Recent Trends in Aerospace Design and Optimization

Proceedings of SAROD - 2005

December 8-9, 2005, Hyderabad

Editors

Biju Uthup
Santhosh P Koruthu
R.K.Sharma
Pankaj Priyadarshi

Tata McGraw-Hill Publishing Company Limited
NEW DELHI

McGraw-Hill Offices

New Delhi New York St Louis San Francisco Auckland Bogotá Caracas
Kuala Lumpur Lisbon London Madrid Mexico City Milan Montreal
San Juan Santiago Singapore Sydney Tokyo Toronto

Information contained in this work has been obtained by Tata McGraw-Hill, from sources believed to be reliable. However, neither Tata McGraw-Hill nor its authors guarantee the accuracy or completeness of any information published herein, and neither Tata McGraw-Hill nor its authors shall be responsible for any errors, omissions, or damages arising out of use of this information. This work is published with the understanding that Tata McGraw-Hill and its authors are supplying information but are not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought.

Tata McGraw-Hill

This edition can be exported from India only by the publishers,
Tata McGraw-Hill Publishing Company Limited.

ISBN 0-07-060829-6

Published by the Tata McGraw-Hill Publishing Company Limited,
7 West Patel Nagar, New Delhi 110 008, Rashtriya Printers, M-135,
Panchsheel Garden, Naveen Shahdara, Delhi 110 032

Cover: Rashtriya

RLCCRDLBDXDYB

The McGraw·Hill Companies

Physical and Numerical Modeling for Advanced Propulsion Systems

Jochem Hauser †# **Walter Dröscher**# **Wuye Dai**‡ **Jean-Marie Muylaert***

Abstract

The paper discusses the current status of space transportation and then presents an overview of the two main research topics on advanced propulsion as pursued by the authors, namely the use of electromagnetic interaction (Lorentz force) as well as a novel concept, based on ideas of a unified theory by the late German physicist B. Heim, termed field propulsion. In general, electromagnetics is coupled to the Navier-Stokes equations and leads to magnetohydrodynamics (MHD). Consequently, the ideal MHD equations and their numerical solution based on an extended version of the HLLC (Harten-Lax-van Leer-Contact discontinuity) technique is presented. In particular, the phenomenon of waves in MHD is discussed, which is crucial for a successful numerical scheme. Furthermore, the important topic of a numerically divergence free magnetic induction field is addressed. Two-dimensional simulation examples are presented. In the second part, a brief discussion of field propulsion is given. Based on Einstein's principle of geometrization of physical interactions, a theory is presented that shows that there should be six fundamental physical interactions instead of the four known ones. The additional interactions (gravitophoton force) would allow the conversion of electromagnetic energy into gravitational energy where the vacuum state provides the interaction particles. This kind of propulsion principle is not based on the momentum principle and would not require any fuel. The paper discusses the source of the two predicted interactions, the concept of parallel space (in which the limiting speed of light is nc, n being an integer, c denoting vacuum speed of light), and presents a brief introduction of the physical model along with an experimental setup to measure and estimate the so called gravitophoton (Heim-Lorentz) force. Estimates for the magnitude of magnetic fields are presented, and trip times for lunar and Mars missions are given.

Key Words: physical principles of advanced propulsion, electromagnetic propulsion, numerical solution of the MHD equations; field propulsion, six fundamental physical interactions, conversion of electromagnetic energy into gravitational energy, Heim-Lorentz force.

1 PHYSICAL PRINCIPLES FOR PROPULSION SYSTEMS

All propulsion systems in use today are based on momentum conservation and rely on fuel [1]. There is one exception, namely gravity assist turns that use the gravitational fields of planets to accelerate a spacecraft. The only other long-range force known is the electromagnetic force or Lorentz force, acting on charged bodies or moving charges. Magnetic fields around planets or in interstellar space are too weak to be used as a means for propulsion. In the solar system and in the universe as known today, large-scale electromagnetic fields that could accelerate a space vehicle do not seem to exist.

However, magnetic and electric fields can easily be generated, and numerous mechanisms can be devised to produce ions and electrons and to accelerate charged particles. The field of magnetohydrodynamics recently has become again an area of intensive research, since both high-performance computing, allowing the simulation of these equations for realistic two- and three-dimensional configurations, and the progress in generating strong magnetic and electric fields have become a reality. Although the main physical ideas of MHD were developed in the fifties of the last century, the actual design of efficient and effective propulsion systems only recently became possible.

One weakness that all concepts of propulsion have in common today is their relatively low thrust. An analysis shows that only chemical propulsion can provide the necessary thrust to launch a spacecraft. Neither fission nor fusion propulsion will provide this capability. MHD propulsion is superior for long mission durations, but delivers only small amounts of thrust. Space flight with current propulsion technology is highly complex, and severely limited with respect to payload capability, reusability, maintainability. Above all it is not economical. In addition, flight speeds are marginal with respect to the speed of light. Moreover, trying only to fly a spacecraft of mass 10^5 kg at one per cent (non-relativistic) the speed of light is prohibitive with regard to the kinetic energy to be supplied. To reach velocities comparable to the speed of light, special relativity imposes a heavy penalty in form of increasing mass of the spacecraft, and renders such an attempt completely uneconomical.

The question therefore arises whether other forces (interactions) in physics exist, apart from the four known

†University of Applied Sciences and HPCC-Space GmbH, Salzgitter, Germany
IGW, Leopold-Franzens University, Innsbruck, Austria
‡ Aerodynamisches Institut, RWTH Aachen, Germany
* ESA-ESTEC, Noordwijk, The Netherlands

SAROD-2005
Published in 2005 by Tata McGraw-Hill

interactions in *Nature*, namely long-range gravitational and electromagnetic interactions, and on the nuclear scale the weak (radioactive decay, neutron decay is an example) and strong interactions (responsible for the existence of nuclei)? It has long been surmised that, because of their similarity, electromagnetic fields can be converted into gravitational fields. The limits of momentum based propulsion as enforced by governing physical laws, are too severe, even for the more advanced concepts like fusion and antimatter propulsion, photon drives and solar and magnetic sails. Current physics does not provide a propulsion principle that allows a lunar mission to be completed within hours or a mission to Mars within days. Neither is there a possibility to reach relativistic speeds (at reasonable cost and safety) nor are superluminal velocities conceivable. As mentioned by Krauss [2], general relativity (GR) allows metric engineering, including the so-called *Warp Drive*, but superluminal travel would require negative energy densities. However, in order to tell space to contract (warp), a signal is necessary that, in turn, can travel only with the speed of light. GR therefore does not allow this kind of travel.

On the other hand, current physics is far from providing final answers. First, there is no unified theory that combines general relativity (GR) and quantum theory (QT) [3-6]. Second, not even the question about the number of fundamental interactions can be answered. Currently, four interactions are known, but theory cannot make any predictions on the number of existing interactions. Quantum numbers, characterizing elementary particles (EP) are introduced ad hoc. The nature of matter *is unknown*. In EP physics, EPs are assumed to be point-like particles, which is in clear contradiction to recent lopp quantum theory (LQT) [3, 4] that predicts a granular space, i.e., there exists a smallest elemental surface. This finding, however, is also in contradiction with string theory (ST) [5, 6] that uses point-like particle in $\mathbb{R}^4$ but needs 6 or 7 additional real dimensions that are compactified (invisible, Planck length). Neither LQT nor ST predict measurable physical effects to verify the theory.

Most obvious in current physics *is the failure* to predict highly organized structures. According to the second law of thermodynamics these structures should not exist. In cosmology the big bang picture requires the universe to be created form a point-like infinitely dense quantity that defies any logic. According to Penrose [7] the probability for this to happen is zero. Neither the mass spectrum nor the lifetimes of existing EPs can be predicted. It therefore can be concluded that despite all the advances in theoretical physics, the major questions still cannot be answered. Hence, the goal to find a unified field theory is a viable undertaking, because it might lead to novel physics [8], which, in turn, might allow for a totally different principle in space transportation.

2 MAGNETO-HDYRODYNAMIC PROPULSION

Because of the inherent limitations of chemical propulsion to deliver a specific impulse better than 450 s, research concentrated on electromagnetic propulsion already in the beginning of the space flight area, i.e., in the fifties of the last century. Electric and plasma propulsion systems were designed and tested some 35 years ago, but until recently have not made a contribution to the problem of space transportation. Allowing for a much higher specific impulse of up to 10^4 s, the total thrust delivered by a plasma propulsion system is typically around 1 N and some 20 mN for ion propulsion. No payload can be lifted form the surface of the earth with this kind of propulsion system. On the other hand, operation times can be weeks or even months, and interplanetary travel time can be substantially reduced. In addition, spacecraft attitude control can be maintained for years via electric propulsion.

2.1 MHD Equations

The MHD equations are derived from the combination of fluid dynamics (mass, momentum, and energy conservation) and Maxwell equations. In addition, generalized Ohm's law, $\boldsymbol{j}=\sigma(\boldsymbol{e}+\boldsymbol{v}\times\boldsymbol{B})$, is used and displacement current $\partial\boldsymbol{E}/\partial t$ in Ampere's law is neglected. The curl of E in farady's law is replaced by taking the curl of j and inserting it into Faraday's law. Making use of the identity $\nabla\times(\nabla\times\boldsymbol{B})=-\nabla^2\boldsymbol{B}$, with $\nabla\cdot\boldsymbol{B}=0$, one obtains the equation for the $\boldsymbol{B}$ field. Introducing the magnetic Reynolds number $\mathrm{Re}_m=vL/\eta_m, \eta_m=\frac{1}{\mu_0\sigma}$, which denotes the ratio of the $\nabla\times(\boldsymbol{v}\times\boldsymbol{B})$ convection term and the $\eta_m\nabla^2\boldsymbol{B}$ diffusion term, the ideal MHD equations are obtained assuming an infinitely high conductivity σ of the plasma. The MHD equations can thus be written in conservative form

$$\frac{\partial\boldsymbol{U}}{\partial t}+\nabla\cdot\boldsymbol{F}=0 \tag{1}$$

$$\boldsymbol{U}=\begin{bmatrix}\rho\\ \rho\boldsymbol{v}\\ E\\ \boldsymbol{B}\end{bmatrix} \tag{2}$$

$$\boldsymbol{F}=\begin{bmatrix}\rho\boldsymbol{v}\\ \rho\boldsymbol{v}\boldsymbol{v}+P\boldsymbol{I}-\boldsymbol{B}\boldsymbol{B}\\ (E+P)\boldsymbol{v}-\boldsymbol{B}(\boldsymbol{v}\cdot\boldsymbol{B})\\ \boldsymbol{v}\boldsymbol{B}-\boldsymbol{B}\boldsymbol{v}\end{bmatrix} \tag{3}$$

where is ρ mass density, *v* is velocity, and *E* denotes total energy. P includes the magnetic pressure $B^2/2\mu_m$.

$$E=p/(\gamma-1)+\rho(u^2+v^2+w^2)/2 \\ +(B_x^2+B_y^2+B_z^2)/2\mu_m \quad (4)$$

$$P=p+(B_x^2+B_y^2+B_z^2)/2\,\mu_m . \quad (5)$$

In additional to the above equations, the magnetic field satisfies the **divergence free constraint** $\nabla\cdot\boldsymbol{B}=0$. This is not an evolution equation and has to be *satisfied numerically at each iteration step for any kind of grid*. Special care has to be taken to guarantee that this condition is satisfied, otherwise the solution may become non-physical. Due to the coupling of the induction equation to the momentum and energy equations, these quantities would also be modeled incorrectly.

2.2 Numerical Solution of the MHD Equations

The above ideal MHD equations constitute a non-strictly hyperbolic partial differential system. From the analysis of the governing equations in one-dimensional spatio-temporal space, proper eigenvector and eigenvalues can be found. The seven eigenvalues of the MHD equations are (the details of the MHD waves are presented in [13]**)**: $[u, u\pm c_A, u\pm c_s, u\pm c_f]$. All velocity component are in the direction of propagation of the wave.

2.2.1 MHD-HLLC Algorithm

In order to approximate the flux function, the appropriate Riemann problem is solved on the domain (x_l, x_r) and integrated in time from $0\ to\, t_f$. A major task is the evaluation of the wave propagation speeds.

$$q^*=s_M= \\ \frac{\rho_r q_r(s_r-q_r)-\rho_l q_l(s_l-q_l)+p_l-p_r-B_{nl}^2+B_{nr}^2}{\rho_r(s_r-q_r)-\rho_l(s_l-q_l)} \quad (6)$$

$$P^*=\rho(s_l-q)(q^*-q)+P-B_n^2+(B_n^*)^2 . \quad (7)$$

In order to evaluate the integrals, the (yet unknown) signal speeds $s_l\, and\, s_r$ are considered, denoting the fastest wave propagation in the negative and positive x-directions. It is assumed, however, that at the final time t_f, no information has reached the left, $x_l<0$, and right, $x_r>0$, boundaries of the spatial integration interval that is, $x_l<s_l t_f$ and $x_r>s_r t_f$. Applying the Rankine-Hugoniot jump conditions to the ideal MHD equations and observing a conservation principle for the B field, eventually leads to

$$\begin{aligned}
\rho_K^* &= \rho_K \frac{S_K-q_K}{S_K-q^*} \\
(\rho u)_K^* &= (\rho u)_K \frac{S_K-q_K}{S_K-q^*} + \\
&\frac{(P^*-P_K)n_x+B_{nK}B_{xK}-B^*B_x^*}{S_K-q^*} ¿ \\
(\rho v)_K^* &= (\rho v)_K \frac{S_K-q_K}{S_K-q^*} + \\
&\frac{(P^*-P_K)n_y+B_{nK}B_{yK}-B^*B_y^*}{S_K-q^*} \\
E_K^* &= E_K \frac{S_K-q_K}{S_K-q^*} + \\
&\frac{P^*q^*-P_K q_K+B_{nK}(\boldsymbol{B}\cdot\boldsymbol{v})_K-B^*(\boldsymbol{B}\cdot\boldsymbol{v})^*}{S_K-q^*}
\end{aligned} \quad (8)$$

$$B_{xl}^*=B_{xr}^*=B_x^{HLL}=\frac{s_r B_{xr}-s_l B_{xl}}{s_r-s_l} \quad (9)$$

$$B_{yl}^*=B_{yr}^*=B_y^{HLL} \quad , \quad B_{zl}^*=B_{zr}^*=B_z^{HLL} \quad (10)$$

$$\boldsymbol{F}_{HLLC}=\begin{cases} \boldsymbol{F}_l & if\ 0<s_l \\ \boldsymbol{F}_l^*=\boldsymbol{F}_l+s_l(\boldsymbol{U}_l^*-\boldsymbol{U}_l) & if\ s_l\le 0\le q^* \\ \boldsymbol{F}_r=\boldsymbol{F}_r+s_r(\boldsymbol{U}_r^*-\boldsymbol{U}_r)^* & if\ q^*\le 0\le s_r \\ \boldsymbol{F}_r & if\ s_r<0 \end{cases} . \quad (11)$$

2.2.2 Wavespeed Computation

The eigenvalues reflect four different wave speeds for a perturbation propagating in a plasma field: the usual *acoustic*, the *Alfven* as well as the *slow and fast plasma waves*

$$a^2=\left(\frac{\partial p}{\partial \rho}\right)_s \quad (12)$$

$$c_A^2=B_n^2/\rho\,\mu_m \quad (13)$$

$$2c_{s,f}^2=a^2+\frac{B^2}{\rho\,\mu_m}\pm\sqrt{\left(a^2+\frac{B^2}{\rho\,\mu_m}\right)^2-4\,a^2 c_A^2} . \quad (14)$$

2.2.3 Divergence Free B Field

To obtain a divergence free induction field in time, a numerical scheme for the integration of the B filed has to be constructed that inherenltly satisfies this constraint numerically. The original equations should not be modified, neither should an additional Poisson equation be solved at each iteration step to enforce a divergence free B field. For the lack of space we refer to Torrilhon [14] or to [13]. In 2D where the vector potentia lonly has a z-component, the divergence of B only depends on components B_x and B_y. the magnetic field is defined at two locations: at the center of the computational cells, and at the surfaces. In fact, only the normal component is defined at the cell surfaces (the magnetic flux), for a Cartesian grid. The evolution of the magnetic field at the cell surface is then obtained by directly solving the Ampere equation. Defining $\boldsymbol{\Omega}=\boldsymbol{v}\times\boldsymbol{B}$ at cell vertices, it can be shown [14] that the field at the cell surface centers can be obtained in such a way that the divergence-free condition is exactly satisfied.

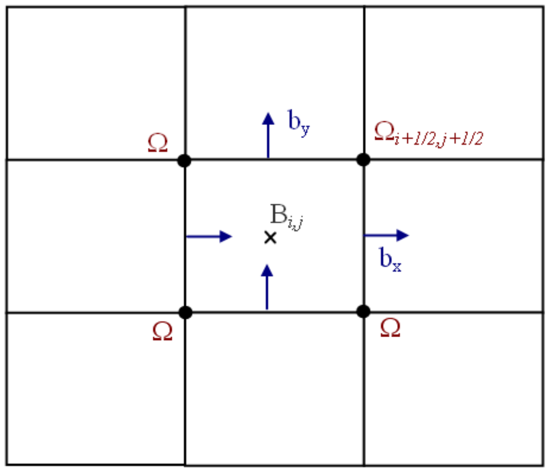

Figure 1: Schematic of staggered-grid variables used in the Dai & Woodward scheme. For a non-orthogonal coordinates a staggered grid does not seem to have an advantage, since cell normal vectors do no longer point in a coordinate direction. A cell centered scheme seems to be advantageous for curvilinear coordinates.

$$\frac{\partial \boldsymbol{b}}{\partial t}=\nabla\times\boldsymbol{\Omega}\Rightarrow\left\{\begin{array}{l}\dfrac{\partial b_x}{\partial t}=\nabla_y\Omega_z\\ \dfrac{\partial b_y}{\partial t}=\nabla_x\Omega_z\end{array}\right\} \quad (15)$$

$$\delta b_{x,(i+1/2,\ j)}=\frac{\Delta t}{\Delta y}[\Omega_{z,(i+1/2,\ j+1/2)}-\Omega_{z,(i+1/2,\ j-1/2)}]$$
$$\delta b_{y,(i,\ j+1/2)}=-\frac{\Delta t}{\Delta y}[\Omega_{z,(i+1/2,\ j+1/2)}-\Omega_{z,(i-1/2,\ j+1/2)}] \quad (16)$$

$$\oint \boldsymbol{b}\cdot d\boldsymbol{S}=0\Rightarrow\Delta y[b_{x,(i+1/2,\ j)}-b_{x,(i-1/2,\ j)}]+\Delta x[b_{y,(i,\ j+1/2)}-b_{y,(i,\ j-1/2)}]=0 \quad (17)$$

$$B_{x(i,j)}=\frac{1}{2}[b_{x,(i+1/2,j)}+b_{x,(i-1/2,j)}]$$
$$B_{y(i,j)}=\frac{1}{2}[b_{y,(i,j+1/2)}+b_{y,(i,j-1/2)}] \quad (18)$$

2.3 Simulation Results

2.3.1 Brio-Wu's shock tube

Initial conditions: $\gamma=2.0, \boldsymbol{V}=0, Bz=0, Bx=0.75$

$\rho=1, p=1, by=1$ for $x<0$

$\rho=0.125, p=0.1, By=-1$ for $x\geq 0$

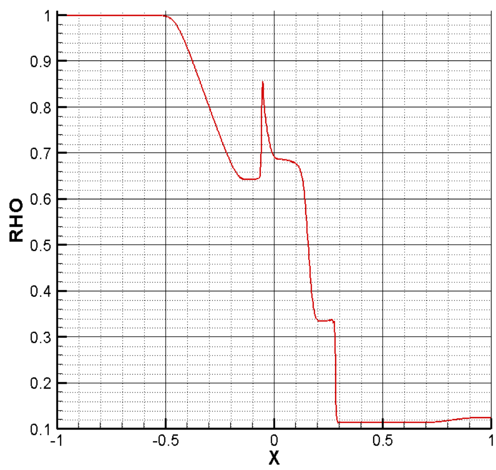

Figure 2: 1D MHD solution at time t = 0.25s.

Computational domain is the rectangle [-1,1].

2.3.2 Supersonic Flow Past Circular Density Field

The solution domain is in the x-y plane [-1.5, 3.5; -4.0, 4.0], example first computed by M. Torrilhon.

Initial conditions: outside the density sphere, velocity component v_x=3, $\rho=1$. Inside the density sphere: $\rho=10$, velocity v_x=0. For all: **B**=(B_x=B_0, 0), p = 1, v_y=0 and $\gamma=5/3$.

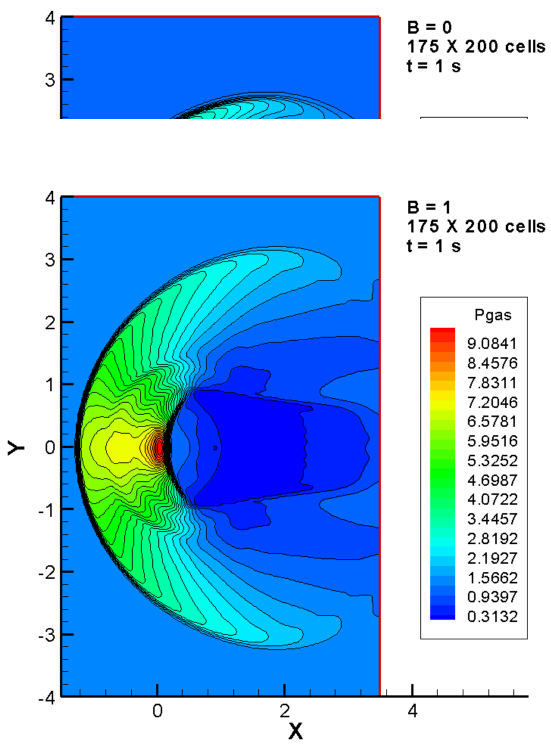

Figure 3: Supersonic flow past initial density field, shown pressure distributions: left: B0=0, right B0=1. The impact of the magnetic induction on the pressure distribution is clearly visible.

2.3.3 Classic 2D MHD Orszag-Tang Vortex

Computation domain is a square domain of size $[0,2\pi]\times[0,2\pi]$.

Initial conditions are given by:

$$(v_x, v_y)=(-\sin y, \sin x)$$

$$(B_x, B_y)=(-\sin y, \sin 2x)$$

$$(\rho, p, v_z, B_z)=(25/9, 5/3, 0, 0) \text{ with } \gamma=5/3$$

This case uses periodic boundary conditions.

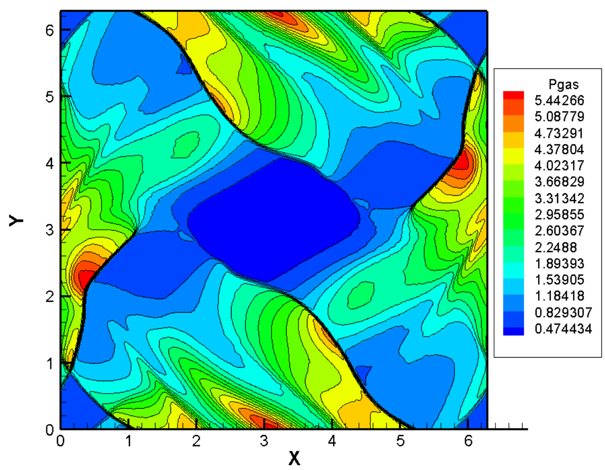

Figure 4: Orszag–Tang MHD turbulence problem with a 384 × 384 uniform grid at t=2s.

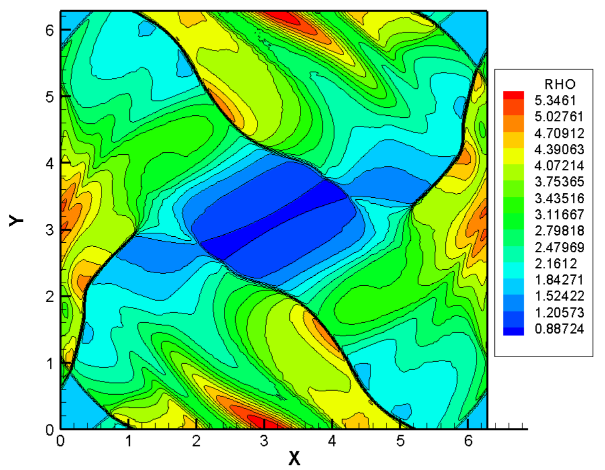

Figure 5: Orszag–Tang MHD turbulence problem with a 384 × 384 uniform grid at t=2s.

3 FIELD PROPULSION

The above discussion has shown that current physical laws severely limit spaceflight. The German physicist, B. Heim, in the fifties and sixties of the last century developed a unified field theory based on the *geometrization principle* of Einstein [18] (see below) introducing the concept of a quantized spacetime but using the equations of GR and introducing QMs. A quantized spacetime has recently been used in quantum gravity. Heim went beyond general relativity and asked the question: if the effects of the gravitational field can be described by a connection (Christoffel symbols) in spacetime that describes the relative orientation between local coordinate frames in spacetime, can all other forces of nature such as electromagnetism, the weak force, and the strong force be associated with respective connections or an equivalent metric tensor. Clearly, this must lead to a higher dimensional space, since in GR spacetime gives rise to only one interaction, which is gravity.

The **fundamental difference to *GR*** is the existence of internal space H^8, and its influence on and steering of events in $\mathbb{R}^4$. In GR there exists only one metric leading to gravity. All other interactions cannot be described by a metric in $\mathbb{R}^4$. In contrast, since internal symmetry space is steering events in $\mathbb{R}^4$, the following (double) mapping, namely $\mathbb{R}^4 \rightarrow H^8 \rightarrow \mathbb{R}^4$, has to replace the usual mapping $\mathbb{R}^4 \rightarrow \mathbb{R}^4$ of GR. This double mapping is the source of the polymetric describing all physical interactions that can exist in Nature. The coordinate structure of H^8 is therefore crucial for the physical character of the unified field theory. This structure needs to be established from basic physical features and follows directly from the physical principles of Nature (***geometrization, optimization, dualization (duality), and quantization***). Once the structure of H^8 is known, a prediction of the number and nature of all physical interactions is possible.

As long as quantization of spacetime is not considered, both internal symmetry space, denoted as Heim space H^8, and spacetime of *GR* can be conceived as manifolds with metrics.

3.1 Six Fundamental Interactions

Einstein, in 1950 [9], emphasized the principle of geometrization of all physical interactions. The importance of GR is that there exists no background coordinate system. Therefore, conventional quantum field theories that are relying on such a background space will not be successful in constructing a quantum theory of gravity. In how far string theory [5, 6], ST, that uses a background metric will be able to recover background independence is something that seems undecided at present. On the contrary, according to Einstein, one should start with GR and incorporate the quantum principle. This is the approach followed by Heim and also by Rovelli, Smolin and Ashtekar et al. [3, 4]. In addition, spacetime in these theories is discrete. It is known that the general theory of relativity (GR) in a 4-dimensional spacetime delivers one possible physical interaction, namely gravitation. Since Nature shows us that there exist additional interactions (EM, weak, strong), and because both GR and the quantum principle are experimentally verified, it seems logical to extend the geometrical principle to a discrete, higher-dimensional space. Furthermore, the spontaneous order that has been observed in the universe is opposite to the laws of thermodynamics, predicting the increase of disorder or greater entropy. Everywhere highly evolved structures can be seen, which is an enigma for the science of today. Consequently, the theory utilizes an *entelechial* dimension, x^5, an *aeonic* dimension, x^6 (see glossary), and coordinates x^7, x^8 describing *information*, i.e., quantum mechanics, resulting in an 8-dimensional discrete space in which a smallest elemental surface, the so-called *metron*, exists. H^8 comprises real fields, the hermetry forms, producing real physical effects. One of these hermetry forms, H_1, is responsible for gravity, but there are 11 other hermetry forms (partial metric) plus 3 degenerated hermetry forms, part of them listed in Table 2. The physics in Heim theory (HT) is therefore determined by the polymetric of the hermetry forms. This kind of polymetric is currently not included in quantum field theory, loop quantum gravity, or string theory.

3.2 Hermetry Forms and Physical Interactions

In this paper we present the physical ideas of the geometrization concept underlying Heim theory in 8D space using a series of pictures, see Figs. 6-8. The mathematical derivation for hermetry forms was given in [10-12]. As described in [10] there is a general coordinate transformation $x^m(\xi^\alpha(\eta^i))$ from $\mathbb{R}^4 \rightarrow H^8 \rightarrow \mathbb{R}^4$ resulting in the metric tensor

$$g_{ik} = \frac{\partial x^m}{\partial \xi^\alpha}\frac{\partial \xi^\alpha}{\partial \eta^i}\frac{\partial x^m}{\partial \xi^\beta}\frac{\partial \xi^\beta}{\partial \eta^k} \tag{19}$$

where indices α, β = 1,...,8 and *i, m, k* = 1,...,4. The Einstein summation convention is used, that is, indices occurring twice are summed over.

$$g_{ik} =: \sum_{\mu,\nu=1}^{8} g_{ik}^{(\mu\nu)} \tag{20}$$

$$g_{ik}^{(\mu\nu)} = \frac{\partial x^m}{\partial \xi^{(\mu)}}\frac{\partial \xi^{(\mu)}}{\partial \eta^i}\frac{\partial x^m}{\partial \xi^{(\nu)}}\frac{\partial \xi^{(\nu)}}{\partial \eta^k}. \tag{21}$$

Twelve hermetry forms can be generated having direct physical meaning, by constructing specific combinations from the four subspaces. The following denotation for the metric describing hermetry form H_ℓ with ℓ=1,...,12 is used:

$$g_{ik}(H_\ell) =: \sum_{\mu,\nu \in H_\ell} g_{ik}^{(\mu\nu)} \tag{22}$$

where summation indices are obtained from the definition of the hermetry forms. The expressions $g_{ik}(H_\ell)$ are interpreted as different physical interaction potentials caused by hermetry form H_ℓ, extending the interpretation of metric employed in *GR* to the poly-metric of H^8. It should be noted that any valid hermetry form either must contain space S^2 or I^2.

Each individual hermetry form is equivalent to a physical potential or a messenger particle. It should be noted that spaces $S^2 \times I^2$ describe gravitophotons and $S^2 \times I^2 \times T^1$ are responsible for photons. There are three, so called degenerated hermetry form describing neutrinos and so called conversions fields. Thus a total of 15 hermetry forms exists.

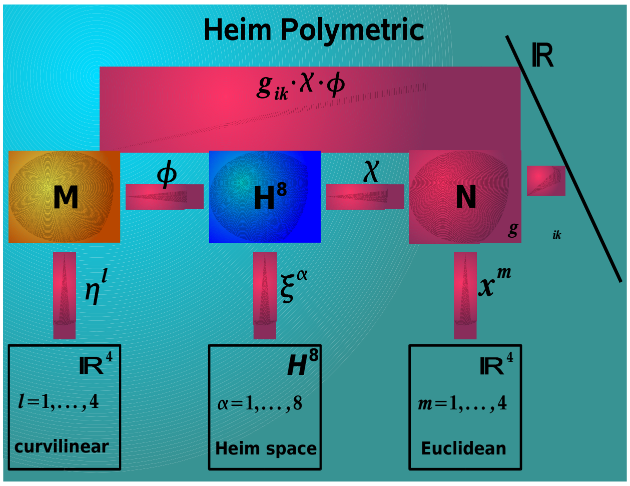

Figure 6: Einstein's goal was the unification of all physical interactions based on his principle of geometrization, i.e., having a metric that is responsible for the interaction. This principle is termed Einstein's geometrization principle of physics (EGP). To this end, Heim and Dröscher introduced the concept of an internal space, denoted as Heim space H^8, having 8 dimensions. Although H^8 is not a physical space, the signature of the additional coordinates being timelike (negative), these invisible internal coordinates govern events in spacetime . Therefore, a mapping from manifold M (curvilinear coordinates η^l)in spacetime IR^4 to internal space H^8 and back to IR^4 .

In Heim space there are four additional internal coordinates with timelike (negative) signature, giving rise to two additional subspaces S^2 and I^2. Hence, H^8 comprises four subspaces, namely IR^3, T^1, S^2, and I^2. The picture shows the kind of metric-subspace that can be constructed, where each element is denoted as a hermetry form. Each hermetry form has a direct physical meaning, see Table 3. In order to construct a hermetry form, either internal space S^2 or I^2 must be present. In addition, there are two degenerated hermetry forms that describe partial forms of the photon and the quintessence potential. They allow the conversion of photons into gravitophotons as well as of gravitophotons and gravitons into quintessence particles.

There are two equations describing the conversion of photons into pairs of gravitophotons, Eqs. (23), for details see [10-12]. The first equation describes the production of N^2 gravitophoton particles from photons.

$$w_{ph}(r) - w_{ph} = N w_{gp}$$
$$w_{ph}(r) - w_{ph} = A w_{ph} . \qquad (23)$$

This equation is obtained from Heim's theory in 8D space in combination with considerations from number theory, and predicts the conversion of photons into gravitophoton particles. The second equation is taken from Landau's radiation correction. C*onversion amplitude:* The physical

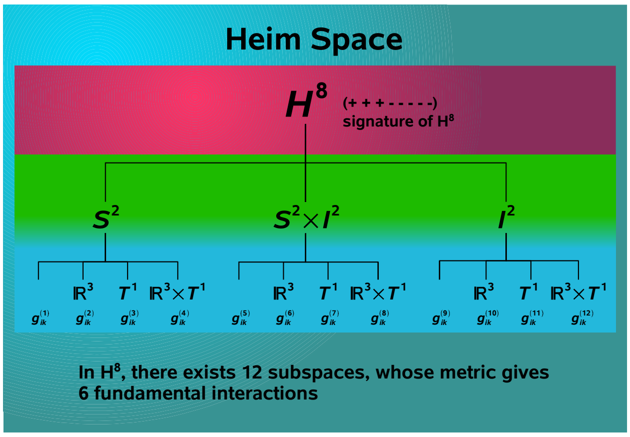

Figure 7: The picture shows the 12 hermetry forms that can be constructed from the four subspaces, nalely namely IR^3, T^1, S^2, and I^2 (see text).

meaning of Eqs. (23) is that an electromagnetic potential (photon) containing probability amplitude Aw_{ph} can be converted into a gravitophoton potential with amplitude Nw_{gp},, see Eq. (24).

$$N w_{gp} = A w_{ph} . \qquad (24)$$

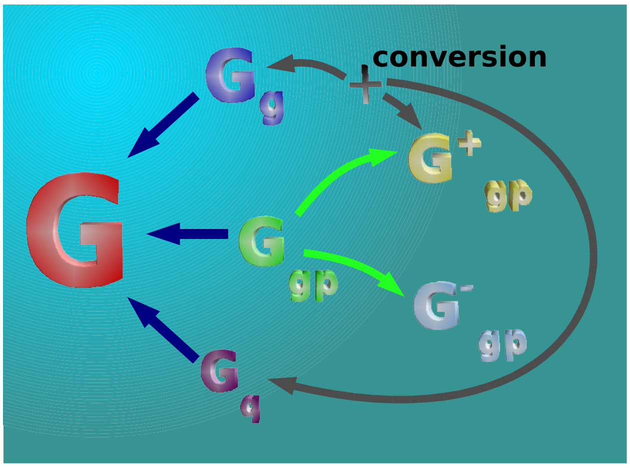

Figure 8: There should be three gravitational particles, namely the graviton (attractive), the gravitophoton (attractive and repulsive), and the quintessenece or vacuum particle (repulsive), represented by hermetry forms H_1, H_5, and H_9, see Table 2.

In the rotating torus, see Fig. 9, virtual electrons are produced by the vacuum, partially shielding the proton charge of the nuclei. At a distance smaller than the Compton wavelength of the electron away from the nucleus, the proton charge increases, since it is less shielded. According to Eq. (24) a value of A larger than 0 is needed for gravitophoton production. As was shown in [10], however, a smaller value of A is needed to start converting photons into gravitophotons to make the photon metric vanish, termed $\tilde{A} = v_k v_k^T / c^2 \approx 10^{-11}$

where v is the velocity of the electrons in the current loop and v^T is the circumferential speed of the torus. From the vanishing photon metric, the metric of the gravitophoton pairs is generated, replacing the value of A by the LHS of Eq. (6) and inserting it into the equation for the gravitophoton metric. This value is then increased to the value of A in Eq.(6). Experimentally this is achieved by the current loop (magnetic coil) that generates the magnetic vector and the tensor potential at the location of the virtual electron in the rotating torus, producing a high enough product v $v^{T,}$ see Eq. 32 in [12]. The coupling constants of the two gravitophoton particles are different, and only the negative (attractive) gravitophotons are absorbed by protons and neutrons, while absorption by electrons can be neglected. This is plausible since the negative (attractive) gravitophoton contains the metric of the graviton, while the positive repulsive gravitophoton contains the metric of the quintessence particle that does only interact extremely weakly with matter. Through the interaction of the attractive gravitophoton with matter it becomes a real particle and thus a measurable force is generated (see upper part of the picture).

3.3 Gravitational Heim-Lorentz Force

The Heim-Lorentz force derived in [10-12] is the basis for the field propulsion mechanism. In this section a description of the physical processes for the generation of the Heim-Lorentz force is presented along with the experimental setup. It turns out that several conditions need to be satisfied. In particular, very high magnetic field strengths are required.

In Table 1, the magnitude of the Heim-Lorentz force is given. The current density is 600 A/mm$^{2.}$ The value Δ is the relative change with respect to earth acceleration g=9.81 m/s^2 that can be achieved at the corresponding magnetic field strength. The value μ_0**H** is the magnetic induction generate by the superconductor at the location of the rotating torus, D is the major diameter of the torus, while d is the minor diameter. In stands for the product of current and times the number of turns of the magnetic coil. The velocity of the torus was assumed to be 700 m/s. Total wire length would be some 106 m. Assuming a reduction in voltage of 1μV/cm for a superconductor, a thermal power of some 8 kW has to be managed. In general, a factor of 500 needs to be applied at 4.2 K to calculate the cooling power that amounts to some 4 MW.

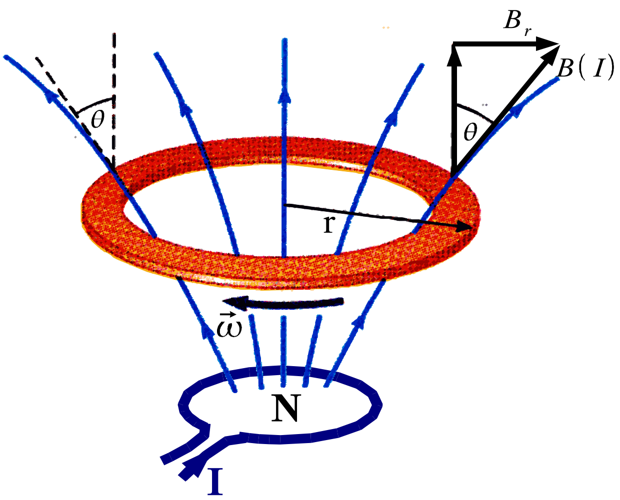

Figure 9: This picture shows the experimental setup to measuring the Heim-Lorentz force. The current loop (blue) provides an inhomogeneous magnetic field at the location of the rotating torus (red). The radial field component causes a gradient in the z-direction (vertical). The red ring is a rotating torus. The experimental setup also would serve as the field propulsion system, if appropriately dimensioned. For very high magnetic fields over 30 T, the current loop or solenoid must be mechanically reinforced because of the Lorentz force acting on the moving electrons in the solenoid, forcing them toward the center of the loop.

$$\frac{32}{3}\left(\frac{Nw_{gpe}}{w_{ph}}\right)^2 \left(Nw_{gpa}\right)^4 \left(\frac{\hbar}{m_p c}\right)^2 \frac{d}{d_0^3} Z. \qquad (25)$$

d [m]	D [m]	*I n* [An]	*N w* $_{gpe}$	μ_0 ***H*** *(T)*	Δ
0.2	2	6.6 ×10^6	1.4× 10^{-7}	13	7×10^{-16}
0.3	3	1.3 ×10^7	7.4 ×10^{-6}	18	2×10^{-5}
0.4	4	2.7 ×10^7	2×10^{-5}	27	1.1×10^{-2}
0.5	5	4 ×10^7	3.9×10^{-5}	33	0.72
0.6	6	1.5 ×10^7	4.8×10^{-5}	38	3

Table 1: From the Heim-Lorentz force the following values are obtained. A mass of 1,000 kg of the torus is assumed, filled with 5 kg of hydrogen.

3.4 Transition into Parallel Space

Under the assumption that the gravitational potential of the spacecraft can be reduced by the production of quintessence particles as discussed in Sec.1., a transition into parallel space is postulated to avoid a potential conflict with relativity theory. A parallel space $\mathbb{R}^4(n)$, in which covariant physical laws with respect to $\mathbb{R}^4$ exist, is characterized by the scaling transformation

$$x_i(n)=\frac{1}{n^2}x(1), i=1,2,3; t(n)=\frac{1}{n^{3t}}(1)$$
$$v(n)=n v(1); c(n)=n c(1) \qquad (26)$$
$$G(n)=\frac{1}{n}G; \hbar(n)=\hbar; n\in\mathbb{N}.$$

The fact that *n* must be an integer stems from the requirement in *HQT* and *LQT* for a smallest length scale. Hence only discrete and no continuous transformations are possible. The Lorentz transformation is invariant with regard to the transformations of Eqs. (26) [1]. In other words, physical laws should be covariant under discrete (quantized) spacetime dilatations (contractions). There are

1 It is straightforward to show that Einstein's field equations as well as the Friedmann equations are also invariant under dilatations.

two important questions to be addressed, namely how the value n can be influenced by experimental parameters, and how the back-transformation from $\mathbb{R}^4(n) \rightarrow \mathbb{R}^4$ is working. The result of the back-transformation must not depend on the choice of the origin of the coordinate system in $\mathbb{R}^4$. As a result of the two mappings from $\mathbb{R}^4 \rightarrow \mathbb{R}^4(n) \rightarrow \mathbb{R}^4$, the spacecraft has moved a distance $n\ v\ \Delta t$ when reentering $\mathbb{R}^4$. The value Δt denotes the time difference between leaving and reentering $\mathbb{R}^4$, as measured by an observer in $\mathbb{R}^4$. This mapping for the transformation of distance, time and velocity differences cannot be the identity matrix that is, the second transformation is not the inverse of the first one. A quantity $v(n)=nv(1)$, obtained from a quantity of $\mathbb{R}^4$, is not transformed again when going back from $\mathbb{R}^4(n)$ to $\mathbb{R}^4$. This is in contrast to a quantity like $\Delta t(n)$ that transforms into ΔT. The reason for this non-symmetric behavior is that $\Delta t(n)$ is a quantity from $\mathbb{R}^4(n)$ and thus is being transformed. The spacecraft is assumed to be leaving $\mathbb{R}^4$ with velocity v. Since energy needs to be conserved in $\mathbb{R}^4$, the kinetic energy of the spacecraft remains unchanged upon reentry.

The value of n is obtained from the following formula, Eq. (27), relating the field strength of the gravitophoton field, g^{+}_{gp}, with the gravitational field strength, g_g, produced by the spacecraft itself,

$$n = \frac{g^{+}_{gp}}{g_g} \frac{G_{gp}}{G}. \qquad (27)$$

For the transition into parallel space, a material with higher atomic number is needed, here magnesium *Mg* with Z=12 is considered, which follows from the conversion equation for gravitophotons and gravitons into quintessence particles (stated without proof). Assuming a value of $g_g = GM/R^2 = 10^{-7}$ m/s^2 for a mass of 10^5 kg and a radius of 10 m, a value of $g_g = 2 \times 10^{-5}$ m/s^2 is needed according to Eq. (27). provided that Mg as a material is used, a value of (see Table 1) $I\ n = 1.3 \times 10^7$ is needed. If hydrogen was used, a magnetic induction of some 61 T would be needed, which hardly can be reached with present day technology.

3.5 Mission Analysis Results

From the numbers provided, it is clear that gravitophoton field propulsion, is far superior compared to chemical propulsion, or any other currently conceived propulsion system. For instance, an acceleration of 1g could be sustained during a *lunar mission*. For such a mission only the acceleration phase is needed. A launch from the surface of the earth is foreseen with a spacecraft of a mass of some 1.5×10^5 kg. With a magnetic induction of 20 T, compare Table 1 a rotational speed of the torus of $v^T = 10^3$ m/s, and a torus mass of 2×10^3 kg, an acceleration larger than 1g is produced and thus the first half of the distance, d_M, to the moon is covered in some 2 hours, which follows from $t = \sqrt{2 d_M / g}$, resulting in a total flight time of 4 hours. A *Mars mission*, under the same assumptions as a flight to the moon, would achieve a final velocity of $v = gt = 1.49 \times 10^6$ m/s. The total flight time to Mars with acceleration and deceleration is 3.4 days. Entering parallel space, a transition is possible at a speed of some 3×10^4 m/s that will be reached after approximately 1 hour at a constant acceleration of 1g. In parallel space the velocity increases to 0.4 c, reducing total flight time to some 2.5 hours [10-12].

4 CONCLUSION

In *GR* the geometrization of spacetime gives rise to gravitation. Einstein's geometrization principle was extended to construct a poly-metric that describes all known physical interactions and also predicts two additional like gravitational forces that may be both attractive and repulsive. In an extended unified theory based on the ideas of Heim four additional internal coordinates are introduced that affect events in our spacetime. Four subspaces can be discerned in this 8D world. From these four subspaces 12 partial metric tensors, termed hermetry forms, can be constructed that have direct physical meaning. Six of these hermetry forms are identified to be described by Lagrangian densities and represent fundamental physical interactions. The theory predicts the conversion of photons into gravitophotons, denoted as the fifth fundamental interaction. The sixth fundamental interaction allows the conversion of gravitophotons and gravitons (spacecraft) into the repulsive vacuum or quintessence particles. Because of their repulsive character, the gravitational potential of the spacecraft is being reduced, requiring either a reduction of the gravitational constant or a speed of light larger than the vacuum speed of light. Both possibilities must be ruled out if the predictions of *LQT* and Heim theory are accepted, concerning the existence of a minimal surface. That is, spacetime is a quantized (discrete) field and not continuous. A lower value of G or a higher value of c clearly violate the concept of minimal surface. Therefore, in order to resolve this contradiction, the existence of a parallel space is postulated in which covariant laws of physics hold, but fundamental constants are different, see Eq. (11). The conditions for a transition in such a parallel space are given in Eq. (12).

It is most interesting to see that the consequent geometrization of physics, as suggested by Einstein in 1950 [9] starting from GR and incorporating quantum theory along with the concept of spacetime as a quantized field as used by Heim and recently in *LQT*, leads to major changes in fundamental physics and would allow to construct a completely different space propulsion system.

Acknowledgments

The first author is grateful to M. Torrilhon, SAM, ETH Zurich, Switzerland for discussions concerning both the implementation of a numerically divergence free magnetic induction field and of boundary conditions. This work was partly funded by Arbeitsgruppe Innovative

Projekte (AGIP) and Ministry of Science, Hanover, Germany under Efre contract.

REFERENCES

[1] Zaehringer, A., *Rocket Science*, Apogee Books, 2004, Chap 7.

[2] Krauss, L.M., "Propellantless Propulsion: The Most Inefficient Way to Fly?", in M. Millis (ed.) *NASA Breakthrough Propulsion Physics Workshop Proceedings, NASA/CP-1999-208694*, January 1999.

[3] Rovelli, C., "Loop Quantum Gravity", *Physics World*, IoP, November 2003.

[4] Smolin, L., "Atoms of Space and Time", *Scientific American*, January 2004.

[5] Zwiebach, R., *Introduction to String Theory*, Cambridge Univ. Press, 2004.

[6] Lawrie, I. D., *A Unified Grand Tour of Theoretical Physics*, 2nd ed., IoP 2002.

[7] Penrose, R., *The Road to Reality*, *Chaps. 30-32*, Vintage, 2004.

[8] Heim, B., "Vorschlag eines Weges einer einheitlichen Beschreibung der Elementarteilchen", Z. für Naturforschung, 32a, 1977, pp. 233-243.

[9] Einstein, *On the Generalized Theory of Gravitation*, Scientific American, April 1950, Vol 182, NO.4.

[10] Dröscher, W., J. Hauser, AIAA 2004-3700, 40th AIAA/ASME/SAE/ASE, Joint Propulsion Conference & Exhibit, Ft. Lauderdale, FL, 7-10 July, 2004, 21 pp., see www.hpcc-space.com .

[11] Dröscher, W., J. Hauser, *Heim Quantum Theory for Space Propulsion Physics*, 2nd Symposium on New Frontiers and Future Concepts, STAIF, American Institute of Physics, CP 746, Ed. M.S. El-Genk 0-7354-0230-2/05, 12 pp. 1430-1441, www.hpcc-space.com .

[12] Dröscher, W., J. Hauser, AIAA 2005-4321, 41th AIAA/ASME/SAE/ASE, Joint Propulsion Conference & Exhibit, Tuscon, AZ, 7-10 July, 2005, 12pp., see www.hpcc-space.com .

[13] Hauser, J, W. Dai: Plasma Solver (PS-JUST) for Magnetohydrodynamic Flow-Java Ultra Simulator Technology, ESTEC/Contract no 18732/04/NL/DC, 2005.

[14] M. Torrilhon, "Locally Divergence-Preserving Upwind Finite Volume Schemes for Magnetohydrodynamic Equations", SIAM J. Sci. Comput. Vol. 26, No. 4, pp. 1166-1191, 2005.

Table 2: The hermetry forms for the six fundamental physical interactions.

Subspace	***Hermetry form Lagrange density***	***Messenger particle***	***Symmetry group***	***Physical interaction***
S^2	$H_1(S^2), L_G$	graviton	*U(1)*	gravity +
$S^2 \times I^2$	$H_5(S^2 \times I^2), L_{gp}$	$\underbrace{-\ neutral\ +}_{three\ types\ of\ gravitophotons}$	*U(1)*× *U(1)*	gravitation + − vacuum field
$S^2 \times I^2 \times \mathbb{R}^3$	$H_6(S^2 \times I^2 \times \mathbb{R}^3), L_{ew}$	Z^0 boson	*SU*(2)	electroweak
$S^2 \times I^2 \times T^1$	$H_7(S^2 \times I^2 \times T^1), L_{em}$	photon	*U(1)*	electromagnetic
$S^2 \times I^2 \times \mathbb{R}^3 \times T^1$	$H_8(S^2 \times I^2 \times \mathbb{R}^3 \times T^1)$	$W^{\pm}$ bosons	*SU*(2)	electroweak
$S^2 \times I^2 \times \mathbb{R}^3 \times T^1$	$H_9(I^2), L_q$	quintessence	*U(1)*	gravitation − vacuum field
	$H_{10}(I^2 \times \mathbb{R}^3), L_s$	gluons	*SU*(3)	strong