

Advanced Propulsion Systems from Artificial Gravitational Fields

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Abbreviated Version ²



Figure 1. The cover picture shows a combination of three pictures. The background picture, taken from [1] shows a view (artist's impression) of a real planet orbiting the solar-type star HD222882 about 137 ly away from earth. The second picture shows all messenger particles as predicted from Extended Heim Theory. It should be noted that EHT predicts three gravitational interactions, which are described by messenger particles termed *gravions*, namely gravitons (attractive, ordinary matter), gravitophotons (attractive and repulsive, dark matter), and the quintessence particle (repulsive, dark energy). The third picture depicts the principle of gravito-magnetic space propulsion as derived from EHT. For further explanations see Fig. 7 of this paper.

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² Mathematical derivations were omitted in this abbreviated version

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⁵ The mathematical derivations in this paper rely on concepts explained in paper [8]. For lack of space these concepts are not presented here, see www.hpcc-space.de for download.

Abstract: Spaceflight, as we know it, is based on the century old rocket equation that is an embodiment of the conservation of linear momentum. Moreover, special relativity puts an upper limit on the speed of any space-vehicle in the form of the velocity of light in vacuum. Thus current physics puts severe limits on space propulsion technology. These limitations can only be overcome if novel physical laws can be found. During the last two decades, numerous experiments related to gravity shielding or gravito-magnetic interaction were carried out, but eventually all proved to be incorrect. However, in March 2006, the European Space Agency (ESA) announced credible experimental results, reporting on the generation of artificial gravitational fields (also termed gravito-magnetic fields, GMF), in the laboratory. The GMF was generated by a rotating niobium superconductor ring, subjected to angular acceleration. The GMF existed only during the acceleration phase of the ring, counteracting the mechanical acceleration, thus obeying some kind of gravitational Lenz rule. These experiments were performed by M. Tajmar and colleagues from ARC Seibersdorf, Austria and C. de Matos from ESA, and since then were repeated with increased accuracy, leading to the same results. Extended Heim Theory (EHT), published in a series of papers since 2002, predicted the existence of such an effect, resulting from a proposed interaction between electromagnetism and gravitation. In EHT, which is a consequent extension of Einstein's idea of geometrization of all physical interactions, the concept of poly-metric developed by the German physicist B. Heim is employed. As a consequence of this geometrization, EHT predicts the existence of six fundamental interactions. The two additional interactions are identified as gravitophoton interaction, enabling the conversion of photons into a gravitational like field, represented by two hypothetical gravitophoton (attractive and repulsive) particles and the quintessence particle, a weakly repulsive gravitational like interaction. The paper starts with an introduction into the physical concepts of EHT. In the next step, EHT will be used to explain two enigmatic phenomena of physics that cannot be described by current physical theories, namely the gravitational effect of dark matter and the generation of artificial gravitational fields. First, though the existence of dark matter was already suggested in the 1930s by Caltech astronomer Zwicky, its gravitational interaction is still a riddle. It will be shown that the gravitophoton concept can be utilized to calculate both the distribution of ordinary matter, dark matter, and dark energy as well as the separate gravitational coupling strengths for these three types of matter. Next, the recent experiments by Tajmar et al. (the artificial gravitational force, however, was observed only in the circumferential direction in the plane of the superconducting ring) will be analyzed, and a quantitative comparison between EHT predictions and experiment is given. Finally, it is shown, provided EHT is correct, how gravitophoton interaction can be used to devise a novel experiment in which the artificial gravitational field would be directed along the axis of rotation, and thus this force could serve as the basis for a field propulsion principle working without propellant. As it turns out, experimental requirements to lift a spacecraft from the surface of the earth can be satisfied by current technology. Based on the gravito-magnetic propulsion concept, mission times to the international space station (LEO), the planned moon basis, to Mars, and missions to the outer planets are calculated. It will be shown that this propulsion system is far superior to any existing propulsion technology, while its technology is far simpler than chemical propulsion.

1 ARTIFICIAL GRAVITATIONAL FIELDS FOR SPACE PROPULSION

Spaceflight as we know it, is based on the century old rocket equation that is an embodiment of the conservation of linear momentum. Current space transportation systems are based on this principle of momentum generation, regardless whether they are chemical, electric, plasma-dynamic, nuclear (fission) or fusion, antimatter, photonic propulsion (relativistic) and photon driven (solar) sails, or exotic Bussard fusion ramjets. Moreover, special relativity puts an upper limit on the speed of any space-vehicle in the form of the velocity of light in vacuum. The only possibility to overcome these severe limitations lies in the finding of novel physical laws that allow constructing propulsion systems based on principles different from classical mechanics (momentum principle). Therefore, there has been a great deal of interest during the last decade in so called breakthrough propulsion physics.

On the other hand, modern physics cannot explain most basic questions, such as the nature of matter, the mass spectrum of elementary particles or their corresponding lifetimes. In particular, the question concerning the number of fundamental interactions cannot be answered by current theory, neither string theory nor quantum gravity. In one of his latest papers, Einstein 1950 in Scientific American [2], stressed the necessity that any successful quantum field theory aiming to unify fundamental physical forces, needs to be derived from the geometry of a dynamic spacetime. The late German physicist B. Heim followed this idea and suggested a way to geometrize physics, but utilizing a quantized spacetime [3]. At the same time a similar approach was suggested by the Italian mathematician B. Finzi [4].

Furthermore, since the 1930s observations of the large-scale motion of star systems within galaxies have suggested the existence of non-baryonic matter (neither protons nor neutrons) that does not interact electromagnetically, and therefore was termed dark matter because of its invisibility. The amount of dark matter is considerable, about 26 %, while ordinary (baryonic) matter comprises some 4 to 5 % of all the matter in the universe. The major part of the matter in the universe is dubbed dark energy and amounts to approximately 70 % [5]. Although the MOND (Modified Newtonian Dynamics) hypothesis [6], which assumes a modified Newtonian law, can explain the rotation of stars in most types of galaxies, it does not work for the inner parts of rich galaxy clusters. Moreover, in a recent article

in Nature [7], it has been shown that dark matter is real and reveals its existence through gravitational lensing that cannot be explained by the MOND hypothesis. However, the MOND parameter, see below, can be used as a working hypothesis, but not as the physical explanation of the phenomenon of dark matter.

Building on Heim's idea of a poly-metric, in a series of papers, the authors proposed a unifying approach for all physical interactions, [8], [9], termed Extended Heim Theory (EHT). As a consequence of its geometrical approach, EHT predicts the existence of six fundamental forces, instead of the four known ones (gravitation, electromagnetism, weak (radioactive decay), and strong interaction (atomic nuclei and elementary particles)). The two additional interactions predicted in EHT are identified as **gravitophoton interaction**, enabling the conversion of photons into a gravitational like field, represented by the two hypothetical gravitophoton (attractive and repulsive) particles (**dark matter**), and **quintessence**, a weakly repulsive gravitational like interaction (**dark energy**). The interpretation of the physical equations for the gravitophoton field leads to the conclusion that this field could be used to accelerate a material body without the use of propellant. Therefore, gravitation, as we know it, seems to be comprised of three interactions, the **graviton (attractive)**, **gravitophoton (attractive and repulsive)**, and the **quintessence or vacuum (repulsive)** particle that is, there **exist three quanta of gravitation**. This means that the gravitational constant G contains contributions of all three gravitational constants, termed G_N , G_{gp} and G_q , respectively. The quintessence interaction, however, is much smaller than the first two contributions. For further details see [10].

In the 1990s a Russian physicist claimed to have measured gravitational shielding. A similar claim was made by an American scientist several years later. However, in their recent paper Woods et al. [11] have delivered overwhelming experimental evidence that these two claims cannot be substantiated. This kind of gravitational shielding simply does not exist.

In 2006, however, the **experimental situation changed completely** when M. Tajmar and his colleagues from ARC Seibersdorf, Austria and de Matos from ESA [12, 13, 14, 15] published a series of papers reporting on the **measurement of artificial gravitational fields (AGF)**, generated by a rotating superconducting niobium ring. These experiments were conducted over a period of four years, and utmost care was used by the experimenters to exclude any noise effects. Moreover, in a recent oral communication *M. Tajmar (May 2007) confirmed that his experimental results (laser-gyro measurements) have been verified by another experimental group and are about to be published.*

Everytime the superconducting niobium ring was subjected to angular acceleration, an AGF was measured in the plane of the ring in circumferential direction. The induced acceleration field was opposite to the angular acceleration, following some kind of gravitational Lenz rule. In addition, an acceleration field was also observed when the niobium ring was rotating with constant angular velocity undergoing a phase change that is, from the normal to the superconducting state. This was achieved by reducing the temperature below 7.2 K, the critical temperature for niobium. No acceleration effects were seen with high-temperature superconductors. No acceleration was measured (averaged) when the niobium ring was in the normal conducting state (Fig. 5). In October 2006 Tajmar et al. repeated their experiments employing both accelerometers as well as laser ring-gyros that very accurately measured the gravito-magnetic field. The AGF was clearly observed, and its rotational nature was determined by a set of four staggered accelerometers. According to Tajmar et al. these experiments demonstrate that an AGF was generated by the magnetic field of the rotating superconducting niobium ring, termed the gravito-magnetic London effect. Although these experiments need to be validated independently, they present definitive indications that an interaction between electromagnetism and gravitation should exist.

The ratio of the measured acceleration field and the angular acceleration of the rotating niobium ring, denoted as coupling factor by Tajmar, is proportional to the theoretically predicted density of Cooper pairs. In addition, when analyzing Tajmar's experiments using EHT, it became clear that an experiment could be devised, demonstrating the generation of an AGF in the vertical direction (along the axis of rotation), capable of lifting a body from the surface of the earth. Due to this Boson coupling (Cooper pairs, Bose-Einstein Condensate) technical requirements like magnetic induction strength, current density, supply power should easily be met. According to EHT, required values are substantially lower than for the previously proposed experiment [10, 16, 17] that assumed Fermion coupling.

2 PHYSICAL CONCEPTS OF EXTENDED HEIM THEORY

The main idea of EHT is that **spacetime possesses an additional internal structure**, described by an **internal symmetry space**, dubbed **Heim space**, denoted H^8 , which is attached to each point of the spacetime manifold. The internal coordinates of H^8 depend on the local (curvilinear) coordinates of spacetime. This is analogous to gauge theory in that a local or gauge transformation is used. In gauge theory it is the particles themselves that are given additional degrees of freedom, expressed by an internal space. Consequently in the geometrization of physics, it is

spacetime *instead of elementary particles* that has to be provided with internal degrees of freedom. The introduction of an internal space has major physical consequences. The structure of H^8 determines the number and type of physical interactions and subsequently leads to a poly-metric. This means that **spacetime comprises both an external and internal structure**. In general, only the external structure is observed, but as has long been known experimentally, matter can be generated out of the vacuum. This is a clear sign that spacetime has additional and surprising physical properties. Therefore, any physical theory that aims at describing physical reality, needs to account for this fact. Since GR uses pure spacetime only, as a consequence, only part of the physical world is visible in the form of gravitation.

This idea was first conceived by the German physicist B. Heim. A similar principle was mentioned by the Italian mathematician B. Finzi. The poly-metric tensor resulting from this concept is subdivided into a set of sub-tensors, and each element of this set is equivalent to a physical interaction or particle, and thus the **complete geometrization of physics** is achieved. This is, in a nutshell, the strategy chosen to accomplish Einstein's lifelong goal of geometrization of physics ⁶.

It must be noted that this approach is in stark contrast to elementary particle physics, in which particles possess an existence of their own and spacetime is just a background staffage [18]. In EHT, considered as the natural extension of GR, **matter simply is a consequence of the hidden physical features of spacetime**. These two physical pictures are mutually exclusive, and experiment will show which view ultimately reflects physical reality. It is, however, well understood that the concept of a pointlike elementary particle is highly useful as a working hypothesis in particle physics.

This approach is substantially different from GR and leads to the complete geometrization of physical interactions.

Naturally, the number and type of interactions depend on the structure of internal space H^8 whose subspace composition is determined in the subsequent section. Contrary to the ideas employed in *String* theory, see for example [19], H^8 is an **internal space of 8 dimensions** that, however, governs all physical events in our spacetime.

The crucial point lies in the construction of the internal space whose subspace composition should come from basic physical assumptions, which must be generally acceptable. In other words, GR does not possess any internal structure, and thus has a very limited geometrical structure, namely that of pure spacetime only. Because of this limitation, GR cannot describe other physical interactions than gravity, and consequently needs to be extended. EHT in its present form without any quantization, i.e., not using a discrete spacetime, reduces to GR when this internal space is omitted. The metric tensor, as used in GR, has purely geometrical means that is, it is of immaterial character only, and does not represent any physics. Consequently, the Einsteinian Geometrization Principle (EGP) is equating the Einstein curvature tensor, constructed from the metric tensor, with the stress tensor, representing energy distribution. In this way, the metric tensor field has become a physical object whose behavior is governed by an action principle, like that of other physical entities. In EHT the internal space H^8 is associated with physics through the introduction of three fundamental length scales, constructed from Planck quantities.

In summary, internal coordinates ξ^i with $i = 1, \dots, 4$ denote *spatial and temporal* coordinates, ξ^i with $i = 5, 6$ denote *entelechiial and aeonic* coordinates, and ξ^i with $i = 7, 8$ denote the two *information coordinates* in H^8 , mandating four different types of coordinates. With the introduction of a set of four different types of coordinates, the space of fundamental symmetries of internal space H^8 is fixed. In the next section, the set of metric subtensors of H^8 is constructed, each of them describing a physical interaction or particle. Thus the connection between physical space and physics (symmetries) is established in a way foreseen by Einstein. Physical space is responsible for all physical interactions. However, in order to reach this objective, spacetime had to be complemented by an internal space H^8 to model its physical properties. Once the internal space with its set of coordinates has been determined, everything else is fixed.

In order to construct a physically meaningful metric sub-tensor (also called **Hermetry form**), **it is postulated that coordinates of internal spaces S^2 (organization coordinates) or I^2 (information coordinates) must be present** in any metric subtensor to generate a Hermetry form. From this kind of selection rule, it is straightforward to show that 12 Hermetry forms can be generated, having direct physical meaning. In addition, there are three degenerated Hermetry forms that describe partial forms of the photon and the quintessence potential, for details see Tables 2, 4 of ref. [8]⁷. Hermetry form 16 is reserved for the *Higgs* particle that should exist, whose mass was calculated at 182.7 ± 0.7 GeV. For instance, the Hermetry form (photon metric) comprises only coordinates from subspaces T^1 , S^2 , and I^2 and is denoted by $H_7(T^1 \times S^2 \times I^2)$. The neutral gravitophoton Hermetry form is given by $H_5(S^2 \times I^2)$. Since gravitophoton

⁶ There is of course a second aspect, namely the quantization of the spacetime field.

⁷ Tables 1-4 of ref. [8] were omitted from this paper because of lack of space

and photon Hermetry forms are described by different coordinates, they lead to different Christoffel symbols, and thus to different geodesic equations. Furthermore, if there were a physical process to eliminate the T^1 coordinates, i.e., the corresponding Christoffel symbols are 0, the photon would be converted into a gravitophoton. **This is how mixing of particles is accomplished in EHT.** We believe this to be the case in the experiments by Tajmar et al. The fundamental question, naturally, is how to calculate the probability of such a process, and to determine the experimental conditions under which it can take place. The word Hermetry is a combination of *hermeneutics and geometry* that is, a Hermetry form stands for the physical meaning of geometry. Each Hermetry form has a direct physical meaning, for details see refs. [8, 10, 16].

Because of the double coordinate transformation (see [8, 16, 17]) each component of any metric tensor describing a Hermetry form is written as a partial sum whose elements are selected from the 64 components that comprise the complete metric tensor, which results from the incorporation of internal symmetry space H^8 . The formation of metric tensors for Hermetry forms follows selection rules described in the publications cited above. Thus, a poly-metric representing the six fundamental interactions (messenger particles) and particle classes is constructed. If space H^8 is omitted, EHT is reduced to GR, and only gravitation remains. It is obvious that a double coordinate transformation does not change, for instance, the curvature of a surface, since it is an invariant. However, this fact is not relevant in the construction process of the poly-metric. The physical reason for the double transformation is to provide spacetime with additional degrees of freedom, which do exist. For instance, it is an empirical fact that particle pair production can occur from the so called vacuum of spacetime. Only metric tensors representing Hermetry forms have physical relevance, and it is clear from their construction principle that all these tensors derived from the underlying poly-metric are different. Consequently, their respective Gaussian curvatures, K_l , where l denotes the index of the corresponding Hermetry form, must also be different. This is straightforward to observe, since Gaussian curvature is only a function of the first fundamental form (metric tensor components) as well as their first and second derivatives, but does not depend on the second fundamental form. Therefore, each Hermetry form H_l has its proper Gaussian curvature K_l , and thus curves space according to its own specific metric. Following the rules of GR that interprets curvature of space as gravitational interactions, Hermetry forms can be interpreted as physical interactions, see Tables [1-4] in [8]. Having established the relationship between Hermetry forms and curvature of space, some remarks between the connection of geometry and physics are in place. All internal coordinates of space H^8 have dimension of length and via the Compton wave length are connected to mass. In [8] it was proved that spacetime also must be quantized on the Planck length scale. Moreover, it is well known that in the case of gravitation for the Newtonian limit, metric element g_{44} is proportional to the gravitational potential equation. In this respect elements of any metric tensor are identified with physical potentials.

In EHT *ten different charges can be identified that is, 3 color charges for the strong force, 1 electric charge for electromagnetic interaction, 2 charges for the weak force, 1 gravitational charge for ordinary matter (4.36 %) and 1 for dark energy (69 %) as well as 2 charges for dark matter, namely for both positive (repulsive, 2.66%) and negative (attractive, 24 %) dark matter.* The distribution of these four types of matter was calculated from EHT. The general coupling constants for charges are given by $w_n^2 = \frac{q_n^2}{\hbar c}$, $n = 1, \dots, 10$. The values of all coupling constants were calculated from EHT and gravitational coupling constants were given in [8, 10]. In addition, the probability amplitudes for conversion of photons into gravitophotons, w_{ph_gp} , and from gravitophoton into quintessence particles, w_{gp_q} , were also calculated. Approximate values of the coupling constants can be found in [20]. With the knowledge of the coupling constants, the respective charges can be determined. Using the relation between metric elements and potentials, a connection between geometry and physics for each physical interaction can be installed. So far, however, a detailed analysis for each individual Hermetry form has to be carried out. The last idea that will be introduced is the incorporation of charges into EHT. To this end, the approach taken was to replace real valued internal coordinates ξ_α by four-spinors. The usage of quaternions is also being investigated. This work is in progress and no conclusive answers can be given at present.

2.1 Gravito-Magnetic Force by Photon Conversion into Gravitophotons

The force produced by gravitophoton generation is termed **gravito-magnetic force**. It is a **gravitational force**, but it is caused by photons that are converted into neutral ⁸ gravitophotons, which eventually decay via two different

⁸ a gravitophoton is termed neutral if it does not interact with matter

channels. Regarding the Hermetry forms for the photon, H_7 , and the gravitophoton, H_5 , see Table 2 in [8], it is straightforward to see that if all metric subcomponents containing the time coordinate in the metric tensor of the photon are deleted, the metric of a neutral gravitophoton is generated. The fundamental question is, of course, how this mathematical process can be realized as physical phenomenon.

Regarding further the Hermetry form of the neutral gravitophoton, it should be possible that under certain circumstances this neutral gravitophoton becomes unstable and decays. According to its metric form, a neutral gravitophoton can decay in two ways. In one case, a graviton and a quintessence particle can be generated, which is the case in the experiment by Tajmar, termed GME I, see Sec. 4.2. In the second case, experiment GME II, see Sec. 4.3, a positive (repulsive) and a negative (attractive) gravitophoton can be produced.

The process of conversion of photons into gravitophotons should be possible in two ways, namely via *Fermion* (vacuum polarization) [10] and through *Boson* coupling (Bose-Einstein condensates). Boson coupling is described by Eqs. (2), (3). These equations are termed conversion equations. The three conversion amplitudes have the following meaning: the first equation in Eq. (3) is obtained from EHT [10], the probability amplitude w_{ph_gp} predicts the conversion of photons into gravitophoton particles and was published already in 1996 [20]. The third probability amplitude w_{gp} for the photon coupling is given by the well known relation

$$w_{ph}^2 = \frac{1}{4\pi\epsilon_0} \frac{e^2}{\hbar c}. \quad (1)$$

The production of **gravitophoton particles through the polarization of the vacuum** by conversion of photons into gravitophotons, is termed **Fermion coupling**, because it is assumed that the production of gravitophotons takes place at the location of a virtual electron. This process is described in detail in references [8], [16], and [17]. With the advent of Tajmar's experiments this process is no longer of interest, since it needs very high magnetic induction fields of about 25 Tesla for a technically relevant application (1g acceleration).

When we analyzed the experiments by Tajmar et al. it became clear that there seems to be a **second way to generate a gravitophoton force**, namely using **Cooper pairs** to trigger the production of neutral gravitophotons. Because of the coupling through Cooper pairs, this conversion is dubbed **Boson coupling**, and is specified by Eqs.(2) and (3). It turned out that the conversion of photons into gravitophotons through Boson coupling has substantially lower technical requirements. Instead of changing the conversion amplitude $w_{ph}(r)$ by reducing the distance between virtual electron and proton below the Compton wavelength, λ_C , (for mathematical details see the above mentioned references), it is now the value of the probability amplitude w_{ph_gp} that changes. In general, i.e., *without the presence of Cooper pairs*, $w_{ph_gp} = w_{ph}$ and, according to Eq. (2), *the probability for gravitophoton production is 0*. For the production process to take place, it is assumed that the onset of superconducting - with its formation of Cooper pairs - has an effect similar to the creation of electron-positron pairs responsible for an increased coupling, and therefore an increase in the magnitude of the coupling constant or charge. This is in analogy to vacuum polarization where the magnetic field is strong enough to produce virtual electron-positron pairs, creating an excess charge. It should be noted that coupling values k and a were derived some ten years ago, and were published by Heim and Dröscher 1996 in [20], see Eq. (11) p. 64, Eq. (15) p. 74, and Eq. (16) p. 77.

$$w_{ph} - w_{ph_gp} = \pm i N w_{gp} \quad (2)$$

$$w_{ph} - w_{ph_gp} = \pm i \left(\frac{1}{(1-k)(1-ka)} - 1 \right) w_{ph} \quad (3)$$

where i denotes the imaginary unit. Inserting Eq. (3) in to Eq. (2) results in the net production of gravitophotons. It should be noted that the imaginary unit is needed, since the square of probability amplitudes also reflect charges. Otherwise Eq. (3) may result in an increased electron charge. However, in the case of Boson coupling there are no virtual charges that can lead to charge increase. Therefore probability amplitude w_{ph_gp} is of the form

$$\Re w_{ph_gp} + i \Im w_{ph_gp} = w_{ph} \mp i \left(\frac{1}{(1-k)(1-ka)} - 1 \right) w_{ph} \quad (4)$$

where the imaginary part is *different from 0 in case of sufficient Cooper pair density*.

2.2 Physical Mechanism for Gravito-Magnetic Force in GME I, II

In the following, a model for the physical mechanism of the conversion of photons into gravitophotons is presented, providing a mathematical expression for the gravito-magnetic force. The mathematical steps are omitted, but final quantitative results are given. It should be understood that such a model needs to be confirmed by experiment. The model is based on plausible physical assumptions, derived from the fundamental principles of EHT, but no proof of correctness in a mathematical sense is possible.

In Fermion coupling the additional charge is produced by the vacuum of spacetime, while in Boson coupling the additional charge comes from the imaginary part of the Cooper pair charge. The Boson coupling therefore is a condensed matter phenomenon. This means that for Boson coupling the probability amplitude (charge) w_{ph} remains unchanged, in contrast to Fermion coupling. Instead, as can be seen from Eq. (3), it is the probability amplitude w_{ph_gp} that is modified when the superconducting state is reached. Next, when Cooper pairs are set into motion, for example, a ring rotating with constant angular frequency, the imaginary part of the charge e^* of the Cooper pairs gives rise to an imaginary vector potential $\mathbf{A}^*$ that couples to the imaginary part of the proton charge of the ions in the crystal lattice. The interaction of the two imaginary charge parts, however, leads to a real interaction energy. This would amount to an electromagnetic interaction that cannot exist inside a superconductor. Therefore, it is *assumed* that the coupling energy of the potential $\mathbf{A}^*$ is converted into gravitational energy, denoted by its proper gravitophoton potential $\mathbf{A}_{gp}$. The gravitational potential, $\mathbf{A}_{gp}$, termed gravitophoton potential arises at the location of the protons, caused by the generation of neutral gravitophoton particles. The relation between the two vector potentials is given by

$$m_p \mathbf{A}_{gp} = e^* \mathbf{A}^* \quad (5)$$

Now we consider the Einstein-Maxwell formulation of linearized gravity that possesses a remarkable similarity to the mathematical form of the electromagnetic Maxwell equations. In analogy to electromagnetism there exists a gravitational scalar and vector potential, denoted by Φ_g and $\mathbf{A}_g$. Introducing the corresponding gravito-electric and gravito-magnetic fields

$$\mathbf{e} := -\nabla \Phi_g \text{ and } \mathbf{b} := \nabla \times \mathbf{A}_g \quad (6)$$

the linearized version of Einstein's equations of GR can be cast in mathematical form similar to the Maxwell equations of electrodynamics. Using Eq. (5) the gravitophoton field, $\mathbf{b}_{gp}$ for niobium is obtained

$$\mathbf{b}_{gp} = \left(\frac{1}{(1-k)(1-ka)} - 1 \right)^2 \frac{2m_e}{m_p} \omega = 2.609 \times 10^{-6} \omega \quad (7)$$

where ω is the angular velocity of the rotating ring and the London moment, Eq. (11), was used. That is, the laser-gyrometer should produce a signal for the ring rotating with constant angular frequency ω . For Pb the theory delivers a somewhat lower value. As we have seen, EHT predicts that the magnetic induction field $\mathbf{B}$ is equivalent to a gravitophoton (gravitational) field $\mathbf{b}_{gp}$. In the experiment by Tajmar et al. , a neutral gravitophoton decays into a graviton and a quintessence particle, according to the theory of Hermetry forms. An AGF, however, will only be generated if the ring is subjected to angular acceleration, i.e., if $\partial \mathbf{b}_{gp} / \partial t$ is different from 0, see Fig (4).

3 DARK ENERGY, DARK MATTER AND EHT

Here we only provide a brief discussion, because of the lack of space and second, because it is *necessary to compare physical models derived from EHT with experimental facts to see whether the models can stand this test*. In any case, the geometrization principle on which EHT is based, requires the existence of a fifth and sixth interaction, which are identified as dark matter and dark energy. Furthermore, the charges for these interactions were identified as gravitophoton (positive and negative) and quintessence particles. Their Hermetry forms were already given in [10]. EHT requires that positive (repulsive) dark matter also exists, however, at a much smaller amount than attractive dark matter.

With the Chandra X-ray pictures of gravitational lensing there is striking astronomical evidence that there is a huge amount of *dark matter*, optically invisible, but active in galaxies, in that orbital velocities of stars and gas clouds as a function of distance from their galactic center contradict Kepler's third law. Orbital velocities should decrease with distance according to Kepler's third law. Measured Doppler shifts for carbon monoxide and hydrogen spectral lines



Figure 2. The picture taken (see Chandra website) by the Chandra X-ray observatory in August 2006, shows for the first time the clear separation of gravitational lensing resulting from ordinary matter, which comprises the hot gas in the cluster (pink) and from dark matter (blue). The gravitational lensing effect of dark matter is substantially stronger. This picture proves that dark matter is real, and that the MOND hypothesis of a modified Newtonian gravitational law is physically not correct.

show, for example in galaxy NGC1097, that orbital velocities almost remain constant or $v_{rot} = const$. According to Newton's law $v_{rot} = \sqrt{G_N M(r)/r}$ is expected. For NGC3198 an almost constant rotation velocity of 150 km/s was measured between distances of 10 to 30 kpc (parsec). The amount of dark matter needed to explain this behavior is in excess of all baryonic matter generated in the so called primordial nucleosynthesis. There is the possibility that the process of nucleosynthesis is described incorrectly by current theory, or that **another type of (invisible) matter exists**, not predicted by the standard model of physics. An alternative is to *give up on Kepler's third law*. This has been proposed by the so called MOND (Modified Newtonian Dynamics) hypothesis that can explain the rotation curves in galaxies, but fails to explain orbital velocities in the core of galaxy clusters where there exists hot gas. Regarding Fig. 2 it is clear that dark matter is real and the MOND as a physical explanation is not correct, but the MOND parameter can be used for quantitative determination of orbital velocities. Some fraction of the invisible matter is baryonic, but from the study of X-ray emission of hot gas, in, for instance the bullet cluster, which contains the bulk of the ordinary matter in the cluster, gravitational lensing shows a clear separation resulting from ordinary matter (pink) and dark matter (blue), see Fig. 2.

The current status thus can be summarized such that a new type of invisible matter (dark matter), dominating ordinary matter exists in the universe, but current physical theory cannot explain its nature. In the following some ideas will be presented that should provide some insight on the physics of dark matter and energy.

In EHT, dark matter and dark energy are generated from masses that are calculated from elemental lengths, derived from elemental surfaces of a quantized spacetime (spacetime becomes two-dimensional at the Planck length) that was already postulated by Heim [21, 3, 22, 23], [10], and more recently by Rovelli et al. [26] and Kiefer [27]. According to Rovelli the spectrum of elemental surfaces is given by (Heim used the simpler model of harmonic oscillator to quantize spacetime)

$$a_j = \gamma \frac{G\hbar}{c^3} (j(j+1))^{1/2}, j = n/2, n = 1, 2, \dots \quad (8)$$

where $\gamma = 1$ was used, which is known as the Immirzi parameter that cannot be derived from quantum gravity. In the following, the correspondence between length and mass is utilized as well as the idea, postulated also by Heim, that

mass was generated in the universe when the elementary length scale became small enough (symmetry breaking, phase transition). This means that the universe existed without matter for a long period [10, 28, 29]. In concert with the fact that three different types of matter exist the three elemental lengths derived from the first three states of a quantized spacetime are associated with dark matter, (ordinary) matter, and dark energy that is,

$$l_{DM} = \frac{G\hbar}{c^3} \sqrt[4]{3/4}, j = 1/2; l_M = \frac{G\hbar}{c^3} \sqrt[4]{2}, j = 1; l_{DE} = \frac{G\hbar}{c^3} \sqrt[4]{15/4}, j = 3/2 \quad (9)$$

The associated masses are

$$m_{DM} = m_{pl} \sqrt[4]{4/3}; m_M = m_{pl} \sqrt[4]{1/2}; m_{DE} = m_{pl} \sqrt[4]{4/15} \quad (10)$$

where $m_{pl} = (\hbar/G)^{1/2} = 2.176 \times 10^{-8} \text{ kg}$ is the well known Planck mass and $m_{DM} > m_M > m_{DE}$. These three types of matter are represented by Hermetry forms H_5 (degenerated), H_1 and H_9 , respectively [10].

These elemental masses, m_{DM} , m_M and m_{DE} were unstable and decayed. As was stated in [28] mass was produced during this process, and, since no density higher than the Planck density, namely m_{pl}/l_{pl}^3 can exist, the **universe was forced to expand**.

After 5 billion years, the time dependence of dark matter changes into a constant energy density, in the same way as for dark energy. Comparing the ratio of dark matter to dark energy, one obtains directly the factor 0.349 which leads to a value of about 24.4 % of dark matter, while dark energy comprises about 70 % of all matter in the universe. Ordinary matter⁹ therefore accounts for approximately 5.6 %.

4 EHT ANALYSIS OF GRAVITO-MAGNETIC EXPERIMENTS

In the following EHT is used to perform an analysis of two gravito-magnetic experiments. The first one, termed gravito-magnetic experiment one, **GME I**, concerns the analysis of the recent experiments by Tajmar et al.. as described in Sec. 4.2. The second gravito-magnetic experiment, termed **GME II**, follows from theoretical considerations, obtained from EHT, and would lead to an AGF of completely different nature than GME I, namely an **AGF acting parallel to the axis of rotation of the ring (disk)**, see Fig. 7, where the **disk rotates with constant angular frequency**.

GME II could serve as a demonstrator for a **field propulsion principle** without propellant as well as the **basis for a novel gravitational engineering technology**. In GME II the superconducting rotating ring, employed in the experiments by Tajmar et al., is replaced by an insulating disk of a special material in combination with a special set of superconducting coils. According to EHT, the physical mechanism is different from GME I in that the neutral gravitophoton decays into a positive (repulsive) and negative (attractive) gravitophoton, which causes the AGF to be directed along the axis of rotation of the disk. The coupling to Bosons is the prevailing mechanism in both experiments, but in GME I the resulting gravitophoton decays into a graviton and a quintessence particle. For Boson coupling experimental requirements, i.e., magnetic induction field strength, current densities, and number of turns of the solenoid, are substantially lower than for *Fermion coupling* (here the vacuum polarization is employed to change the coupling strength via production of virtual pairs of electrons and positrons) that was so far assumed in all our papers prior to 2006, see, for instance, refs. [17], [16], [10].

Fig. 4 depicts the experiment (GME I) of Tajmar et al., where a superconducting ring is subjected to angular acceleration and an artificial gravitational field was measured in the plane of the ring in circumferential direction, counteracting the angular acceleration, i.e., following some kind of gravitational Lenz rule. Fig. 7 describes the experimental setup for GME II, the field propulsion device. Here an insulating disk rotates directly above the superconducting solenoid. In both cases an artificial gravitational field arises, generated by gravitophoton interaction. The major difference between the two experiments is that Tajmar et al. (GME I) need to *accelerate the rotating superconducting ring*, producing the *AGF in azimuthal direction*. GME II uses a *uniformly rotating disk*, generating an *AGF directed along the axis of rotation*. It is the latter experiment that could serve as the basis for a novel propulsion technology - *if EHT is correct*. It will be shown in the following section that the postulated gravitophoton force completely explains the experimental facts of GME I, both qualitatively and quantitatively. It is well known experimentally that a rotating superconductor generates a magnetic induction field, the so called *London moment*.

⁹ A more detailed discussion on the topic of dark matter and dark energy is foreseen in a forthcoming review paper, due summer 2008

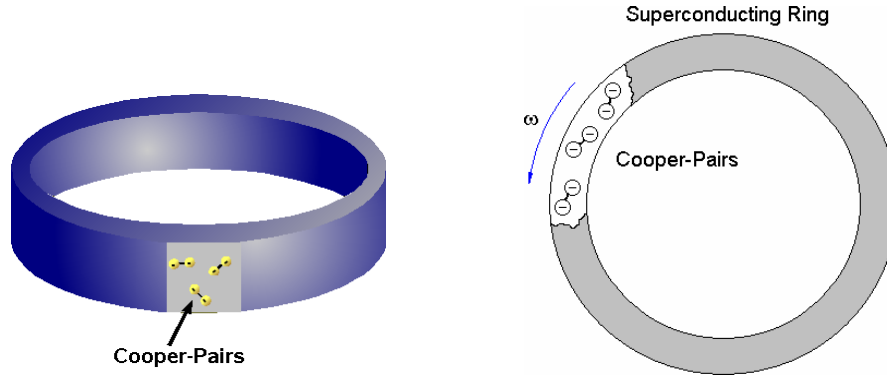


Figure 3. Theory explains superconductivity by the coupling of two electrons forming a so called Cooper pair. While a single electron is a Fermion, a Cooper pair is a Boson. Without the presence of Cooper pairs, $w_{ph_gp} = w_{ph}$ is a real value. According to EHT, the motion of the Cooper pairs changes the value of probability amplitude w_{ph_gp} adding the imaginary part $\pm i \left(\frac{1}{(1-k)(1-ka)} - 1 \right) w_{ph}$ so that the left-hand-side of Eq. (3) is obtained. Therefore, the probability (square of the amplitude) for the conversion of photons into gravitophotons is different from 0.

4.1 Momentum and Energy Conservation for Gravito-Magnetic Force

In the following it will be shown that the neutral gravitophoton that causes the gravito-magnetic force can decay via graviton and quintessence particle (GME I) or via positive (repulsive) gravitophoton and negative (attractive) gravitophoton (GME II). In GME I, the AGF is in the circumferential direction and needs a time varying neutral gravitophoton field, see Eq (12). In GME II the time varying differential operator is replaced by a spatially varying operator, which should leading to a completely different nature of the gravito-magnetic force that is much more amenable to space propulsion purposes.

In both cases the energy extracted from the vacuum is 0, since graviton and quintessence particles have negative and positive energy densities, respectively. If in GME I, only the energy of the gravitons is measured, it **should seem that energy conservation is violated**. However, this would be a clear sign that the energy budget is not complete, because the positive energy density of the quintessence particle was not accounted for. In GME II, the total energy taken from the vacuum is also 0. The two gravitophoton fields have opposite energy densities and add up to zero energy density. As is shown in Eq. (16), the gravito-magnetic force from positive gravitophotons is directed along the axis of rotation, while the gravito-magnetic force of the negative gravito-photons is in radial direction and exerts a force on the the mechanical structure of the space vehicle.

Regarding momentum conservation this is, obviously, not conserved. Regardless whether a gravitational field is generated by the mass of a planet or in the laboratory, it exerts the same force on a material body. Since the beginning of space-flight, the gravitational fields of the planets have been used to accelerate a spacecraft. Any gravitational field modifies spacetime and the spacecraft simply follows a geodesic trajectory. In this sense, there is no medium needed for gravito-magnetic propulsion. The only difference to the well known gravity-assist technique is that instead of using gravitational fields of the planets, the spacecraft is moving by its proper gravitational field, generated by the conversion of photons into gravitophotons.

4.2 Gravito-Magnetic Experiment I

In the experiments by Tajmar et al. it is shown that the acceleration field vanishes if the Cooper pairs are destroyed. This happens when the magnetic induction exceeds the critical value $B_C(T)$, which is the maximal magnetic induction that can be sustained at temperature T , and therefore depends on the material. For temperatures larger than the critical temperature, T_C , superconductivity is destroyed, too. The rotating ring no longer remains a superconductor and the artificial gravitational field disappears.

It will be shown in the following section that the postulated gravitophoton force completely explains the experimental facts of GME I, both qualitatively and quantitatively. It is well known experimentally that a rotating superconductor

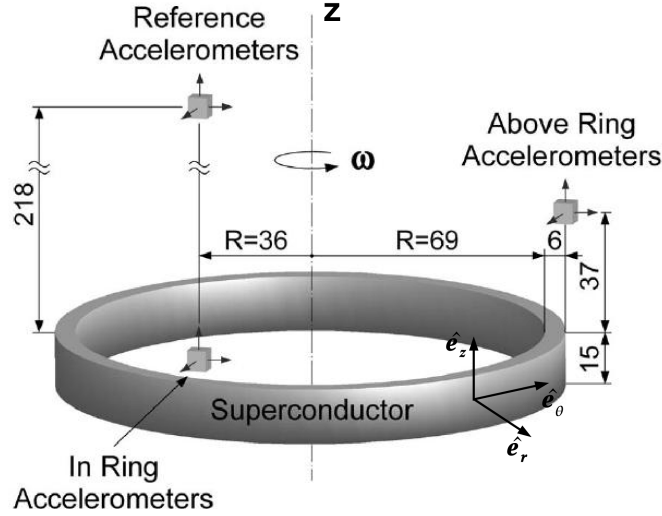


Figure 4. Rotating superconducting torus (Niobium) modified from Tajmar et al., see ref. [15]. All dimensions are in mm. A cylindrical coordinate system (r, Θ, z) with origin at the center of the ring is used. *In-Ring* accelerometers measured a gravitational acceleration of $-1.4 \times 10^{-5}g$ in the azimuthal (tangential, Θ) direction when the ring was subjected to angular acceleration, see Fig. 8(a) ref. [15] for the so called curl configuration that comprises a set of four accelerometers. In an earlier publication, see Fig. 4a) in [14], an acceleration field of about $-10 \times 10^{-5}g$ was measured for a single accelerometer. According to M. Tajmar, the curl value should be used. The acceleration field did not depend on angular velocity ω . No acceleration was measured in the z -direction (upward). The more recent experiment employed a set of 4 in-Ring accelerometers and confirmed the rotational character of this field. When the direction of rotation was reversed, the acceleration field changed sign, too.

generates a magnetic induction field, the so called *London moment*

$$\mathbf{B} = -\frac{2m_e}{e}\omega \quad (11)$$

where ω is the angular velocity of the rotating ring. It should be noted that this magnetic field is produced by the rotation of the ring, and not by a current of Cooper pairs that are moving within the ring.

4.3 EHT Analysis for Gravito-Magnetic Experiment I

Here only the final result for the acceleration field is stated without derivation. Comparisons of theoretical and experimental values for their most recent gravito-magneto measurements are shown below. In GME I the neutral gravitophoton decays into a graviton and a quintessence particle.

Without further demonstration, the gravitophoton acceleration for the in-Ring accelerometer is presented. It is assumed that the accelerometer is located at distance r from the origin of the coordinate system. From Eq. (11) it can be directly seen that the magnetic induction has a z -component only. Applying Stokes' law it is clear that the gravitophoton acceleration vector lies in the $r - \theta$ plane. Because of symmetry reasons the gravitophoton acceleration is independent of the azimuthal angle θ , and thus only has a component in the circumferential (tangential) direction, denoted by $\hat{\mathbf{e}}_\theta$. Since the gravitophoton acceleration is constant along a circle with radius r , integration is over the area $\mathbf{A} = \pi r^2 \hat{\mathbf{e}}_z$. Using the values for Nb, k and a , and carrying out the respective integration, the following expression for the gravitophoton acceleration is eventually obtained

$$\mathbf{g}_{gp} = -(0.04894)^2 \frac{m_e}{m_p} \dot{\omega} r \hat{\mathbf{e}}_\theta \quad (12)$$

where it was assumed that the $\mathbf{B}$ field is homogeneous over the integration area.

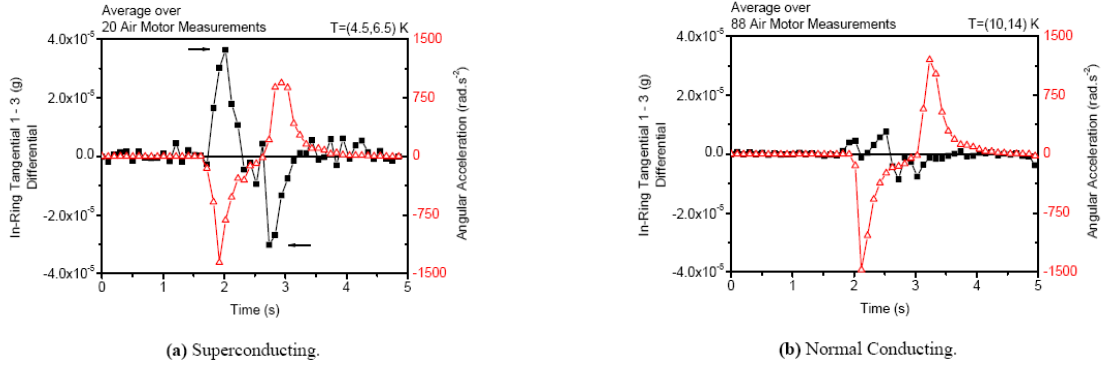


Figure 5. Picture taken from Tajmar et al., see [15]. In part (a), the Nb ring is in superconducting state. In the beginning, the ring is rotating with constant angular frequency, and thus no AGF is present. As soon as the ring is subjected to angular acceleration (red curve), an AGF is produced, causing the accelerometers to generate an acceleration field in opposite direction (black curve). The AGF points in circumferential direction and is located in the plane of the ring, opposite to the angular acceleration. Thus no propulsion force can be generated. In part (b), the ring is in normal conducting state, and regardless of its state of mechanical motion, no AGF is observed. This is a clear indication that the presence of Cooper pairs (Boson coupling) seems to be responsible for the generation of AGFs.

For comparisons of the predictions from EHT and the gravito-magnetic experiments, the most recent experimental values taken from the paper by Tajmar et al. [15] were used. The following values were utilized:

$$\dot{\omega} = 10^3 \text{ rad/s}^2; r = 3.6 \times 10^{-2} \text{ m}; \frac{m_e}{m_p} = 1/1836$$

$$g_{gp} = -(0.04894)^2 \times 10^{-4} \times 3.610^{-2} \times 10^3 \times 9.81^{-1} g \quad (13)$$

resulting in the computed value for the circumferential acceleration field

$$g_{gp} = -4.79 \times 10^{-6} g \quad (14)$$

For a more accurate comparison, the coupling factor $^{10} k_{gp}$ for the in-Ring accelerometer, as defined by Tajmar, is calculated from the value of Eq. (14), resulting in $k_{gp} = -4.79 \times 10^{-9} g \text{ rad}^{-1} \text{ s}^2$. The measured value is $k_{gp} = -14.4 \pm 2.8 \times 10^{-9} g \text{ rad}^{-1} \text{ s}^2$. This means that the theoretical value obtained from EHT is underpredicting the measured value by approximately a factor of 3. The agreement between the predicted gravitophoton force is *reasonable but not good*. Comparisons for lead are not made, since according to Tajmar ¹¹ these measurements [14] need to be repeated.

It should be kept in mind that the present derivation from EHT does give a dependence on the density of Cooper pairs for coupling values k and a , but, according to our current understanding, such a coupling only could be calculated for two materials, namely Nb and Pb.

In [15] a second set of measurements were taken using laser gyroscopes to determine the $\mathbf{b}_{gp}$. The formula used in this paper employing the actually measured value has the form

$$b_{gp} = -1.95 \times 10^{-6} \omega \text{ rad s}^{-1} \quad (15)$$

Comparing this with the equation derived from EHT, Eq. (14), it is found that the theoretical prediction is overpredicting the measured results by a factor of 1.34, which is in *good agreement with experiment*. The value computed by Tajmar, see [15], is overpredicting the measured value by about a factor of 2.

¹⁰ This coupling factor, as defined by Tajmar [15], is the ratio of the magnitudes of observed tangential acceleration g_{gp} and applied angular acceleration $\dot{\omega}$.

¹¹ e-mail communication February 2007

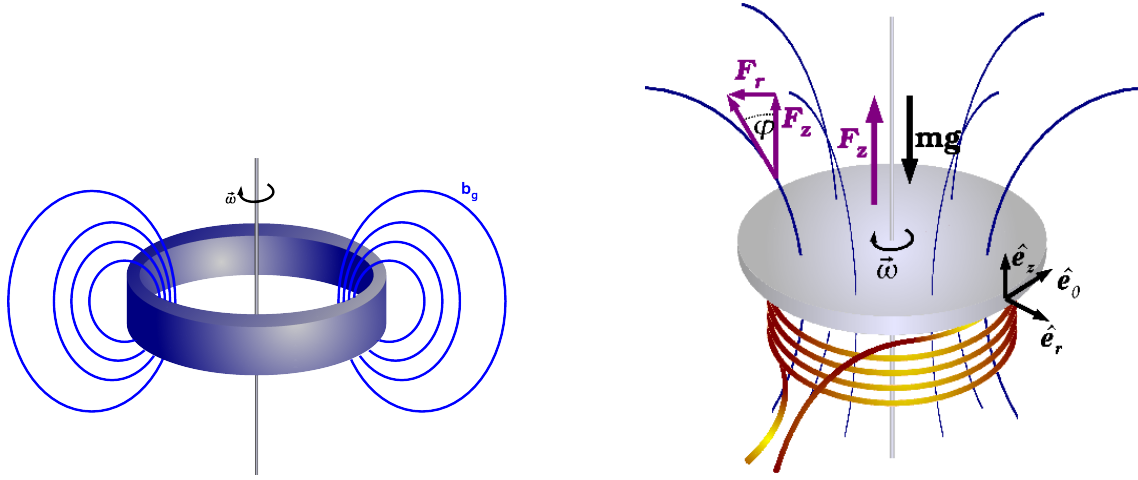


Figure 6. Comparison of experiments GME I (Tajmar) and GMEII (gravito-magnetic propulsion experiment). GME II, derived from EHT, is fundamentally different from GME I in two ways. First, EHT predicts the neutral gravitophoton to decay in a negative (attractive) and a positive (repulsive gravitophoton) that is, the physical mechanism itself is different. Second, the artificial gravitational field generated would be directed along the axis of rotation. Hence, this acceleration field could be used as propulsion mechanism. In other words, this experimental setup would serve as a demonstrator for a propellantless propulsion system. It comprises a superconducting coil and a rotating disk of a special material.

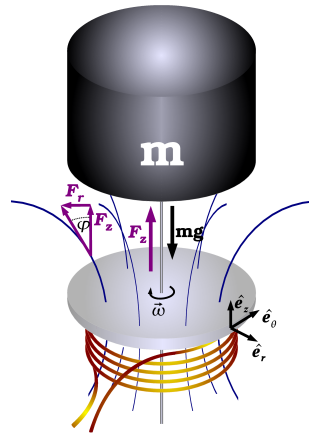


Figure 7. In a gravito-magnetic propulsion device the payload would be above the rotating disk, since the acceleration field would be generated above the disk. The propulsion would be very similar to gravity-assist technology, except that the planet producing the gravitational field accelerating the spacecraft is being replaced by the AGF generated by the gravito-magnetic effect resulting from the conversion of photons into gravitophotons. The vacuum itself would resume the role of the planet. In both cases, momentum of the spacecraft is not conserved.

4.4 EHT and Gravito-Magnetic Experiment II

There exists a major difference between the experiment of Fig. (4) and a gravito-magnetic field propulsion device. Present experiments only show the existence of a gravitational field as long as the ring undergoes an angular acceleration. The artificial gravitational field is directed opposite to the applied angular acceleration, following some kind of gravitational Lenz rule. For a propulsion device, however, the force must be directed along the axis of rotation, and not in the circumferential direction of the rotating ring. Therefore, a fundamentally different experiment must be designed to obtain a field along the axis of rotation. While the experiments by Tajmar et al. demonstrate the possibility of generating artificial gravitational fields, emphasizing the importance of a condensed state (Cooper pairs, Bosons), a novel experiment is needed to demonstrate the feasibility of gravito-magnetic field propulsion. The experimental

setup for such a device is pictured in Fig. (7).

Two acceleration components are generated: one in the radial r direction, and the second one in the z - direction. These components are given by

$$a_r \hat{\mathbf{e}}_r = v_\theta^T b_z \hat{\mathbf{e}}_\theta \times \hat{\mathbf{e}}_z, \quad a_z \hat{\mathbf{e}}_z = \frac{(v_\theta^T)^2}{c} b_z (\hat{\mathbf{e}}_\theta \times \hat{\mathbf{e}}_z) \times \hat{\mathbf{e}}_\theta \quad (16)$$

where v_θ^T denotes the velocity of the rotating disk or ring, and b_z is the component of the (gravitational) gravitophoton field $\mathbf{b}_{gp}$ (dimension 1/s) in the z -direction, see Fig. (7). In contrast to Fermion coupling, ref. [10], experimental requirements are substantially lower.

According to our current understanding, the superconducting solenoid of special material (red), see Fig. (7), should provide a magnetic induction field in the z direction at the location of the rotating disk (gray), made from a material different than the solenoid. The z -component of the gravitophoton field is responsible for the gravitational field above the disk. This experimental setup could also serve as field propulsion device, if appropriately dimensioned. Fig. (7) describes the experimental setup utilizing a disk rotating directly above a superconducting solenoid. In the field propulsion experiment of Fig. (7), the gravitophoton force produces a gravitational force above the disk in the z -direction.

5 TECHNICAL REQUIREMENTS AND PERFORMANCE OF GRAVITO-MAGNETIC SPACE PROPULSION

Only a brief account is presented. The following assumptions were made for demonstration experiment GME II: $N = 10$, number of turns of the solenoid, current of about 1A (needed to calculate b_z), diameter of solenoid 0.18 m, and $v_\theta^T = 25$ m/s. The disk should be directly above the solenoid to produce a magnetic field in z -direction only. This experiment should give an acceleration field $\mathbf{g}_{gp} = 6 \times 10^{-3} g \hat{\mathbf{e}}_z$, which is an appreciable field acting directly above the rotating disk.

From these numbers it seems to be feasible that, *if our theoretical predictions are correct*, the realization of a space propulsion device that can **lift itself from the surface of the Earth is within current technological limits**.

For a more realistic propulsion device in order to generate a force of $8.71 \times 10^5 N$, a mass of $3.15 \times 10^3 kg$ and a rotation speed of 200 m/s, a coil of 0.5 m diameter with 1,000 turns and a current of 1 A was calculated. The surface area of the coils was determined to about 4 m². These numbers will be recomputed in our forthcoming review article. All trip times given in [10] remain unchanged, but as can be seen from the specifications above, technical requirements were substantially reduced and should be feasible employing current technology. The reason for this change is Boson instead of Fermion coupling.

CONCLUSIONS AND FUTURE ACTIVITIES

Since 2002 ideas for a fundamental physical theory, termed Extended Heim Theory (EHT), predicting two additional gravitational interactions that might give rise to the generation of artificial gravitational fields (AGF), have been published, see for instance, [8], [17], [16], [10]. A popular description of this research may be found in [32], [33], [34].

EHT was used to describe the gravitational action of dark matter and dark energy, calculating the distribution of the three (four) types of matter, namely ordinary matter, dark matter (attractive and repulsive), and dark energy (repulsive) in the universe as well as the gravitational coupling of dark matter to ordinary matter. Second, EHT was used to analyze the recent experiments by **Tajmar et al. on the generation of AGFs (Sec. 4.2). This would be the first experiment to generate an artificial gravitational field (AGF) and could lead to a new era of gravitational engineering.** A popular description of this research may be found in [30, 31]. The underlying physical mechanism of the experiments as well as the direction and magnitude of the artificial acceleration field were calculated. Both phenomena were explained using the concept of three gravitational interactions that is, the existence of six fundamental forces as predicted by EHT. It should be noted that neither the behavior of dark matter can be explained by nor do AGFs exist in current physical theories. The experimental results by Tajmar **cannot be derived from the well known frame dragging effect of GR**, since measured values are more than 30 orders of magnitude larger than predicted by GR, and thus should not be visible in the laboratory.

Furthermore, guidelines were established using EHT to devise a novel experiment for a field propulsion device working without propellant, termed **GME II** (Sec. 4.3). In this experiment an AGF should be generated **along the axis of the rotating disk (ring) rotating with constant angular frequency**. Initial calculations show that experimental requirements are well within current technology. Boson coupling (Cooper pair density) seems to substantially alleviate experimental requirements like magnetic field and current density. Future research should focus on the theoretical aspects and experimental requirements of this device, because of its potential applications in the field of transportation. In particular, EHT predicts that superconductivity with a high density of Cooper pairs is an essential part for the (Boson) coupling between electromagnetism and gravitation.

The coupling constants for the two additional gravitational interactions were obtained from number theory, and thus are calculated theoretically. It is interesting to note that they were already published in 1996 and used without modification to explain and quantitatively compare with the experiments by Tajmar et al.

A gravito-magnetic propulsion device would be far superior compared to any device based on momentum generation from fuel, and would also result in a much simpler, far cheaper, and much more reliable technology.

As a next step, experiment GME II should be analyzed in detail. Dark matter and dark energy predictions from EHT should be investigated further. From the experimental side, major efforts should be devoted to validate or to falsify the experiments by Tajmar et al. and to improve experimental accuracy. Tajmar's experiments could well become landmark experiments for the completely novel technology of gravitational engineering.

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