamics of spacetime is rather a difficult problem in which equilibrium vacuum fluctuations would entail an ill-defined spacetime metric. That is why it seems it is too premature to discuss macroscopic quantum phenomena in spacetime based on thermodynamics and fluctuations of vacuum.

[5] **V. Krasnoholovets**
Regarding the questions: Can gravitation be expressed as information? Is there evidence for it? The answers are positive, but the solution to them is very very specific. Our R&D team developed and designed a device that measures quasi-particles of quantum mechanical and gravitational interactions - they are inertons (carriers of the force of inertia, a substructure

of the particle's matter waves, i.e. they completely fills the so-called particle's wave \psi-funcrtion). Besides, we managed to develop and design a generator of inerton fields. So, in the nearest future when funds are available we will carry out an experiment with inerton communication, which looks as potentially more attractive in comparison with the communication on the basis of electromagnetic field. Because inertons have deeper penetration potential, they can easy pass through water and we can operate at a low intensity, then is the case with electromagnetic field.

[6] **Willem de Muynck**
The only way to express gravitation (as well as any other entity or phenomenon) is by means of a written or spoken account of what you know about it, i.e. information. If the reason of the question is to ask whether gravitation consists of information, the answer, obviously, is `No'. Information is stored in articles, books, and all kinds of memories. Information is `about entities or phenomena'; it is not itself an entity or a phenomenon.

[7] **V. Krasnoholovets**
The communication channel is the information. One more example of information, which can be stored after an action, is homeopathy.

[8] **Antonio Alfonso-Faus**
I think that information, in general. is contained in any system that has a non-zero energy. In other words, a quantum of energy can be adscribed to one bit. Following this way of thinking the information content in the seeable universe is about 10^122 bits. The equivalent" mass" of one bit is 10^(-65) grams. Therefore the gravitational field, having energy, it also has an equivalent number of bits, information.

[9] **Ludwig Combrinck**
The it from bit and bit from it is a chicken and egg approach and can only lead to perpetual motion. It can be used as a viewpoint, or point of departure, but one will always be able to start with either the bit or the 'it' or show that both approaches are actually the same. Gravity explained as an entropic force caused by changes in the information associated with the positions of material bodies is an interesting approach, but it all boils down to J Wheeler's statement that mass here affects gravity (spacetime curvature) there. This is an observable fact, and can be 're-described' in alternative approaches or gedanken experiments, of which the entropic force is one.

Of course 'information' flows freely in the universe, and one could probably describe the universe to some level of approximation using (as example) modulation types, as we typically use modulation to transmit information and demodulation to extract/decode information on Earth. With this modulation example available detected energy (our observations, which can all be de-modulated) can be described in terms of amplitude modulation, phase modulation, angular modulation and different types of digital modulation. All of our detected energy will be emitted (from source) and will become sampled 'information'.

To some extent that is already how we measure and see the universe...detectors on optical and radio telescopes, gamma and x-ray telescopes etc. We de-modulate the signals to 'understand' the universe.

So we actually have a modulation type view of the universe.

All the information flowing in the universe affects the observable nature of the universe. So, yes gravitation can be expressed as information (as it is) so can all the other observables. This does not mean to imply that gravity consists or is made up of information, it simply means gravitation contains or provides information. I add this last sentence in case this is misread.

[10] **Resconi Germano**
Recently I proof that quantum mechanics can be generated by an extension of the entropy idea and by information space. I also create Synthetic Physics where common commutator model join electromagnetism , gravity and quantum mechanics. In conclusion I am ready to write a new paper where information iis the key element for all physics or synthetic physics.

[11] **Bernard Lavenda**
A statistical principle will never govern a deterministic force, let alone an action-at-a-distance like Newton's law. Gravity is not an entropic force caused by the "changes in information in the position of material bodies." Gravity acts even in the absence of motion. But it can cause a reduction in the entropy with respect to the reference state at infinity. The nature of the interactions, discussed by Verlinde, do not lead to increases in entropy; rather, they cause a reduction in entropy from a uniform state to a more constained one through the application of a constraint. The force is mechanical and not entropic in origin. In analogy with the polymer model discussed by Verlinde, the entropy decreases when the elongation increases that is caused by an applied tension. All this has been worked out long ago in Lavenda, "Thermodynamics of Extremes" (Horwood, 1995) Sec. III.2.3 and V.4.1, and (partially) previously by Callen ("Thermodynamics" Wiley, 2nd ed. , 1985, p. 80) in his 'rubber band' model, where the internal energy is given by an ideal gas (like Verlinde's). See also Frenkel, "The Kinetic Theory of Liquids"(Oxford U. P., 1946). The entropy reduction is proportional to the square of the elongation (and not the elongation itself because that can be of either sign), which is the Gaussian limit. With the internal energy given by an ideal gas, all that can be concluded from the analysis is that the ratio of the force to temperature is independent of the temperature, and can only be a function of the stretching.
Setting the minimum characteristic radius of a normal star (V.123 in Lavenda) equal to the Unruh temperature gives the radius of the star as the Compton wavelength! [Something is missing like the cube root of the number of protons in the star that multiplies the Compton wavenlength (V.138) to obtain the radius,] The Unruh temperature picks out Newton's law, automatically because the force to temperature ratio is constant. Verlinde also recognized this by the appearance of 'c' in a nonrelativistic framework. He even tells us to forget about it. However, he uses a completely ad hoc a relation between the number of bits used and the area. Going through his derivation, he does get Newton's law but iff the temperature is

given by the Unruh temperature! So it is no more general than postulating Unruh's temperature to begin with! Moreover, why can't the Bekenstein expression for the entropy in terms of the area of the horizon be used in (3.10) to related it to the number of bits used? Because together with the law of equipartition of energy (3.11) and the second law, it gives an incorrect relation between entropy and energy.
Finally, the motivation behind the paper---Jacobson's derivation of Einstein's equations as an equation of state from the second law---is invalid because dQ=TdS(=TdA/4)=0 for Einstein's equations, and Jacobson's derivation is 0=0. Einstein's equations are adiabatic; they are not thermal equations of state.

[12] **Demetris Christopoulos**
I doubt about. We have many evidences that gravitation is very close related with the differential geometry involved for every space-time we study. Besides geometrical arguments I agree with Bernard Lavenda' s remark about:
"A statistical principle will never govern a deterministic force, let alone an action-at-a-distance like Newton's law"

[13] **V. Krasnoholovets**
to Christopoulos: an action-at-a-distance does not exist, which directly follows from the science known as physics. Each kind of interaction is provided with carriers. In the case of the gravitation they are field carriers, quasi-particles. The origin of gravity is the oscillation of entities inside of a massive body. When they oscillate, they rub against space, which generates spatial excitations (Poincare wrote about such principle of motion of a particle in 1906). These excitations form the so-called wave \psi-function around each entity. These clouds are overlap and the total cloud is formed around the massive body. Due to the radial /spherical symmetry, the solution for these standing excitation waves has the dependence 1/r. This is the origin of the Newton's gravitational law. The appropriate excitations were named in my works "inertons", because they represent inert properties of particles. Inertons were revealed in a number of physical systems by my colleagues and me. Besides, we designed two different devices that measure inerton signals; and also designed a few different generators of the inerton field. Moreover, we have been developing some technologies in which inerton fields play an important role.

There is an idea to found the first inerton observatory to observer the outer space (instead of the study of abstract gravitons and/or dark matter particles of unknown nature). I invite researchers - first of all astrophysicists and astronomers - to participate in this interesting project of inerton astronomy.

[14] **Victor Christianto**
Dear Torsten and Resconi, thank you for your answers, i will read the cited fqxi papers soon. With regards to your Synthetic Physics, it seems interesting to link many physics theories to bits. Perhaps you already know a book by Kantor, an inventor, his book has title: information mechanics. He tried to express all particle physics plus gravitation in terms of bits.
There is also a 1989 Santa Fe publication book with title Complexity and The Physics of Information edited by W. Zurek. That book includes many papers including a seminal paper

by John Wheeler, where he explained in detail about it from bit.
I once had each copy of Kantor,s book and that Santa Fe book, but my copies were lost. But if you wish, perhaps you can search on amazon.com
Best wishes

[15] **J. Madore**
If you allow me to add a very light two bits, I would say that gravity is the field which arises when one quantizes points. By ´point quantization´ I mean replacing coordinates by noncommuting operators. The requirent that the product be nevertheless associative as expressed by Jacobi identities places restrictions on the algebra of operators. This has been worked out in explicit models. One finds a
relation between curvature and commutator whch yield second-order equations for the metric.
To return now to your point, which I guess is a generaliziation of the black-hole relation
Does the above help? Not a bit! But it gives a concret answer to another question which might be related to it.
If I may add I think Wheeler was more to the point (pun intended) when he thought of gravity as a distribuiion of defects in a solid.

[16] **V. Krasnoholovets**
Dear Dr. Madore,

Might be Wheeler thought of gravity as a distribuiion of defects in a solid. But it was shown only in my works starting from a submicroscopic concept. Noncommuting operators are fantasy. At the submicroscopic scale the space demonstrates only exact determinism. Noncommunity appears when researchers unify two objects, which tightly connected, in one monster known under the name of 'wave-particle'. When one operates with two linked objects (a particle and its cloud of spatial excitations - named inertons in my approach), then the one can easily overcome any uncertainty. Submicroscopic mechanics exists in the real space; conventional quantum mechanics works in an abstract phase space (like a Fourier image of the original function).

In the real space a particle is surrounded with its inerton cloud. In an abstract phase space a particle is presented as a wave \psi-function. In the real space the particles' inerton clouds overlap forming an interaction between particles. In an abstract phase space particles' wave \psi-functions overlap, which results in the particle-particle interaction.

These particle's inertons are carriers of both quantum mechanical and gravitational interactions. When this aspect is taken into account, we can easy to construct the behaviour of an ensemble of massive points. In the interaction of these points there will be usual gravitational potentials (Newton's) and also the elastic repulsion. These two interactions form galaxies and also so-called dark matter between them. NOTE: general relativity cannot be apply for two or more interacting massive points! This is the reason why researchers miss the elastic repulsion between stars - so far they did not have the appropriate means how to write correctly such an interaction between gravitating masses.

[17] **Bernard Jones**
May I suggest that you read Sections 44.4 (Pre-Geometry) and 44.5 (Calculus of Propositions) of the great Misner, Thorne and Wheeler "Gravitation"?

Along those lines is the article by Patton and Wheeler on pre-geometry and information (if you can find a copy - anyone out there have one they can post?): Patton, C.M. and Wheeler, J.A. (1975) Quantum Gravity, edited by Islam, Penrose and Sciama, Oxford.

The paper by Bohm, Davies and Hiley is technically difficult, but worth a go: http://arxiv.org/ftp/quant-ph/papers/0612/0612002.pdf

The difficulty with such conceptual discussions is to sort out the serious from the ill-conceived or plain nonsense. There is very little of the first, but an enormous amount of the last.

[18] **Demetris Christopoulos**
Dear V. Krasnoholovets, your theory seems to be an interesting one. Have you predicted any special case where the presence of 'inertons' will be unambigously obvious and without any other 'overlapping condition'? Thank you.

[19] **V. Krasnoholovets**
In the paper of Bohm, Davies and Hiley (http://arxiv.org/ftp/quant-ph/papers/0612/0612002.pdf) they quote: Santhanam, T.S. and Tekumalla, A.R., Foundations of Physics, vol. 6, p. 583 (1975). Santhanam and Tekumalla state that the discrete case does not have an uncertainty principle, which is OBVIOUS.

However, Bohm, Davies and Hiley simply claim: we believe this conclusion to be incorrect, as we demonstrate in the following way: coordinate X and momentum P are both hermitian and since they have a non-zero commutator

$$[X,P] = i \int\int \exp\{2\pi i.jk\}\, e^{k_0}\, dk\, dj. \quad (32)$$

Hence there must exist an uncertainty relation between the two observables.

It is easy to see that Bohm, Davies and Hiley started from uncertainty!

Regarding "Gravitation" by Misner, Thorne and Wheeler: the book has a new approach, or rather new mathematical means to the the same Einstein's-Hillbert's formalism. That is all. The book does not suggest ideas on the origin of gravity, on the origin of the Newton's gravitational potential and it does not have even a hint how two massive points can interact.

In my recent paper entitled "Submicroscopic viewpoint on gravitation, cosmology, dark energy and dark matter, and the first data of inerton astronomy" published in: Recent Developments in Dark Matter Research, Editors: Nori Kinjo and Akira Nakajima (Nova Science Publishers, Inc., 2014), pp. 1-61, the origin of gravity has been accounted for in

detail. 7 conceptual difficulties of the formalism of general relativity have been demonstrated. The submicroscopic approach used in the paper is based on a cellular concept of the space structure. It provides solutions to the four classical tests of general relativity: exactly the same equations have been derived and the same solutions obtained for the motion of Mercury's perihelion, the deflection of starlight by the Sun, the gravitational redshift of spectral lines, and the Shapiro time delay effect.

And the same approach shows how the formalism of quantum mechanics emerges. The novelty is the physics beyond the Standard Model: it allows one to look inside of the particle behaviour, or the hidden particle kinetics/dynamics. The submicroscopic approach describes the behaviour of a particle in each section \lambda of its whole path. Here, \lambda is the so-called de Broglie wavelength of the particle.

Besides, the submicroscopic approach accounts for particles, namely, it can describe particle physics from the viewpoint of the real physical space: what a particle is, what is the difference in the inner structure of a lepton and quark, what kinds of excitations surround a lepton and what kinds of excitations surround a quark, what the electric charge is, what the magnetic charge is, etc., etc.

[20] **V. Krasnoholovets**
Dear Dr. Christopoulos, you asked: Have you predicted any special case where the presence of 'inertons' will be unambigously obvious and without any other 'overlapping condition'? SPECIAL CASES: 1) inerton astronomy; 2) communication through the inerton signals (e.g. mobile phones that will operate via inertons).

Our R&D team is open to work with any team dealing with astronomy and astrophysics, as we have a project of the first inerton astronomy. The first positive results, a couple of first steps in this direction, have been described in my recent paper "Submicroscopic viewpoint on gravitation, cosmology, dark energy and dark matter, and the first data of inerton astronomy" (it can be downloaded from my web site http://inerton.kiev.ua).

In my activity I indeed predict some effects (theoretically) and then immediately demonstrate how they manifest themselves experimentally.

In my said web site you may download also papers:

V. Krasnoholovets and I. Gandzha, A submicroscopic description of the formation of crop circles, Chaotic Modeling and Simulation (CMSIM), vol. 2, April issue, 323-335 (2012) [there, see also Presentation of this work]

V. Krasnoholovets, Sub microscopic description of the diffraction phenomenon, Nonlinear Optics, Quantum Optics, vol. 41, no. 4, pp. 273 - 286 (2010)
[there, see also Presentation of this work].

But in 99% of cases inertons rather appear owing to overlapping. Or, for example, we can extract a bunch of inertons from one substance and apply these inertons to the other

substance. This second substance will immediately demonstrate very new chemical physical properties. Our R&D team used it at the production of biodiesel; this accelerates chemical physical reactions hundreds of times. There are also many other commercial applications (for example, in agriculture: water saturated with inertons can be used for watering plants at dry climate conditions; in plants, which adsorb such water, the level of transpiration is reduced about 2 times. So, there is a possibility to save water resources).

[21] **Bernard Jones**
@V. Krasnoholovets
Thanks for the remarks.
Please note that I did not recommend MTW "Gravitation" in hte context of this discussion - I only recommended those specific sections which I would regard as at least interesting in the context of the present discussion.

MTW is, as the title says, a book on gravitation and a fine one at that. Those last chapters honour the imagination of John Wheeler, who, along with Zel'dovich, is perhaps the most innovative physicist I have ever met.

[22] **Vladimir Majernik**
In the strict exact way the information relies on the concept of probability and statistics. It represents the degree of statistical dependence of two (or more) random variables and so it is suitable for describing statistical system or statistical behavior. In the Newton and Einstein theory the description of physical laws is deterministic. This is why the information, as a probabilistic concept, is not suitable for the description of classical gravitation. However, in the quantum gravity this concept can play an important role.

[23] **Resconi Germano**
Dear Victor Christianto

Thank you for the information. In your reply there is a misunderstand of my work. For the first point, information is not connected with bits but with geometry. Information space and its curvature or torsion given by Fisher information or other metric give us the structure the information to relate a multidimesnional type of entropy with quantum mechanics. Information is not always connected with probability but with geometry. I use to connect geometry with commutators relate to Gauge. So with gauge theory and metric with a novel structures of commutators give us the formal description of Maxwell equation , generalisation of Einstein equation and quantum mechanics with Casmir effect. So if you read my paper Synthetic Physics you have the opportunity to discovera new general theory Beyond the Kantor and Zurek work.

[24] **Louis Rancourt**
hi
I am more an experimental physics guy who rely more on experimental results than theory. Can your explanations work for these experimental results.
When a beam of light is passed between two mobile masses, the masses are getting closer

to one another.
I could give a summary of the results that were published in Physics Essays, Dec. 2011 on the effect of light on gravitational attraction.
Have a good week
Louis

[25] **Antonio Alfonso-Faus**
Hi Louis: I have found that the source of gravitation, the gravitational atraction, is due to the total relativistic energy of each system. This means that gravitation is due to energy, and therefore it includes a photon gas. Then your experimental results are by these results explained ok: the beam of light atracts the two mobile masses when passing between them and therefore the masses atract each other (due to the energy of the photons). These results will soon appear in the Journal "Astrophysics and Space Science" and I will upload it here shortly.

[26] **Antonio Alfonso-Faus**
Hi Louis: I have added here my paper in the "Astrophysics and Space Science" that has been approved for publication on January 17, 2014. It includes the theoretical grouns to consider gravity source to be the relativistic energy of the system, thus including photons.

[27] **Demetris Christopoulos**
Dear Antonio, I read your article and found it very interesting. Could you suggest a proper experiment to show and clarify the primary nature of your suggested relation between G and c? Since it is so fundamental it is most probable to exist an experiment that proves it. Thank you.

[28] **Louis Rancourt**
Hi.
Thanks for your answer. There is a point that has to be clarified. If we accept that nothing can go faster than c, then light going between 2 masses of 100 g cannot affect the 2 masses because what light would be sending to the masses would have to go faster than c. The vector of light going East to West for example is = to c. Then anything leaving light at an angle has to go faster that c.
Is it possible that light going from East to West interferes or blocks some of what was going from North to South, thus shielding some of its effect. That would give a push to the mass and they would seem to attract one another. If so, that means that light can really interfere with what is the force of gravity.
Louis

Concluding Remarks
This discussion is not yet conclusive so far. But perhaps we can draw some conclusions, as follows:
a. In the Newton and Einstein theory the description of physical laws is deterministic. This is why the information, as a probabilistic concept, is not suitable for the description of classical gravitation.
b. However, in the quantum gravity this concept can play an important role. (Majernik)

Hopefully you will find that this summary of discussion may stimulate further research.

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