Is the General Theory of Relativity equivalent to the Ginzburg-Landau theory of superconductivity?

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Abstract

There is a quite recent paper (2011) by Santiago-German which says that the Einstein's general theory of relativity is formally equivalent to the Ginzburg-Landau theory of superconductivity (http://arxiv.org/pdf/1112.1179v1.pdf). He further wrote that this fact lead us to suspect that the superconductivity of gravitation ought to be a real physical process occurring in the outskirts of galaxies. If such a proposition is correct, then perhaps we can view some problems in cosmology from new angle. Not only dark matter but perhaps the solar system and planets can be viewed as superconductors too. Other possible analogy is between cosmology and condensed matter phenomena such as superfluidity. This analogy has been explored for instance by G. Volovik et al.

Introduction

This article is based on a question discussed in researchgate.net. Because it attracts many comments, be it supportive or opposed, I think it is worth to share this discussion in other forum.

There is a quite recent paper (2011) by Santiago-German which says that the Einstein's general theory of relativity is formally equivalent to the Ginzburg-Landau theory of superconductivity (http://arxiv.org/pdf/1112.1179v1.pdf). He further wrote that this fact lead us to suspect that the superconductivity of gravitation ought to be a real physical process occurring in the outskirts of galaxies.

Such a proposition seems to support previous articles by Horowitz (you can search at google.com), suggesting connection between General Relativity and superconductivity. There is also a paper sometime ago by Kholodenko and Ballard, saying that in dimensions three and higher the famous Ginzburg-Landau equations used in theory of phase transitions can be obtained (without any approximations) by minimization of the Riemannian-type Hilbert-Einstein action functional for pure gravity in the presence of cosmological term. See their paper at http://arxiv.org/abs/gr-qc/0410029.

If such a proposition is correct, then perhaps we can view some problems in cosmology from new angle. Not only dark matter but perhaps the solar system and planets can be viewed as superconductors too. Other possible analogy is between cosmology and condensed matter phenomena such as superfluidity. This analogy has been explored for instance by G. Volovik et al.

So, what do you think? Do you agree that General Theory of Relativity is equivalent to the Ginzburg-Landau theory of superconductivity?

Answers:

[1] **Arno Gorgels**

GRT is an idea. It is spacially (possibly more surrealistically) descriptive of the attraction of masses without considering possible field effects. Recent observations (called dark matter) allow suspicion that GRT is at the brink of being falsified, i.e. antiquated. That's why it is imho difficult to seek any comparison with other theories that the reality of engineering brings forth. Though, the quoted article seeks to reconcile dark matter with GRT. My humble personal opinion is that the falsification is factual. But I am surely open for other approaches if reconcilable. The article is, however, three year old but I don't know of further developments in this direction. Finally, the last side remark in the article: "This result can be regarded as a direct manifestation of the wave-particle duality of gravitation." doesn't comfort me at all because, in spite of great efforts, experimentally, gravitational waves have not been detected.

[2] **Patrick Das Gupta**

I have'nt read the paper, so I ask: If GR is equivalent to superconductivity, what in gravitation are equivalent to persistent current without any resistance, or Meissner effect or Flux quantization or Josephson tunneling?

[3] **Daniel Potrepka**

Many ideas from superconductivity were borrowed to describe characteristics of particle physics: coherence length, order parameter, thermodynamic transitions similar to Tc, M(Hc). So it makes sense that these concepts of superconductivity can be carried over into systems that GR describes; what are the parameters that describe black holes? Whether GR is the definitive theory or something else will supercede it will depend on how well it describes cosmological physical realities compared to theoretical alternatives. The answer to that question is still unresolved, but tantalizing.

[4] **Victor Christianto**

@Arno. Thank you for your answer. Yes i agree with you that it is difficult to predict where the new analogy will bring us. However, it seems that superconductivity offers new experiments which can be explored in microscale, where the general relativity is lacking.

@Patrick. Thank you for your question and comments. Yes if the hypothesis is correct that there is relationship between general relativity and superconductivity, then it seems possible to explore new observational implications of that idea. For example, i think it will be interesting to see if Podkletnov's experiment with rotating superconductor can be explained too using this approach. Best wishes

[5] **Jürg Fröhlich**

Well, well! I wonder where this one will go to. Let me quote the artist Ad Reinhardt, who said: "The one thing to say about art is that it is one thing. Art is art-as-art and everything else is everything else." You know it isn't really useful to mix everything with everything else and to suspect that there may exist connections between unrelated phenomena. There is no way around understanding gravitation as gravitation and superconductivity as superconductivity! (Incidentally, you might - if you like - look up an old paper by P. W. Anderson wherein he speculates about screening of gravitational interactions by phonons. This is a speculation somewhat related to yours. But it didn't lead anywhere.)
If you had wondered about formal connections between superconductivity and the Higgs mechanism in the theory of weak interactions some reasonable explanations could have been sent to you.

[6] **Victor Christianto**

Dear Dr. Jurg Frohlich, thank you for your comments. Yes we are interested to see whether there is formal connection between general relativity and Ginzburg-Landau theory. If you have or know other paper saying otherwise, please inform us. Thank you.

[7] **Daniel Potrepka**
@ Jurg. The screening of gravitational interactions by phonons is a speculative physical claim. I was thinking about what verifiable phenomena exist and what are the models that describe them. I see no problem with borrowing models from other disciplines. That would be the description not the art. Do electrons even though in a cloud around nuclei remind us of planetary orbits just a bit? I think so.

[8] **Daniel Potrepka**
@ Arno, @ Victor. If dark matter does lead to falsification of GR, then I agree GR would be a tough place to start from and a bit of a gamble to invest in.

[9] **Victor Christianto**
@Daniel. Thanks for your comments. Yes perhaps dark matter and dark energy indicate that we should keep an open mind, especially with cosmology where nobody ever goes beyond the moon. You are from superconductor science, perhaps you would like to read this one: http://arxiv.org/abs/1010.2784.

@Anatolij. Thanks you for your comments. Yes of course they are two different fields, but sometimes there can be cross fertilization between two apparently different fields. Perhaps you would like to read Santiago-German's paper and make comment on where are his faults? Best wishes.

[10] **Resconi Germano**
I am very happy to see gravity as superconductor. In my work on Synthetic Physic I use gauge theory and commutators to model gravity by superconductor theory

[11] **M. Maia**
In the 50's Soraj Gupta proved that any massless spin-2 field defined in Minkowski's space-time by the Fierz-Pauli Lagrangian, is equivalent to the linear approximation of Einstein's equations in the appropriate coordinate gauge. Reciprocally, by reversing the linear approximation process he found Einstein's equations (see Gupta PRD 96, 1683 (1954), also S. Deser GRG 1, 9, (1970)). Therefore, if the answer for your question would be a yes, then the Landau-Ginzburg superconductivity theory should be equivalent to a Fierz-Pauli massless spin-2 field in Minkowski space-time.

[12] **Torsten Asselmeyer-Maluga**
Dear Victor,
only a first reaction after your interesting question, I recommend a book:
G. E. Volovik, The Universe in a Helium Droplet (The International Series of Monographs on Physics, 117), Clerendon Press Oxford 2007
Here, he describes the simularities between the superfluid Helium-3 (also releated to Gisnburg_landau) and cosmology but also QCD and other particle physics approaches (casimir energy etc.).
Best wishes

[13] **Victor Christianto**
To all. For all of you who are interested in superconductivity, there is a fine book by Andrei Marouchkine, with title Room temperature superconductivity. The book is available online at http://arxiv.org/pdf/cond-mat/0606187.pdf. Best wishes

[14] **Resconi Germano**

Dear Victor Christianto
To see computation in Synthetic Physics you can have a look at the paper
New black hole solutions in a modified gravity arXiv 1109.2928v4 [gr-qc] 14 Dec. 2011 or the same paper in ISRN Astronomy and Astrophysics vol.2011 (2011) Article ID 341919 7 pages.
For the paper Synthetic Pgysical Theory. gauge generalized principle in quantum geometry and gravity Germano Resconi Ignazio Licata you can see the paper Symmetry ISSN 2073-8994.

[15] **Resconi Germano**
Dear Victor
In the paper Synthetic Physics is not explicitilly named the superconductivity but the three terms Proca Term , Chern-Simon term and Maxwell like terms are all terms relate to the superconductivity as you can see for example in the paper arXiv:1311.7640v2 [hep-th] 2 dec.2013
if you want send to me any message you can use my e-mail resconi@speedyposta.it

[16] **Panagiotis Stefanides**
Dear Jurg,

Strictly speaking you indicate the correct separation lines between one thing and something else or everything else.

However, with condition that “art” is not one thing i.e. something usual, standard, or conventional, but something else, something, as I use to say "art having soul", could be useful, when one is searching for “unification” conditions. It could bear information as much as that of an image of a pure geometry, or nature’s beauties in abstracted forms:
http://articles.timesofindia.indiatimes.com/2013-10-28/art-culture/43461329_1_nariman-point-beauty-nature

Regards from Athens,

Panagiotis Stefanides
http://www.stefanides.gr

[17] **Stefan Mehedinteanu**
I all my papers, independentely of there indicated, I have applied GL-theory to nucleons substructure, and based on the values of the monopole (rotating magnetic field) induction , I have derived G, the power radiated (waves-10^22 Hz), the force transmitted to space-time as gravitational force, and which reflected by the object as attraction force. All the data related to gravity (g, gravitational potential of Earth, light deflection, dark matter nature etc.) were calculated without G, which resulted to be related only to Planck lenght. Therefore, there are not gravitons ,

[18] **Stefan Mehedinteanu**
My paper is just now in editing in Prespace Jornal, after publication I will indicate the link, a early version is available on vixra: http://vixra.org/abs/1401.0142

[19] **Stefan Mehedinteanu**
Prespacetime Journal has just published Volume 5 Issue 1 entitled "Standard Model, Causal Structure, Modified GR & Origin of Gravity" at
http://prespacetime.com/index.php/pst/issue/view/50
Prespacetime Journal| January 2014 | Volume 5 | Issue 1 | pp. 44-59

[20] **Resconi Germano**
Dear Torsten Asselmeyer Maluga

Yes the synthetic differential geometry is natually connected with synthetic physics by topos as gauge physic process . The difference is that in syhthetic physics we have a prototype model as Electromagnetic Maxwell equations that represent the universal form or syntesis for Gravity and quantum see my papers Unification of quantum gravity by non classical infromation entropy space (Resconi , Ignazio). For similar resukt for Brain you can see Geometry for Brain Optimal Control in a Network of adaptiver <memristors (resconi Ignazio)

[21] **James Dwyer**
In "Theory of superconductivity of gravitation and the dark matter enigma," http://arxiv.org/abs/1112.1179, Wenceslao Santiago-Germ´an states on page 8:
"... It follows that the superconductivity of gravitation is destroyed in a region when there is a sufficiently strong gravitational spatial curvature. Hence, the most probable place to observe the superconducting phenomenon just described is in the outer skirts of galaxies and not near a central region where a supermassive black hole might be present."

In simplistic terms that I can comprehend, this seems to indicate that superconductivity of gravitation can only be found in weak gravitational fields, far from strong gravitational sources. This does not seem at all consistent with the superconductivity of electromagnetism.

I'm compelled to add that galactic dark matter was inferred from discrepancy between observed flat rotation curves of spiral galaxies and expected rotational velocities that diminish as a function of radial distance. However, planar disk distributions of mass can only produce expectations of diminishing velocities when improperly evaluated using two-body equations, with the gravitational force diminished as an inverse square function of the two bodies' separation distance (r).

In evaluations that more properly represent the planar distribution of spiral galaxy disk masses and especially the distribution of their separation distances, no such diminishment of radial velocity is indicated.

Only when attempting to fit the expected diminishing rotation curves to observations does an enormous, extended halo of dark matter seem to be required.

This much simpler assessment does not depend on any complex effects such as superconductivity of the weak peripheral gravitational field produced by exceedingly compound structures consisting of many billions of discrete objects distributed over perhaps hundreds of thousands of light years...

Even if GTR and the Ginzburg-Landau theory of superconductivity are formally equivalent, are the conditions that produce the superconductivity of electromagnetism even approximated by enormous spiral galaxies?

[22] **James Dwyer**
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region where a supermassive black hole might be present."

BTW - not even a supermassive black hole would curve spacetime to such an extent that it would produce any effect whatsoever at a distance of tens of thousands of parsecs - which would be necessary in order to restrict the proposed (intensified) superconductive gravitational effects to the peripheries of large spiral galaxies.
This seems to be the intent of this specification - to explain why vast planar distributions of mass do not produce rotational velocities that diminish as an inverse square function of radial distance (see prior comment).

Concluding remarks

While not conclusive, it seems possible to find connection between General Relativity and Ginzburg Landau theory of Superconductivity. However, this territory is not explored fully yet like superfluid analogy of cosmological phenomena. Perhaps we can expect future observations to verify where superconductor analogy can be observed.

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References:

[1] Gary T. Horowitz, Surprising Connections Between General Relativity and Condensed Matter, http://arxiv.org/abs/1010.2784
[2] Physicists apply Einstein's general theory of relativity to superconducting circuits, June 11, 2011, http://www.sciencedaily.com/releases/2011/06/110610094513.htm