Is Gravity Control Propulsion viable?

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Abstract

In 2015 the answer is still no. However this paper will look at what current physics has to say on this topic and what further questions need to be put forward to advance our enquiries. This work is a modified compilation of several posts that were originally published in the author's blogsite [1] on Gravity Control Propulsion (GCP) looking at several papers that deal with related topics with some ideas and speculations for further research.

Keywords: Gravity Control Propulsion, general relativity, quantum vacuum, spacetime metrics, virtual particles.

1 Introduction

"*I am tormented with an everlasting itch for things remote. I love to sail forbidden seas.*"

Herman Melville, Moby-Dick, 1851.

It appears that our reliance on chemical rocketry to get hardware into orbit will be with us for a long time to come. Private space companies are making Low Earth Orbit more accessible and cheaper however the fundamental high cost of launching hardware into orbit (between $20,000/Kg to $50,000/Kg depending on the launch platform) with its limitations for deep space exploration and restrictions to small payloads will still be there. Getting hardware out of Earth's gravity well only 150 Km above the surface requires vehicles with high thrust (rockets) which can expel large amounts of energy in a short period of time to overcome Earth's relentless gravitational pull. Rockets provide enough escape speed (11.2 Km/s) to reach a stable orbit. The alternatives such as the space elevator, external nuclear pulse propulsion and the Skylon Project all have some shortcomings. As usual funding is a big problem for research and whether such projects one day come to realisation seems to depend on economics, politicians or the profit potential for private investors.

The author has been looking at other alternatives such as Gravity Control Propulsion. If the weight problem can be reduced or eliminated altogether then

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Figure 1: Can we one day replace rockets with an alternative (less expensive) propulsion method? Photo: NASA

this would be a game changer for space exploration but is the concept viable or simply fantasy? Physics at the moment tells us that there is no means to shield an object from gravity or even control gravity for propulsion purposes. In a scene in the latest StarTrek movie in Figure 2, the Enterprise is built on the ground in a shipyard. This would solve many problems with cost and practicalities of building the starship instead of assembling it together into space, however it also begs the question: when the starship is finished, how do they get this big piece of hardware into orbit? In the StarTrek universe, have they found a means to circumvent the effects of gravity? In the movie one doesn't see the crew floating around on the bridge of the Enterprise when galloping the galaxy as well, have they developed a means to create artificial gravity deck plating? Recreating Earth's gravity environment in the Starship is important, it would solve many health issues for the astronauts who could otherwise be exposed to a zero-gee environment for long periods without rotating structures, not to mention doing basic tasks easier (space radiation exposure is another problem not discussed here).

Mastery of Gravity Control Propulsion implies a deep understanding of the physics of gravity and the origin of weight on mass. So where are we up to? We have General Relativity (GR)[2]; all experiments agree with it so far. However GR explains very well how mass moves in spacetime but not why. It is not a quantum theory of gravity and currently there are no such models that have been verified. More specifically GR does not explain for instance the dynamics of the quantum vacuum near mass or how mass interacts with the dynamic quantum vacuum. Why does mass affect spacetime? These are some of the questions that need to be answered. Closely related, what is the origin of inertia[3]? Is

Figure 2: Can a Starship be built and launched from the ground? Photo: StarTrek

Mach's principle a local or universal effect?

2 Hypothetical Gravity Control Propulsion

Several papers will be looked at that touch on these topics starting first with Marc Millis on Assessing Hypothetical Gravity Control Propulsion[5]. The paper refers to hypothetical gravity propulsion as a propellantless vehicle which can manipulate gravity, inertia or spacetime. The primary goal is to eliminate the need for propellant to get the vehicle into orbit. A space drive is defined as "*an idealised form of propulsion where the fundamental properties of matter and spacetime are used to create propulsion forces anywhere in space without having to carry and expel a reaction mass*". The space drive would convert potential energy into kinetic energy for this purpose. Millis also compares the energy efficiencies of the hypothetical space drive compared to the conventional rocket equation, noting that however these are very preliminary calculations. It is noted that rockets can only levitate (ie hover with no change in altitude) an object for a short period of time until their propellant runs out. The ability of a vehicle to hover indefinitely would be a big advantage. So Millis has outlined what is meant by hypothetical gravity propulsion. The elimination of the need for propellant is the big advantage here.[1]

So are there any loose ends in General Relativity today? According to Schiller's Strand Model[6] of Physics, which looks promising, one of the many predictions of the model include "*No deviations from special or general relativity appear for any measurable energy scale. No doubly or deformed special relativity arises in nature.*" The next paper to be looked at is by Orfeu Bertolami et al. on General Theory of Relativity: Will it survive the next decade?[7] Yes. However several interesting comments are made. It is mentioned on p2 "*Even at the classical level, and assuming the Equivalence Principle[8], Einstein's theory does not provide the most general way to establish the spacetime metric.*" Note the

[1] See also Marc's talk on Space Drives and Gravity Control Propulsion at a recent conference[30] and also the chapter "Review of Gravity Control within Newtonian and General Relativistic Physics" in Frontiers of Propulsion Science[57].

Equivalence Principle ie freely falling bodies have the same acceleration in the same gravitational field **independent of their compositions** which explains why a feather and a cannon ball for example dropped in a vacuum will touch the ground at the same time[9]. It is also mentioned that GR does not provide an understanding how gravity should be described at the quantum level.

Many researchers are concentrating their efforts on a unified theory of Physics that would include the electromagnetic, weak and strong interactions with gravity. Currently Quantum Field Theory (QFT) fails in strongly curved spacetime metrics (ie where GR is applicable) while GR only works when Planck's constant (QFT) is ignored. The two models, when considered separately, work very well at describing Nature on the large and small scales however concepts such as warp drives[10] and wormholes[11] for eg which are allowed in GR are denied by QFT (more specifically the physics of the quantum vacuum see Vol 5 p116 of Motion Mountain[12]). The paper goes on to describe the many solar system wide experiments that have been carried out to confirm GR in great detail. Bertolami in Section 3.4 deals with the interesting concept of gravity shielding. An earlier paper by Majorana in 1920 suggested the introduction of a screening or extinction coefficient$h$, to measure the shielding of a material of density $\rho(r)$ of the gravitational force between two masses which can be modelled as follows

$$F' = \frac{Gm_1 m_2}{r^2} \exp\left[-h \int \rho(r)\ dr\right].$$

There is currently no avenue in physics to derive h, the gravitational shielding constant, without violating the equivalence principle and there are no materials known that would affect this coefficient. According to Bertolami, the modern laboratory constraint is currently set at $h \leq 4.3 \times 10^{-15} m^2 kg^{-1}$. So is gravitational shielding a dead concept? It appears that no materials, regardless of their density or composition, will do the job. In the rest of the paper, other cosmological studies to confirm GR are looked at together with alternate models of gravity, dark matter (made of conventional matter and black holes surrounding galaxies) and dark energy (vacuum energy)[78].

So far Gravity Control Propulsion doesn't look promising. Bertolami and Tajmar[23] point out that "*even if gravity could be modified it would bring somewhat modest gains in terms of launching of spacecraft and no breakthrough for space propulsion*", although they mention further on that "*for a Geosynchronous Orbit however, the gain would be more important, but really significant only through a drastic "shielding" of the gravitational mass (> 95%).*"

We know spacetime tells mass how to move and mass tells spacetime how to curve (gravity) however with our current understanding of GR and QFT we don't understand the underlying quantum processes that causes this, GR however models the above very well. In QFT, a hypothetical particle, called the graviton[76] is thought to mediate gravity. The problem is there is no means to detect a single graviton by any experiment today and the foreseeable future; they are predicted to have no mass and no electric charge hence do not interact with photons and the absorption of a single graviton by a particle would only change its spin or position however the change would be indistinguishable from

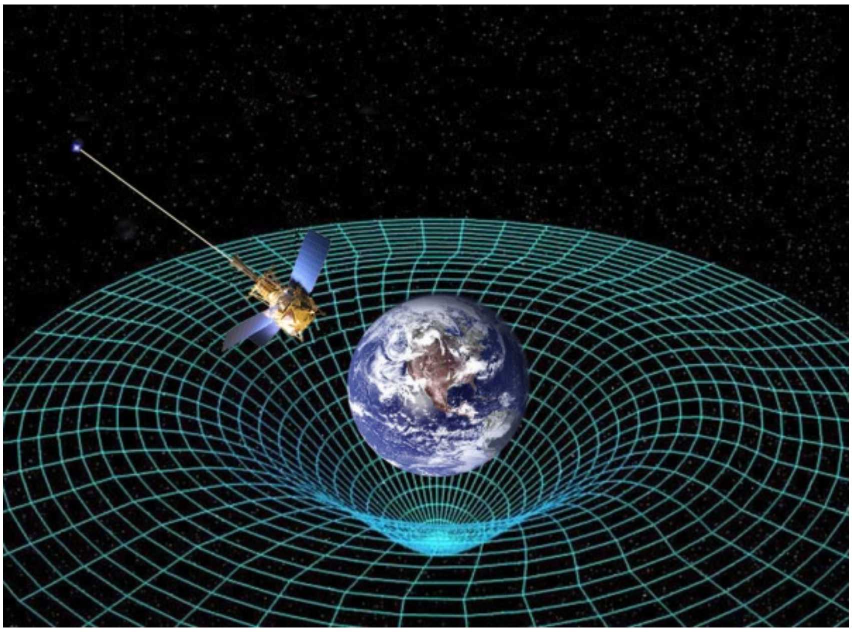

Figure 3: The Gravity Probe B experiment[13] confirmed spacetime effects predicted by GR. Image: NASA

a quantum fluctuation. So this will remain a hypothetical particle, although detecting gravitational waves[77] would be possible, this wouldn't confirm the graviton hypothesis since other models can explain gravitational waves.

Is it possible for mass not to tell spacetime how to curve? It was previously shown that mass doesn't appear to influence h, the gravitational shielding constant, in any way which makes sense since mass and energy ($E = mc^2$) are the cause of the spacetime curvature in the first place. What if we modify the vacuum energy density? This can be done today in the lab by Casimir plates.

The third interesting paper that touches on these topics is: Gedanken experiments with Casimir forces, vacuum energy, and gravity by Gordon Maclay. In the abstract it is mentioned "*we demonstrate that a change ΔE in vacuum energy, whether positive or negative with respect to the free field, corresponds to an equivalent inertial mass and equivalent gravitational mass $\Delta M = \Delta E/c^2$.*" Maclay also looks at the energy considerations of a hypothetical gravitational shield. Further on "*We are interested in considering several aspects of vacuum energy and Casimir forces, including the inertial mass associated with vacuum energy, the interaction of vacuum energy and gravity, and the possibilities of utilizing vacuum energy for propulsion or other purposes.*" Three concepts of mass are outlined:

- **gravi-inertial mass**: inertial mass that resists acceleration.
- **active gravitational mass**: mass that generates a gravity field around it.

- **passive gravitational mass**: mass that reacts to a gravitational field.

In GR, all three are equal and equivalent. For the purposes of this discussion however it is useful to look at the three concepts separately. It is mentioned that the vacuum field appears to contribute to inertial mass[14] and "*the general consensus is that only changes in vacuum energy act as a source of a gravitational field*". Several interesting gedanken experiments are outlined to answer the following questions:

1. Is a change in inertia of a system associated with a change in the vacuum energy of the system?
2. Is a gravitational field generated by the change in vacuum energy (equivalent active gravitational mass)?
3. If an external gravitational field is present, is there a change in the gravitational energy of the system that is associated with the change of vacuum energy (equivalent passive gravitational mass)?

The interesting (yet unconfirmed by experiment) Scharnhorst effect[15] is also mentioned. Why resort to gendanken experiments (thought experiments)? Because the quantum vacuum effects looked at are so small, it makes it a real challenge with today's lab technology to measure these with enough precision. High precision experiments in Physics unfortunetly means high costs. There's an interesting quote from the late Arthur C. Clarke[16]:

> "*If vacuum fluctuations can be harnessed for propulsion by anyone besides science-fiction writers, the purely engineering problems of interstellar flight would be solved.*"

In Gedanken Experiment two, the author refers to another paper: A Gedanken spacecraft that operates using the quantum vacuum (Dynamic Casimir effect)[17]. Unfortunetly the thrust generated, if confirmed, is tiny although interesting since the Dynamic Casimir Effect was only verified recently in the lab in 2011, where mirrors (SQUIDs[18]) are vibrated very fast at $\frac{1}{4}c$ which created real photons out of the quantum vacuum. It is very unlikely that down the track this Gedanken spacecraft will replace rockets anytime soon.

In Gedanken Experiment Three: Vacuum Energy Contributes to Inertial Mass, Maclay considers an isolated sphere with a battery operated motor which can move Casimir plates inside the sphere. As the plates are moved closer, what happens to the total energy of the system? Total energy of the sphere is conserved however the distribution of the energy within the system has changed from the vacuum energy between the plates and the battery. Maclay "*suggests that it might be possible to make components that have negative inertial mass. Such objects would tend to rise in a uniform gravitational field. Indeed negative vacuum energy in the stack of parallel plate capacitors considered theoretically by Calloni et al resulted in a force in a gravitational field that was in the opposite direction from that experienced by normal positive matter, but the positive force due to the mass of the silicon wafers, was much larger. Could one make an object that floated in a gravitational field?*".

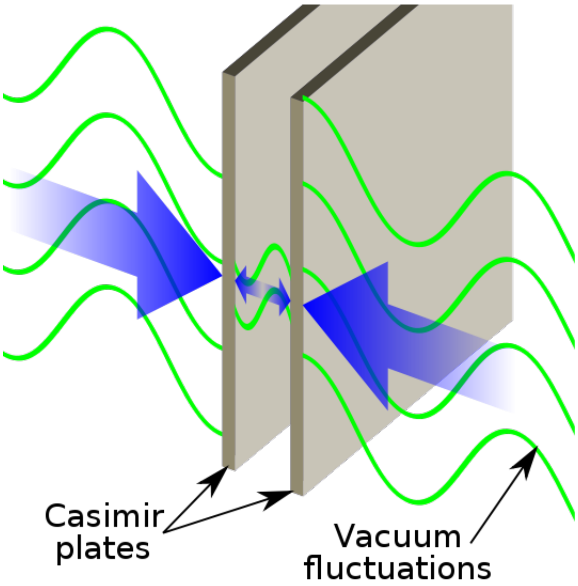

Figure 4: Casimir plates[19] partly suppressing vacuum fluctuations. Image: Wiki

One needs to be careful here with the terms "negative vacuum energy" and "negative inertial mass." Lower vacuum energy between the Casimir plates, by restricting the wavelengths of photons and reducing the vacuum energy does not necessarily imply a negative vacuum energy compared to the vacuum energy outside the plates. It is a lower energy density state compared to the outside environment but does not imply negative energy and mass, the distinction is important and here the answer to the author's last question would be no. Negative mass[21] also has not been observed in Nature, so this is a hypothetical concept. Nevertheless the paper proposes an experiment to measure the ratio of the gravitational force to the Casimir force. Note that we are not talking about anti-matter[22] here (which is also predicted to fall with gravity just like normal matter). Here is what Schiller also has to say on negative mass in Motion Mountain Vol 1, p98[12]:

> *"Indeed, a negative (inertial) mass would mean that such a body would move in the opposite direction of any applied force or acceleration. Such a body could not be kept in a box; it would break through any wall trying to stop it. Strangely enough, negative mass bodies would still fall downwards in the field of a large positive mass (though more slowly than an equivalent positive mass). Are you able to confirm this? However, a small positive mass object would float away from a large negative-mass body, as you can easily deduce by comparing the various accelerations involved. A positive and a negative mass of the same value would stay at constant distance and spontaneously accelerate away along the line connecting the two masses. Note that both energy and momentum are conserved in all these situations. Negative-mass bodies have never been observed. Antimatter,*

which will be discussed later, also has positive mass."

Gedanken Experiment three doesn't look promising. GE 4 shows that "*Vacuum energy couples to gravity the same way any other form of energy is expected to couple to gravity.*", all forms of energy (mass) couple to gravity as shown further in GE 5. GE 7 concludes that "*our assumption that vacuum energy does not contribute to active gravitational mass is not true.*" In the last GE 8, Maclay looks at energy considerations of a hypothetical gravity shield and asks "*Would a box that shields against vacuum fluctuations be fundamentally impossible?*". The paper has been useful in outlining various concepts related to the quantum vacuum, gravity and mass. It is clear that more experiments are needed to answer some of the questions raised. It would be useful for example to be able to modify the vacuum energy without having to resort to Casimir plates to carry out experiments in this difficult field and to be able to carry out measurements with other geometries other than parallel plates and spheres to verify the various models of Casimir forces in these conditions. Is Quantum Vacuum Engineering a viable field in the future for example? Before going on to have a deeper look at how the quantum vacuum might contribute to gravity, it is worth reading some interesting comments from Sean Caroll[20] on the Higgs particle, inertia and mass.

3 Gravity and the Quantum Vacuum

If one does a survey of the online preprints on arXiv.org and viXra.org and does a search for terms gravity and quantum vacuum, one will find a large number of papers dealing with the subject. Many of the papers looked at appear to be highly speculative or introduce assumptions to their models or appear to have contradictions to known Physics. The papers that were more useful described their model rigorously and proposed an experiment to verify their hypothesis with testable predictions. Our inability to understand the physical mechanism of the bending of spacetime by mass and energy density is the main stumbling block to answering this question. All the models currently proposed as alternatives to GR[24] are either unconfirmed, speculative or have their own problems.

Let's have a look at the following paper by Alfonso Rueda and Bernard Haisch[25] on Gravity and the Quantum Vacuum Inertia Hypothesis. We'll first note "*Neither our approach nor the conventional presentations of GR for that matter, can offer a physical explanation of the mechanism of the bending of spacetime as related to energy density*", however from their hypothesis the authors explain:

"*Inertial mass arises upon acceleration through the electromagnetic quantum vacuum, whereas gravitational mass — as manifest in weight — results from what may in a limited sense be viewed as acceleration of the electromagnetic quantum vacuum past a fixed object. The latter case occurs when an object is held fixed in a gravitational field and the quantum vacuum radiation associated with the freely-falling frame instantaneously comoving with the object follows curved geodesics as prescribed by general relativity.*"

In others words one only feels weight while for example sitting on a chair but not while in free fall when jumping out of an aeroplane. We know the quantum vacuum consists of a sea of particles created and annihilated in very short time frames, these are called virtual particles[26]. Among these virtual pairs of particles are positive and negative electrons popping in and out of existence. This process also appears to be responsible for determining the universal speed limit of light, mass and energy in vacuum $c_0 = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$ (see The quantum vacuum as the origin of the speed of light[27]). Is an accelerating quantum vacuum, with its sea of virtual particles, interacting with every atom in an object and responsible for weight? Is gravity electromagnetic in origin? If this were the case one still would have to explain the physics of what causes the acceleration of the quantum vacuum by mass and energy density. According to the paper, the Quantum Vacuum Inertia Hypothesis is consistent with GR and the authors derive the same result using both SED[28] and QED[29]. They also propose that "a*t least part of the inertial force of opposition to acceleration, or inertia reaction force, springs from the electromagnetic quantum vacuum.*" This Rindler frame force as it is called stems from the local interaction of mass with the electromagnetic quantum vacuum. When accelerated, however, there is no force on objects with constant velocity (inertial frames) and is proportional to the acceleration imparted on the object.

> "*We have called the notion that at least part of the inertia of an object should be due to the individual and collective interaction of its quarks and electrons with the quantum vacuum as the quantum vacuum inertia hypothesis with the proviso that analogous contributions are expected from the other bosonic vacuum fields.*"

The Rindler frame force (or the vacuum electromagnetic counteracting reaction force) is derived as

$$-f^{zp} = \left[\frac{V_0}{c^2} \int \eta(\omega)\rho(\omega)d\omega \right] a.$$

This is a description of the electromagnetic component of the proposed reaction force and it remains to be seen what the other components of the force are. An experiment is proposed with a cavity resonator to verify the following: "*First, some confirmation would be given to the electromagnetic vacuum contribution to inertial mass concept, or quantum vacuum inertia hypothesis. An important confirmation would be the reality — or virtuality — of the zero-point field.*" If this hypothesis is confirmed, this would rule out Mach's principle[31] and inertia would be shown to be purely a local effect between mass and the quantum vacuum. Rueda and Haisch also suggest that gravity even in part is electromagnetic in origin so before continuing on it is worthwhile to look at what options are available for electromagnetic shielding.

Earlier on, the hypothetical gravitational shielding concept was discussed. Although unrelated, it is useful to explore the following two effects in physics which are confirmed by experiment. Electromagnetic shielding or the Faraday cage[32] is widely used in electronics and the lab to exclude both static and non-static electric fields inside a metal cage, due to the electrons in the metal shield rearranging themselves to effectively cancel the outside electric field inside the

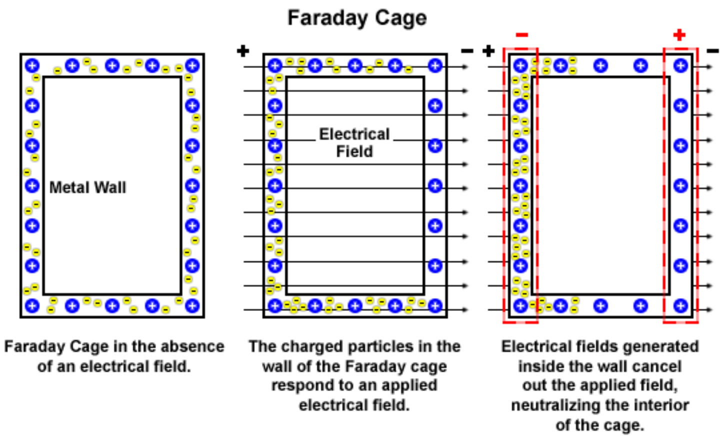

Figure 5: The Faraday cage excludes electric fields inside the cage. Image: Magnet Lab

cage as shown below. It will also shield the inside from the fluctuating magnetic field component of electromagnetic waves (such as radio waves) but cannot block static or slowly varying magnetic fields (such as the Earth's magnetic field).
For magnetic fields we have the Meissner effect[33], a property of superconductors which exclude magnetic fields inside the object when a critical cold temperature is reached as shown in Figure 6 and this also applies to hollow superconductor objects.

Questions:

- If the dynamic quantum vacuum is partly responsible for gravitational effects as suggested in the paper, is there a means to shield an object from the accelerating quantum vacuum?
- Can we stop the interaction of electrons and quarks of the object inside the shield from the outside accelerating dynamic quantum vacuum?
- If a shielded object was disconnected from the outside quantum vacuum, how would this affect the object's mass and the quantum vacuum inside?
- Is it plausible to have a static quantum vacuum within an accelerating quantum vacuum?

Returning to Rueda and Haisch, the Equivalence Principle is explained:

> "*The physical basis for the principle of equivalence is the fact that accelerating through the electromagnetic quantum vacuum is identical to remaining fixed in a gravitational field and having the electromagnetic quantum vacuum fall past on curved geodesics.*"

Their hypothesis appears to agree with GR and also explains the bending of light near mass "*However this does not mean that we have explained the mechanism for the actual bending of space-time in the vicinity of a material object. This is the origin of so-called active gravitational mass that still requires an explanation*

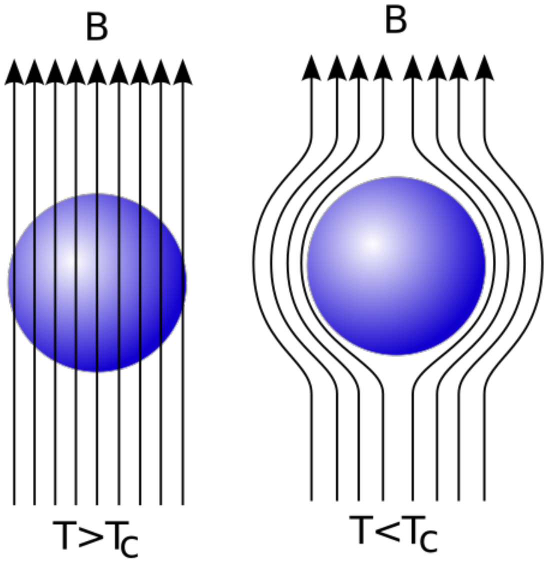

Figure 6: The Meissner effect for superconductors, magnetic field lines are excluded from the object when a critical cold temperature is reached. Image: Wiki

within the viewpoint of the quantum vacuum inertia hypothesis." There is a useful reference to the (highly recommended) textbook Gravitation[34] by Misner, Thorne and Wheeler and points to Chapter 17 "*How mass-energy generates curvature*" which describes the alternative models and provides a good insight on the various approaches to this problem. The sixth model by Sakharov begins with general vacuum considerations as did the authors of this paper. Rueda and Haisch also gives an explanation of mass "*it was made clear that within the quantum vacuum inertia hypothesis proposed therein, the mass of the object, m, could be viewed as the energy in the equivalent electromagnetic quantum vacuum field captured within the structure of the object and that readily interacts with the object.*"

So it appears from the above hypothesis that the key is to understand how electrons and quarks in atoms interact with the dynamic quantum vacuum. The authors point out that the mechanism responsible for the acceleration of the quantum vacuum due to mass and energy density hasn't been established. However returning to the original question regarding GCP it appears that this answer cannot be answered by GR, the current alternate models to GR or the above hypothesis, however they do provide some good pointers to follow. The problem is pointing to quantum physics and particle physics, we lack the understanding of the quantum processes that occur between matter - dynamic quantum vacuum interactions. The particles mentioned in the paper ie electrons and quarks both have electric charge. We cannot interact with quarks[35] as they are locked in the nucleus of protons and neutrons due to colour confinement[36] so the lepton[37] family of particles will be looked at next.

4 A dynamic and accelerating Quantum Vacuum

Following on from the general idea of an accelerating quantum vacuum composed of virtual particles interacting with mass which we perceive as gravity (spacetime curvature) and responsible for weight, emphasising that this is only a hypothesis that appears to fit GR and may provide an avenue to make new testable quantum predictions on gravity. We haven't ruled out the other possibilites though, which are graviton exchange between mass, a combination of quantum vacuum electromagnetic interactions and gravitons, or other interactions via unknown particles. As noted previously, the graviton hypothesis is not a testable model for the foreseeable future and cannot be proved or disproved by experiment so it can't be ruled out although this is not helpful for our aim for GCP since we have no control of graviton interactions. We will also look at Gravitoelectromagnetism[38] (vacuum dragging effects). Although there are similarities between Maxwell's field equations and the GR field equations, we will show later that it appears these cannot be used for GCP. Both classical electromagnetism and gravity operate under Gauss's inverse square law in a three dimensional space, this is where the similarities end, however gravitoelectromagnetism is a useful tool to model the effects of gravity under certain circumstances (such as gravitational waves). Our main aim is to investigate if there is any direct relation between electromagnetism and gravity and understand Nature's mechanism for spacetime curvature due to mass and energy density. Since we are good at manipulating experiments that are electromagnetic based, if there is a relation, there would be avenue for GCP related experiments down the track. If there is no relation between electromagnetism and gravity, GCP is in trouble.

The accelerating quantum vacuum is composed of the full spectrum of virtual particles which have their counterpart real particles[39]. Among them there are virtual electrons and positrons (part of the lepton family of particles) both of which have electric charge, meaning there is an avenue for interaction via electromagnetism. We will also need to look at the mix of virtual particles that have zero charge. Figure 7 shows the situation quite well for a particle with charge **q**, velocity **v**, and the effect of the Lorentz force[40] on this test charge (negative, positive or neutral) due to a magnetic field **B** coming out of the screen perpendicular towards the reader.

Another paper that proposes a similar hypothesis to the previous paper follows: Does the Quantum Vacuum Fall Near the Earth? The Downward Acceleration of the Quantum Vacuum is Responsible for the Equivalence Principle[41]. The authors make several modifications to the previous accelerating quantum vacuum model, although it makes several interesting points, it also introduces some highly speculative propositions. In summary Ostoma and Trushyk propose:

> "*The downward acceleration of the virtual electrically charged fermion particles of the quantum vacuum is responsible for the Einstein Weak Equivalence Principle and for our perception of 4D space-time curvature near the earth. Since the virtual fermion particles of the quantum vacuum (virtual electrons for example) possess mass, we assume*

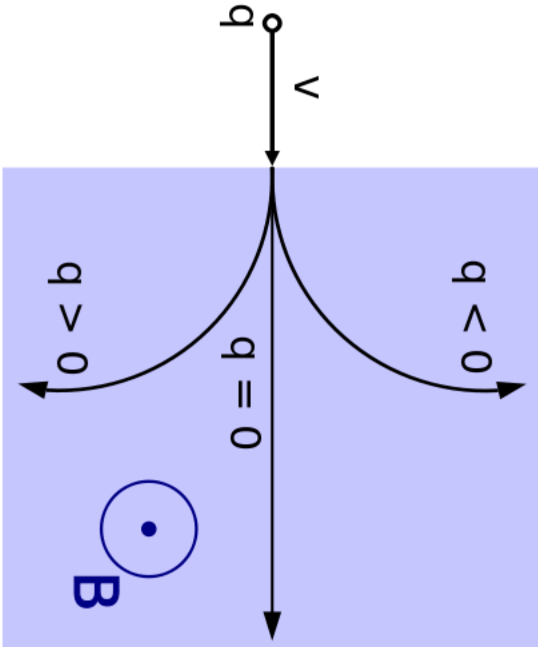

Figure 7: Deflection of a test charge q due to a magnetic field coming out of the screen. Image: Wikipedia.

> *that during their short lifetimes the virtual fermions are in a state of downward acceleration (or free-fall) near the earth. Many of the virtual fermions also possess electrical charge, and are thus capable of interacting electrically with a real test mass, since a test mass is composed of real, electrically charged, fermion particles. The electrical interaction between the downward accelerated virtual fermions with nearby light or matter is responsible for the equivalence of inertial and gravitational mass, and also responsible for our perception of 4D space-time curvature near the earth.*"

The opposition to acceleration of a test mass by the reverse process is proposed to be the cause of inertia. The key point here that is of interest is where it is mentioned that the virtual fermions are interacting electrically with mass.

It remains to be seen if this hypothesis (ElectroMagnetic Quantum Gravity or EMQG) is correct and if this is the only cause of gravity. The paper does not give a root cause for the mechanism of the downward acceleration of the quantum vacuum however the concept as outlined is enough to explain GR and vacuum dragging effects which is why the model is interesting. The authors move on from the classical explanation of GR to a quantum model of gravity:

> "*4D curved Minkowski space-time is now a consequence of the behavior of matter (particles) and energy (photons) under the influence of this (statistical average) downward accelerated 'flow' of charged virtual particles of the quantum vacuum. This coordinated 'accelerated flow' of the virtual particles can be thought of as a special 'Fizeau-like vacuum fluid' that 'flows' through all matter near a gravitational*

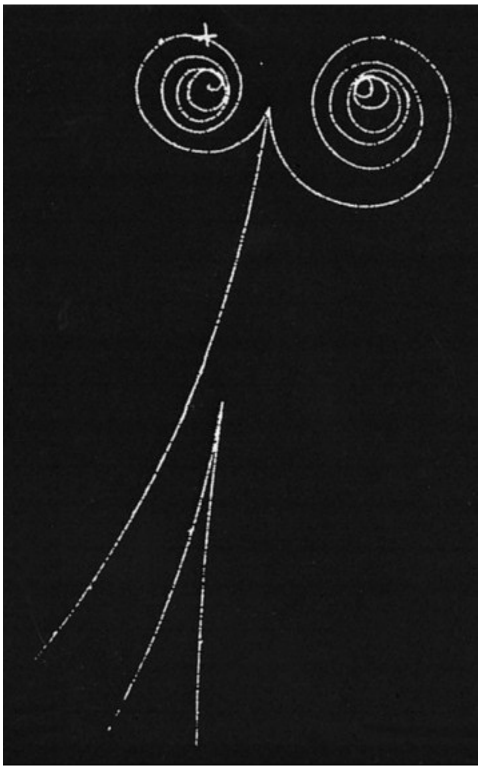

Figure 8: Real electron and positron curl in opposite directions in a bubble chamber magnetic field. Image: Britannica[46]

> *field (and also in matter undergoing accelerated motion). Like in the Fizeau experiment (which was performed with a constant velocity water flow) the behavior of photons, clocks, and rulers are now affected by the downward accelerated flow of the virtual particles of the quantum vacuum caused by gravity.*"

The vacuum's net electric charge is neutral and there must be equal numbers of virtual electrons and virtual positrons (anti-electrons) at a given time due to pair creation[42] and annihilation[43] processes. Since these two particles have equal and opposite electrical charge they both react to magnetic fields. Also since this "Fizeau-like vacuum fluid" of virtual particles interacts with normal matter, we can deduce that the motion of matter can also influence this "vacuum fluid" which we observe as vacuum dragging effects (gravitomagnetism), normal matter being made of protons and neutrons which are made of charged quarks with our usual cloud of charged electrons surrounding the nucleaus for a standard atom. Note this is not a Superfluid Vacuum Theory[44] or Aether[45] model, although there are some similarities.

On p8 Ostoma and Trushyk talk about Hawking radiation[47] for black holes which is of interest because this is a special case where the virtual particle and anti-particle pairs do not undergo annihilation at the event horizon and offers further insight on the physics of the quantum vacuum virtual particle field. Vacuum polarisation[48] also shows that our observations of real electron charge is affected by the cloud of virtual positrons of the quantum vacuum that congregate around the electron (also known as charge screening). On p11 the paper goes on to explain the EMQG model of gravity involving two particle exchange mechanisms:

> "*What is unique about EMQG theory is that gravitation involves both the photon and graviton exchange particles operating at the same time, where now the photon plays a very important role in gravity! In fact, the photon exchange process dominates over the pure gravitational interaction, and is in the most part, responsible for the principle of equivalence of inertial and gravitational mass. The photon particle is also responsible for another property that all matter possesses, the inertial force that acts to give a mass the property of Newtonian inertia.*"

The part of the claim that gravitation involves graviton exchange particles cannot be verified by experiment (although this is the current accepted norm in Physics) however we can verify photon exchange mechanism in principle. It is mentioned on p13 that there appears to be a deep connection between electromagnetism and gravity because Coulomb's electrical force law[49]: $F = \frac{KQ_1Q_2}{r^2}$ and Newtonian gravitational force law[50]: $F = \frac{GM_1M_2}{r^2}$ are similar. Both classical electromagnetism and gravity operate in a three dimensional space where Gauss's inverse square law is applicable. Gravitomagnetism was devised well before GR as a tool to model gravity using the similarities between the two forces. Gravitational waves, for example can be modeled by splitting the gravitomagnetic and gravitoelectric components just like electromagnetic waves can be split into their electric and magnetic field vector components. It appears that no further insight will be gained with this approach since this is a classical tool devised for a classical model of gravity although useful to explain vacuum dragging effects and gravitational waves. We'll keep it as a set for our classical toolbox though. Attempts to discover direct mechanisms to convert electromagnetism to gravity based on the gravitoelectromagnetic field equations are expected to be unsuccessful (see for example Coupling of Gravitation and Electromagnetism in the Weak Field Approximation[51]).

On p14 interesting questions are put forward:

> "*Does the graviton particle move in a 4D flat space-time like the photon of QED? Does the graviton exchange process somehow 'produce' curvature on an otherwise flat background 4D space-time, when propagating from one mass to another? If the graviton is not responsible, then what is it about mass that is directly capable of producing 4D space-time curvature surrounding the mass? In other words, if the 4D space-time curvature is not caused by the graviton exchanges, then what is the connection between matter and 4D space-time? If you double the mass, you change the amount of space-time curvature. Why?*
>
> *To our knowledge, these questions remain unanswered. In EMQG, we propose a quantum action based on the quantum vacuum and the*

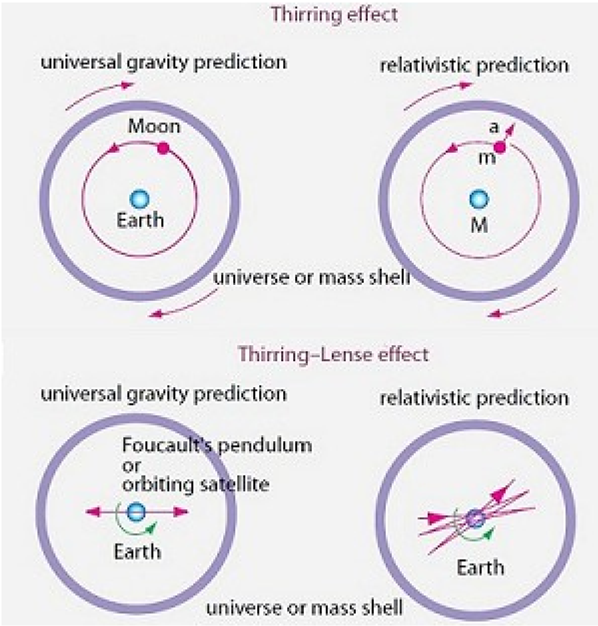

Figure 9: Examples of vacuum dragging[52]: Thirring and Thirring-Lense effects. Image: Motion Mountain[12], Vol 2, p150

> *existence of graviton particles (that have characteristics very similar to the photon) that resolves these questions. It turns out that the state of acceleration of the quantum vacuum with respect to another test mass represents the quantity of 4D space-time curvature!*"

The concept of an accelerating quantum vacuum which is responsible for 4D spacetime curvature is plausible and also can explain vacuum dragging effects. There are however some problems with the model and possible modifications are required, without resorting to new particles (such as the paper's "masseon" particle). Although EMQG also resorts to gravitons for part of their explanation for 4D curvature, it is not clear at this stage if this is a requirement for a successful model since we are unable to question Nature if she is actually using gravitons to mediate gravity. It should be noted that from p16 regarding a derivation for GR, there is a relatively straightforward derivation offered in Motion Mountain Vol 2 Ch 4 "Simple General Relativity: Gravitation, maximum speed and maximum force". Just like Special Relativity is based on maximum speed c in Nature, GR can be derived from the following: There is in Nature a maximum force: $F \leq \frac{c^4}{4G} = 3.0 \cdot 10^{43} N$. Both maximum speed c and maximum force are properties of the vacuum. It is interesting to note here from Motion Mountain Vol 2 p33:

> "*However, there is at least one system in nature where the speed of sound is indeed a limit speed for energy: the speed of sound is the limit speed for the motion of dislocations in crystalline solids. (We discuss this in detail later on). As a result, the theory of special relativity is also valid for dislocations, provided that the speed of light*

is replaced everywhere by the speed of sound! Indeed, dislocations obey the Lorentz transformations, show length contraction, and obey the famous energy formula $E = \gamma mc^2$. In all these effects the speed of sound c plays the same role for dislocations as the speed of light plays for general physical systems."

This observation above is interesting for the model of the accelerating quantum vacuum looked at. On p 35, Ostoma and Trushyk ask the important questions:

"*Does the general downward acceleration of the virtual particles of the quantum vacuum near a large mass affect the motion of photons propagating within the gravitational field? Or is the deflection of photons truly the result of an actual spacetime geometric curvature (which holds down to the tiniest of distance scales)?*

The answer to this very important question hinges on whether our universe is truly a curved, geometric Minkowski 4D space-time on the smallest of distance scales, or whether curved 4D space-time results merely from the activities of quantum vacuum virtual particles interacting with other real quantum particles. EMQG takes the second view.

According to postulate 4 (appendix A-11) of EMQG theory, light takes on the same general acceleration as the net statistical average value of quantum vacuum virtual particles, through a 'Fizeau-like' scattering process involving many virtual particles. By this we mean that the photons are frequently absorbed and re-emitted by the electrically charged virtual particles, which are (on the average) accelerating towards the center of the large mass. When a virtual particle absorbs the real photon, a new photon is re-emitted after a small time delay in the same general direction as the original photon. This process is called photon scattering (figure 5). We will see that photon scattering is central to the understanding of space-time curvature."

The second view looks plausible however the EMQG model as proposed in the paper, with its introduction of several new hypothetical particles other than gravitons to explain how gravity is mediated, is highly speculative and doesn't appear to be correct. We'll keep this aside for the time and make a mental note that this part of the model may need more work. The explanation from p39 on photon scattering in a static and accelerated quantum vacuum is interesting.

It is feasible that the photon undergoes a time delay between absorption and re-emission between each charged virtual particle it encounters in the quantum vacuum and undergoes a "photon vacuum delay"; which gives an average light velocity of 300,000 Km/s. It is not clear however if there is a higher "raw light velocity" of the photon between each charged virtual particle, at this stage this cannot be verified (however see the following paper: Does the speed of light depend upon the vacuum?[53]). One could speculate if the density of the charged virtual particles could be reduced somehow in a given volume of the quantum vacuum, this average light velocity could be increased as the number of encounters with charged virtual particles is decreased. The charged virtual particles can be seen as offering resistance to the propagation of the photons. This fits in well with photon scattering processes in materials, Fizeau's moving water experiment and the equations of motion of dislocations in crystalline solids mentioned above. Continuing on from p44:

> "*We are now in a position to understand the concept of the geodesic proposed by Einstein. The downward acceleration of the virtual electrically charged masseons of the quantum vacuum serves as an effective 'electromagnetic guide' for the motion of light (and for test masses) through space and time. This 'electromagnetic guide' concept replaces the 4D space-time geodesics that guide matter in motion in relativity. For light, this guiding action is through the electromagnetic scattering process of section 9.5. For matter, the electrically charged virtual particles guide the particles of a mass by the electromagnetic force interaction that results from the relative acceleration. Because the quantum vacuum virtual particle density is quite high, but not infinite (at least about* 10^{90} *particles* $/m^3$*, the quantum vacuum acts as a very effective reservoir of energy to guide the motion of light or matter.*"

If the overall model turns out to be correct and we can devise a method to interfere with the electrical interactions of the vast numbers of falling virtual charged particles with the real, electrically charged matter particles for a test mass then there is an avenue to carry out GCP related experiments. What is interesting here is that although the details in the gravity mediation process is still unclear at this stage, the effect isn't and if the secondary cause is via electrical interactions we can in principle interact or interfere with the process even if the root cause turns out to be via neutral gravitons with which we cannot interact or modify.

At this stage however, using the above model (if correct) we can for example rule out the Podkletnov and Tajmar experiments which both rely on rotating superconducting rings. Podkletnov's experiment in Figure 10 claimed a 2% weight reduction on a test mass in the center of the ring. The magnetic field generated by the rotating superconducting ring is not preventing the accelerating quantum vacuum charged virtual particles from interacting with the test mass at its center as the field configuration is incorrect. Another experiment by Tajmar in Figure 11 was devised to look at gravitomagnetic and gravitoelectric fields is also incorrect. As mentioned previously above, one should not confuse vacuum dragging effects that can be modeled with classical gravitomagnetism with actual real fields in Nature.

We'll next need to look at some of the problems with the EMQG model and modifications required that don't rely on hypothetical particles. We also need to deal with the neutral virtual particles that make up the accelerating quantum vacuum and look at some testable predictions that can be verified by experiment today.[2]

[2] There is an interesting post on Backreaction also worth a read: Quantum gravity phenomenology \neq detecting gravitons[56].

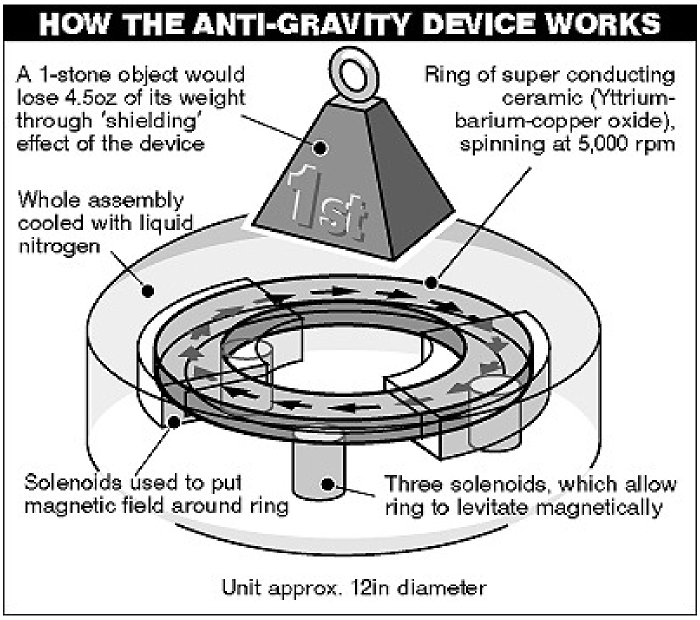

Figure 10: Podkletnov's experiment[54]: no weight reduction can be obtained with this configuration.

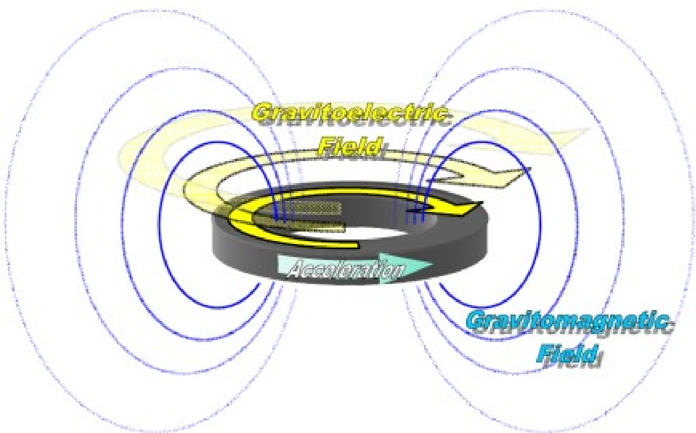

FIGURE 1. Gravitomagnetic and Gravitoelectric Field Generated by a Rotating and Angularly Accelerated Superconductor.

Figure 11: Tajmar's experiment[55]: no gravitoelectric and gravitomagnetic fields can be found, only vacuum dragging effects can be measured.

5 Engineering spacetime for GCP

It appears that General Relativity alone will not answer our questions related to GCP. Despite the several speculative ideas presented so far by the previous authors, some of the interesting concepts proposed are worth exploring further. Let us look at a modified EMQG model and dissect the fermion family of virtual particles of the accelerating quantum vacuum and attempt to establish which virtual particles are contributing to spacetime curvature (gravity). More specifically, one can speculate that the interactions between the accelerating charged virtual fermion particles and the real fermion particles in a test mass is the result of the effect we perceive as gravity. Since there is interaction, not surprisingly real fermion particles can also influence the average motion of virtual fermion particles for a particular reference frame, we observe this as vacuum dragging effects mentioned earlier however these effects are much weaker than the gravitational effects due to the much lower mass of the virtual fermion particles, all this loosely translates from GR as spacetime tells mass how to move and mass tells spacetime how to curve. It is suspected that the cross section of real fermion particles in a test mass presented to the accelerating virtual particle field (spacetime) plays some part in this process together with the motion of quarks within nuclei and energy density.

For GCP to be useful for propulsion purposes, one aim is to be able to impart a 100% weight reduction on a test mass at ground level. From a GR point of view since gravity is curved spacetime, we need to give a certain volume a flat spacetime metric within a curved spacetime metric as shown in Figure 12.

The test mass needs to be totally enclosed in the flat spacetime volume. Another aim for GCP is to be able to move this imparted flat spacetime metric with the test mass within the gravity well (from ground to orbit for example). Note from a GR point of view there is no difference in the metric far away from Earth's gravity well, the imparted flat spacetime metric within the gravity well or at the center of Earth taking an ideal spherical model of Earth and excluding gravitational influences from the Sun, Milky Way etc for discussion purposes. According to the modified EMQG model for this flat spacetime to happen in the gravity well there can be no interaction allowed between the test mass and the downward accelerated virtual fermion particle field (spacetime). So in summary for GCP to be viable there are two requirements that must be met from a GR point of view:

1. To be able to impart a flat spacetime metric around a test mass within a curved spacetime gravity well.
2. To be able to move this imparted flat spacetime metric with the test mass within a gravity well.

To be clear here, we are not warping the spacetime metric to render it flat as it might be interpreted when looking at the graph, this is not related to "Alcubierre's warp drive" which although appears viable when looked at within GR only, has been shown in this paper[58] for example to be unviable when quantum effects are also taken into account. The net effect of the flat spacetime is not the result of any "warping" of the spacetime metric. The good news for

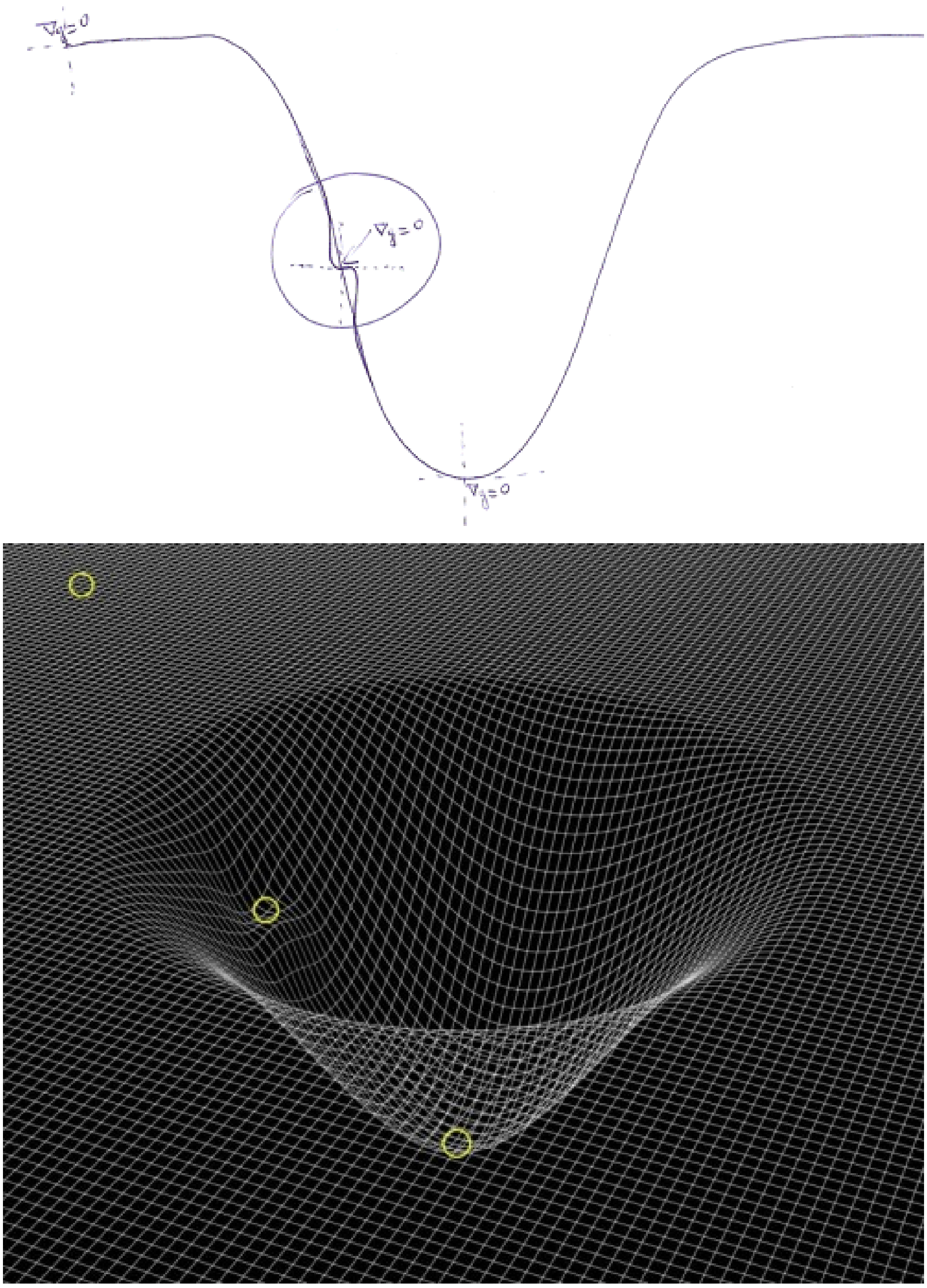

Figure 12: One aim for GCP is to be able to impart a flat spacetime metric around a test mass within a curved spacetime gravity well.

FERMIONS matter constituents spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2			
Flavor		Mass GeV/c^2	Electric charge
ν_e	electron neutrino	$<1\times10^{-8}$	0
e	electron	0.000511	–1
ν_μ	muon neutrino	<0.0002	0
μ	muon	0.106	–1
ν_τ	tau neutrino	<0.02	0
τ	tau	1.7771	–1

Quarks spin = 1/2			
Flavor		Approx. Mass GeV/c^2	Electric charge
u	up	0.003	2/3
d	down	0.006	–1/3
c	charm	1.3	2/3
s	strange	0.1	–1/3
t	top	175	2/3
b	bottom	4.3	–1/3

Figure 13: Fermion particles (anti-matter equivalent not shown have same mass but opposite electric charge). Image: The Standard Model[59]

GCP in principle charged virtual fermion particles can be deflected via magnetic fields however the bad news is we cannot do so for neutral uncharged particles. If we look at the fermion class of particles in Figure 13 however we are in luck as the only family of fermion particles that are neutral are the neutrinos.

Do we need to concern ourselves with the neutrinos[60]? It appears no. Remembering we are dealing with virtual[26] not real particles, the currently accepted model specifies that the three family of real neutrinos have a tiny mass and are electrically neutral weakly interacting particles. The virtual neutrinos (yet to be confirmed) are expected to have an insignificant mass and appear not to be involved in the EMQG gravity process we are looking at. A large number of neutrinos come from our Sun and pass right through Earth without ever interacting with a single atom in it. The radioactive isotopes of calcium and potassium[61] in the bones of a human body for example emit some 400 neutrinos per second and travel throughout the Universe even if lightyears of lead were hypothetically laid in their path. Since the electron neutrino, muon neutrino, tau neutrino and their anti-matter counterparts are the only virtual fermion particles that are electrically neutral and appear not to contribute to spacetime curvature (as per the modified EMQG model), the following is proposed:

All accelerating virtual fermion particles that contribute to gravity have a non-zero electric charge.

A few remarks on virtual particles need to ne made before going on further, after all the model relies heavily on them. Virtual particles can be regarded as very short lived excitations of the background fluctuating quantum vacuum

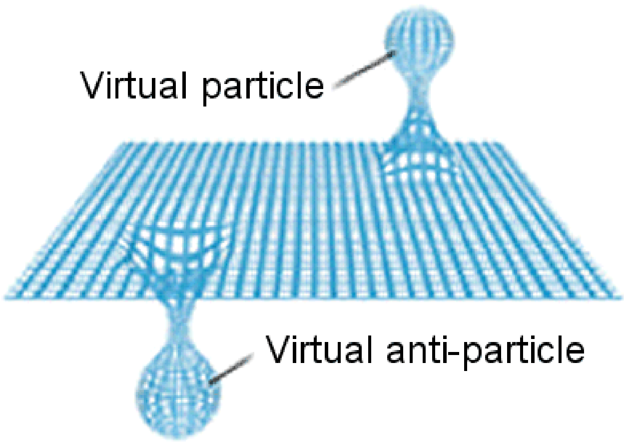

Figure 14: A visualisation of a virtual particle / anti-particle pair, not free particles hence called virtual. Note that Nature does not allow us to distinguish or observe virtual particles. Image: unknown

that can act as interaction mediators but don't quite have enough energy to become real particles themselves (however sometimes they do break free to become real particles if given enough energy). Their existence is so short lived they cannot be directly observed (hence the term virtual) however they make their presence known to us by various effects they cause to real particles which we can observe such as vacuum polarisation[62], Casimir effect[63], Hawking radiation[64], Lamb shift[65], spontaneous emission of photons[66], radioactive decay[67] etc. They always come in pairs ie the virtual particle and its counterpart virtual anti-particle both with equal but opposite electric charge. The pair of virtual particles then annihilate giving back the energy borrowed from the quantum vacuum during their short lived existence. In some situations for example in the presence of a strong electric field exceeding the critical value of $E_c = \frac{m_e^2 c^3}{e\hbar} = 1.3EV/m$ (a prediction from the Dirac equation[68]) or at a black hole event horizon via Hawking radiation, the virtual electron-positron pairs are prevented from recombining and the system pair is boosted by energy to become real electron and positron free particles. This "pair creation" process is the result of transformation of energy into matter via the quantum vacuum.

Electric charge for virtual particles is conserved (otherwise the vacuum's net electric charge would not be neutral and there would be vacuum polarisation) and because of the Heisenberg indeterminacy relation[69] for virtual particles we have $\Delta E \Delta t < \frac{\hbar}{2}$ (for real particles $\Delta E \Delta t \geq \frac{\hbar}{2}$ applies) ie in Nature:

Actions or changes smaller than $\hbar = 1.06 \cdot 10^{-34} Js$ cannot be observed.

All of Quantum Physics comes from this simple statement, Nature's "behind the scene clockwork" is directly hidden to us behind $\hbar$. Virtual particle mass also differs from their real particle counterparts which depends on how long in time they exist (the longer they exist, the less massive they can be and vice versa) and they do not obey the energy-momentum relation[70] as real particles

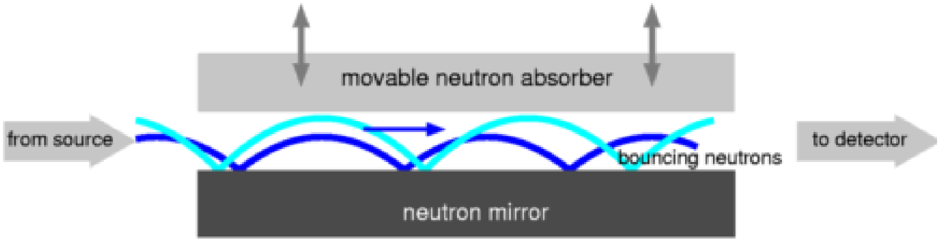

Figure 15: Bouncing neutrons in the gravitational field. Image: Scherer[72]

do ie for virtual particles $E^2 \neq m^2c^2 + p^2c^2$ hence in some instances virtual particles can move faster than light (which real particles cannot) and since they are unobservable this doesn't contradict Special Relativity.

We need to look at next which accelerating charged virtual fermion particles are interacting with the nuclei (protons and neutrons) of a test mass to cause the effect we perceive as gravity. We can discount an interaction acting on the electron cloud surrounding nuclei for this effect. Most matter in the Universe is in the form of nuclei stripped bare of their electron cloud (ionized), for example matter inside stars, cosmic rays, intergalactic matter mostly made of protons etc, your run in the mill atom with an electron cloud is not the most common form of matter in the Universe. On Earth we are somewhat shielded by an atmosphere and magnetic field that prevents most matter on the surface from being ionized. A neat experiment also settles the issue: Bouncing Neutrons in the Gravitational Field[71]. It was shown in the experiment that slow neutrons bounced off a reflecting surface in a gravitational field alone like a ball bouncing off a table.

It is interesting to note that the neutron states were found to be quantised which is expected however the experiment says nothing if the background gravitational field is quantised or not because no transition of a neutron between two states was observed, if it was, this would be a strong case for the graviton model and we can throw the modified EMQG model in the bin. Although neutrons[73] are electrically neutral they do have a small magnetic moment since each neutron is made of charged quarks namely 1 up quark and 2 down quarks (udd or +2/3 -1/3 -1/3 = 0). A proton[74] is made of 2 up quarks and 1 down quark (uud or +2/3 +2/3 -1/3 = +1).

So far the model can explain all of General Relativity but we still lack a detailed description of the interactions between the nuclei and the accelerated charged virtual fermion particle field, the model does explain photon behaviour in a gravitational field though. We need to look at how the virtual Quarks and Leptons interact with nuclei to explain GR effects on a test mass. We are getting into Quantum Chromodynamics[75] here which is not straightforward physics especially since current QCD says nothing on the properties of spacetime and how it behaves in curved spacetime. As mentioned previously, the EMQG model also does not explain the root cause of the downward acceleration of the virtual fermion particle field. It is suspected that the individual quark makeup of a nuclei isn't a major factor in the interaction involved but it is the motion of quarks within the nuclei that play a major role (as confirmed by GR; it is any energy density that causes spacetime curvature). How the strong nuclear interactions for quarks within a nuclei with their exchange of virtual gluons that keep them together relates to the accelerated charged virtual fermion particle field is another area being looked at.

We will also need to demonstrate that suppressing the virtual fermion field around a test mass can indeed affect gravitational effects. An experiment will need to be carried out to test this for a range of magnetic field intensities upto 100 Tesla (or current state of the art). The virtual fermion particle field can be treated as a "virtual charged fluid" for all intents and purposes. Note that accelerated real charges produce a magnetic field, this is not observed for the virtual field case. A tightly collimated magnetic bottle will be required and a hollow superconductor sphere will be needed to exclude the magnetic field which houses a test mass within as shown in Figure 16.

The difficulty in the experiment will lie in how tight the collimation can be achieved at the extremeties with the expected high magnetic field intensities. It is unlikely that this experiment would prevent all charged virtual fermion particles from interacting with the test mass inside the superconductor sphere, if this were to occur, according to the model, a 100% weight reduction will occur for the test mass. What we wish to happen here is a change of the nearly linear downward accelerated motion of the charged virtual fermion particle field to a circular one. The net effect of this is equivalent to having a flat spacetime metric within a curved gravity well as mentioned previously. Looking at the side view of the envelope, the magnetic field can be made to go into or out of the screen with the same result for the test mass. We'll leave the finer technicalities of this model for a future paper currently being worked on by the author. The challenging part of this model is to come up with viable physics for the interaction of nuclei with charged virtual fermions which doesn't contradict known working physics models and is compliant with General Relativity.

6 Summary

Answering the original question with which this article started: *Is Gravity Control Propulsion viable?* At this stage the answer is clearly still no. None of the research and experimental results looked at so far today have shown otherwise. However there are still too many physics unknowns to answer the question with a definate no for the near or far future. It is clear, though, that General Relativity alone cannot answer this question and a viable quantum model of the spacetime - matter/energy gravitational interactions is required. If in this hypothetical model there is avenue for electromagnetic interactions via fields we are good at manipulating today, ie electromagnetic fields, then this would leave open the possibility of GCP.

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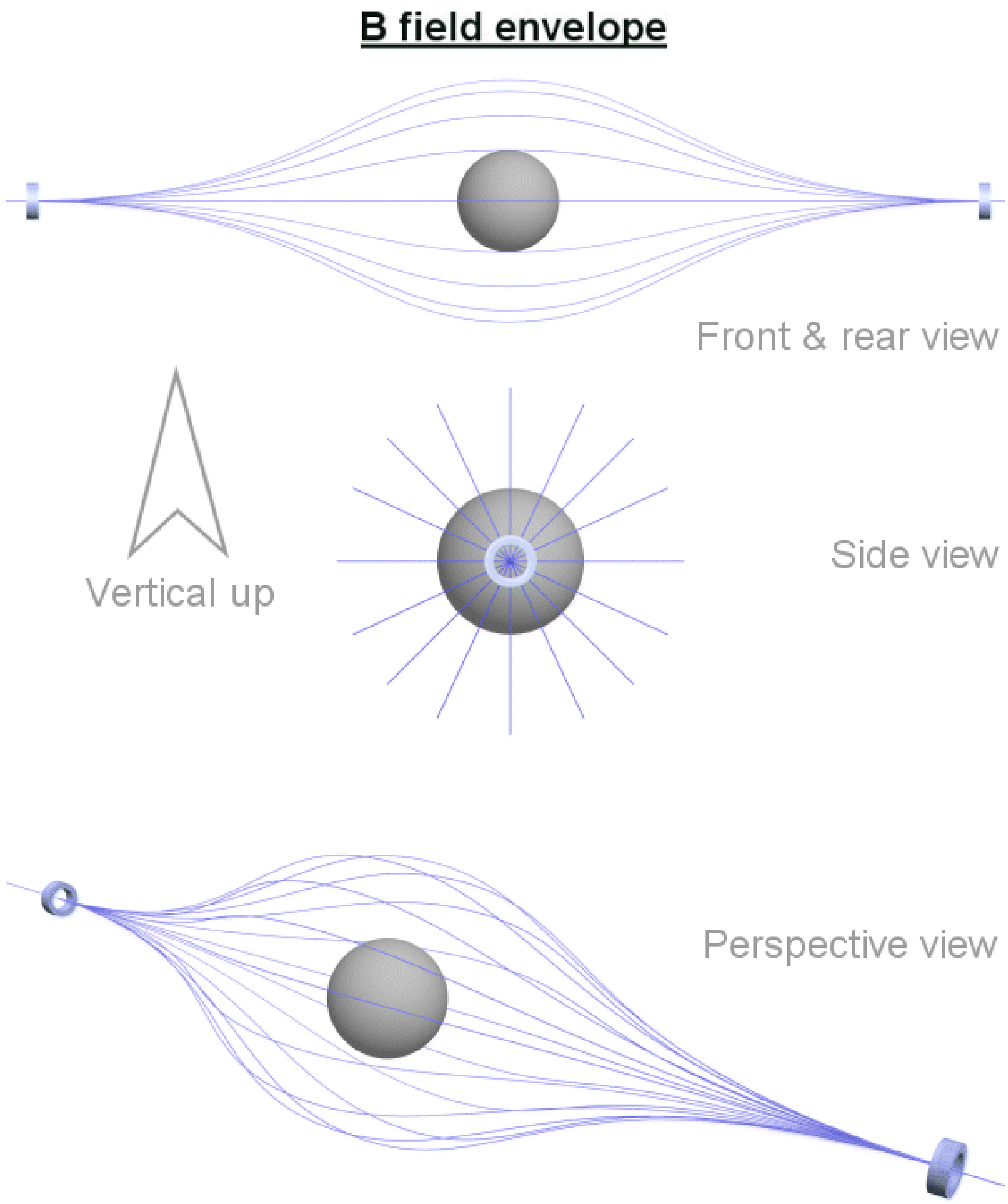

Figure 16: A proposed experiment to test the modified EMQG model. A test mass is placed inside the spherical hollow superconductor. The magnetic bottle has to be tightly collimated at both extremeties. Circular vacuum polarisation is predicted to occur within the magnetic field envelope.

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