Reconsidering Gravity as Dynamic Phenomenon

Martin Mayer
ma.mayer.physics@outlook.com
Aichach, Germany
Rev 1.00, March 2025

Abstract

The purpose of this paper is to explore gravity as a dynamic phenomenon where the gravitational effects described by the Schwarzschild metric are transferred to changes in the quantities of time, length, velocity, acceleration, mass, energy and force. These changes are assumed to be physically real and not just a superficial effect of the used coordinate system. Subsequently, physics calculations can be done in classical orthogonal space using these malleable quantities even beyond the Newtonian regime, as gets demonstrated by applying them to the typical tests of general relativity. Moreover, the dynamic gravity notion gets corroborated by uncovering concealed connections between Newtonian gravity and the theory of general relativity, in particular gravitational potential energy is identified as an effect of changing mass energy. Thereafter a quantum gravity approach is put forward, as originally proposed by John A. Macken, which provides clues to how gravity can be expressed on the quantum level using a classical wave based approach. In that context the electrostatic force is also examined, since it exhibits an unexpected mathematical similarity to gravity. Finally, an inertial mass adjustment gets introduced that is caused by a cavity effect of excluded gravitational waves, which would break the equivalence principle if it turns out to be physically real.

Keywords: gravity; gravitational potential; space; general relativity; Schwarzschild metric; special relativity; time dilation; Planck units; Planck force; quantum physics; light speed; relativistic mass; refraction; waves; perihelion precession; light bending; redshift

1 Introduction

Ever since the theory of general relativity has been seemingly affirmed beyond doubt by experimental evidence, the notion that an unified as well as curved space-time is responsible for gravity is not questioned any more by most physicists, particularly since special relativity and classical Newtonian gravity can also be derived from the equations of general relativity as limiting cases. The general theory of relativity is certainly a useful tool that brought up new ideas about space, time and the evolution of our universe, but its suppositions are not proven irrefutably. For example, time is phenomenologically distinct from space and there is no good conceptual justification for treating time like an additional spatial dimension, except that it works out nicely mathematically. Moreover, experimental evidence for the physical reality of curved space is still sparse since proving it requires very sensitive experiments and therefore the main evidence for spacetime curvature still seems to be the perihelion precession of the planet Mercury which could not be explained satisfactorily before general relativity. There are, however, ways to explain the typical tests of general relativity, at least inside our solar system, in other ways as will be demonstrated later on. To achieve this it is necessary to derive dynamic quantities for time, length, velocity, energy and mass from the line element of the Schwarzschild metric, which is considered here to be applicable in general to static and spherically symmetric bodies, and not only to black holes. For those bodies the Schwarzschild radius is simply not reachable because it lies inside the object. Naturally, the question that follows from all this is what mechanism allows those malleable dynamic properties to arise? We definitely need to look for a framework that is already dynamical in nature and a wave based quantum gravity, which is embedded in some kind of medium that can also carry gravitational waves and light, might be what is needed. However, it should be emphasized that this paper does not disavow any physical effects predicted by general relativity theory. Before venturing deeper into this paper, though, it is sensible to first establish a few prerequisites.

2 Prerequisites

The Planck units are used extensively in the quantum gravity sections of this paper, in particular the Planck mass m_l, Planck length l_l and the Planck force $F_l = c^4/G$, which may also be called the super force. This is a term coined by Salvatore Pais that emphasizes the extreme strength of the Planck force. The definitions of the Planck units, as well as the values of the natural constants used in this paper, can be found in appendix A.

2.1 Relativistic particle energy

The total special relativistic energy for an object with rest mass m that possesses a velocity v can be stated as $E_\gamma = \sqrt{(mc^2)^2 + (\gamma mvc)^2}$, whereby the relativistic Lorentz factor is defined as $\gamma = 1/\sqrt{1 - v^2/c^2}$ and light speed is denoted as c. For spin ½ particles which possess a Compton wavelength $\lambda_c = h/(mc)$ it is also possible to define their total relativistic energy using their Compton wavelength and their de Broglie wavelength $\lambda_{dB} = h/(mv)$, but it is more sensible to use their frequency counterparts $f_c = c/\lambda_c$ as well as $f_{dB} = c/\lambda_{dB}$ and to combine those into a novel frequency $f_\gamma = \sqrt{f_c^2 + \gamma^2 {f_{dB}}^2}$, which I refer to as the Lorentz frequency, for describing total special relativistic energy, as originally shown in (1).

$$E_\gamma = h\sqrt{f_c^2 + \gamma^2 f_{dB}^2} = hf_\gamma \tag{2.1}$$

The last equation suggests that the special relativistic energy of a spin ½ particle is stored intrinsically to the particle, contrary to the currently prevalent opinion in physics. This assertion might also be related to the notion of Doppler shifted spherical waves, as proposed by John A. Macken (4)(5). Moreover, it is shown in (1), (3), (4) and (5) that spin ½ particles possess an equatorial perimeter speed of c, from which it follows that a spin ½ particle's relativistic radius is given by $r_\gamma = c/(2\pi f_\gamma)$ or that its size is at least proportional to that radius by a constant factor. This, in turn, leads to the controversial situation that electrons should be bigger than protons, a topic which is also discussed in the aforementioned papers. In case a spin ½ particle is at standstill r_γ equals the so called reduced Compton wavelength $\lambda_c/2\pi$, since its de Broglie frequency will be zero, and its Lorentz frequency f_γ simply equals its unchanging Compton frequency f_c. Moreover, spin ½ particles should exhibit a Lorentz frequency increase as they move faster since then their total relativistic energy E_γ is increasing, which in turn implies that they are shrinking as they move faster since their equatorial perimeter speed cannot exceed light speed c.

2.2 Properties of space

The energy density of space itself is given by

$$\rho_s = \frac{1}{2}\frac{m_l}{l_l^3} = 2.577\,59 \times 10^{96}\,\mathrm{kg/m^3} \tag{2.2}$$

as proposed in (1). This huge energy density is consistent with the so called zero point energy of quantum physics which presumably is caused by tiny Planck oscillators that space is comprised of. Subsequently, the "acoustic" impedance of space itself, in which gravitational waves are propagating with light speed c, evaluates to

$$Z_s = \rho_s\, c = \frac{c}{2}\frac{m_l}{l_l^3} = \frac{c^3}{2G\, l_l^2} = 7.727\,42 \times 10^{104}\,\mathrm{s\,Pa/m} \tag{2.3}$$

as originally shown in (2). Moreover, the impedance of space can also be specified without the Planck units, in which case it takes on the form $Z_s = 1/(2\hbar)\,(c^3/G)^2$. The gigantic value resulting from these formulas for Z_s implies that space has a huge stiffness, which is why even gravitational waves that were caused by black holes are barely detectable by highly sophisticated measurement equipment.

Physics literature usually denotes the impedance of space as c^3/G, for example in (11), which is also the expression that John Macken uses in his works (4)(5). This alternative expression for the impedance of space is equivalent to the one stated in equation 2.3 when using it in wave equations together with a dimensionless strain amplitude instead of an amplitude which is defined in an unit of length. In this paper, however, Z_s is always used as expressed in equation 2.3 so that an ordinary amplitude, specified in an unit of length, can be used for wave equations that involve Z_s.

Interestingly, the impedance of space can also be specified in terms of the Hubble mass m_H and Hubble radius r_H, i.e. $c^3/G \cong 2\,c\,m_H/r_H$ and $Z_s \cong 4\pi\,c^2\,m_H^2/(r_H^2\,h)$. Whether these relations are exact, or only approximate, remains to be seen. In any case, however, the various formulations for the impedance of space indicate that the microscopic quantum world, the macroscopic world as well as the cosmological world can be brought together through the impedance of space.

2.3 Scope

This paper operates within a space-time as described by the so called Schwarzschild metric, from a general relativity point of view, i.e. the gravitational effects of rotating masses are not covered. Consequently, the appropriate line element is associated with a non-rotating non-moving spherically symmetric homogenous and dominant central mass M which can be stated in polar coordinates as follows

$$\mathrm{d}s^2 = -\left(1 + \frac{2\Phi}{c^2}\right) c^2\mathrm{d}t^2 + \left(1 + \frac{2\Phi}{c^2}\right)^{-1} \mathrm{d}r^2 + r^2\mathrm{d}\Theta^2 + r^2\sin^2(\Theta)\,\mathrm{d}\phi^2 \tag{2.4}$$

whereby Φ denotes the classical Newtonian gravitational potential

$$\Phi = -GM/r \tag{2.5}$$

Using the following dimensionless factor to quantify gravitational effects

$$\Gamma = 1/\sqrt{1 - 2GM/(r\,c^2)} \tag{2.6}$$

the aforementioned line element can also be rewritten as follows

$$\mathrm{d}s^2 = -(1/\Gamma^2)\,c^2\mathrm{d}t^2 + \Gamma^2\mathrm{d}r^2 + r^2\mathrm{d}\Theta^2 + r^2\sin^2(\Theta)\,\mathrm{d}\phi^2 \tag{2.7}$$

whereby the factor Γ practically equals 1.0 far away from the central mass M and slowly increase in value towards that mass. In close vicinity to the Schwarzschild radius $r_s = 2GM/c^2$ associated with a mass M the value of Γ starts to increase faster until it finally reaches positive infinity at r_s. The region inside a black hole is not treated in this paper.

3 Dynamic gravitation

Using the aforementioned line element it is possible to explore how the quantities of frequency, time duration, energy, length, speed, acceleration, mass and force are changing inside the gravitational field of a mass M and to derive the appropriate scaling factors. This endeavour is motivated by the presumption that those changes are physically real, which in the case of gravitational time dilation is universally accepted by physicists and proven experimentally. Consequently, it is only logical to extend that notion to other physical quantities. Please note that in the following sections the subscript $_f$ always denotes a physical quantity infinitely far away from the gravitational field of M and the subscript $_\Gamma$ denotes a physical quantity within its gravitational field, whereby the mass M always denotes a non-rotating non-moving dominant spherical mass with a homogeneous density. Linear approximations are always preceded by a $\cong$ sign hereafter.

3.1 Time

As proven experimentally clocks run slower near a large mass than far away from it. The following table contains an example of this gravitational time dilation for an extreme black hole scenario with $\Gamma = 10$.

	Near	$\leftarrow$	Far
Frequency	$1\,\mathrm{Hz}$	$1/\Gamma$	$10\,\mathrm{Hz}$
Period	$1\,\mathrm{s}$	Γ	$0.1\,\mathrm{s}$

Table 1: Example with $\Gamma = 10$

This table shows that while a needle watch completes 10 turns far away from a black hole it only does complete 1 turn close to the black hole, as observed from far away, when $\Gamma = 10$. From this example we can infer that frequencies change as follows inside the gravitational field of a mass M:

$$f_\Gamma = f_f/\,\Gamma \cong \left(1 - \frac{GM}{r\,c^2}\right) f_f \tag{3.1}$$

Since a certain time period and its associated frequency are always inversely related a time duration Δt, like a full clock period, changes inside the gravitational field of a mass M according to:

$$\Delta t_\Gamma = \Delta t_f\,\Gamma \cong \left(1 + \frac{GM}{r\,c^2}\right) \Delta t_f \tag{3.2}$$

3.2 Energy

The factor Γ can also be formulated in terms of an escape velocity $s = \sqrt{2GM/r}$ as follows for a scenario with a central non-rotating non-moving homogeneous spherical mass M.

$$\Gamma = \frac{1}{\sqrt{1 - s^2/c^2}} \tag{3.3}$$

Interestingly, this equation looks very similar to the Lorentz factor γ, which is also used for special relativistic energy calculations.

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} \tag{3.4}$$

This congruence gives rise to the supposition that Γ should be relevant for describing the presumed change in the quantity of energy inside a gravitational field. Since energy terms of the form $E = hf$ are applicable to spin ½ particles as well as photons, and Planck's constant h is assumed to be independent of gravity, it can be inferred using equation 3.1 that energy must in general scale as follows inside a gravitational field:

$$E_\Gamma = E_f / \Gamma \cong \left(1 - \frac{GM}{r\,c^2}\right) E_f \tag{3.5}$$

Extending equation 2.1 in the same way the mass energy of a spin ½ particle can be expressed as follows,

$$E_\Gamma = hf_\gamma / \Gamma = h\sqrt{f_c^2 / \Gamma^2 + (\gamma^2/\Gamma^2) f_{dB}^2} = h\sqrt{(1 - s^2/c^2)\, f_\gamma^2} = hf_\Gamma \tag{3.6}$$

whereby f_γ, f_c and f_{dB} keep their respective meaning and are therefore defined in the absence of a gravitational field. A decreasing mass energy due to gravity seems to be concerning at first glance, but this change is assumed to be undetectable locally, as discussed later on, and moreover lost mass energy is accounted for by a changing gravitational potential energy, as shown in section 5.1.

3.3 Length

Since the scaling behaviour of length should be inverse to the scaling of a time duration, according to the line element described by equation 2.7, a reasonably small length element Δd should scale as follows inside the gravitational field of a mass M under consideration of equation 3.2.

$$\Delta d_\Gamma = \Delta d_f / \Gamma \cong \left(1 - \frac{GM}{r\,c^2}\right) \Delta d_f \tag{3.7}$$

This result implies that a ruler which had a length of $1\,\mathrm{m}$ outside of a gravitational field shrinks to $0.1\,\mathrm{m}$ at a location where $\Gamma = 10$, as observed from outside of the gravitational field. In this interpretation for the effect of gravity on length there is no need for a curved space and thus the three dimensions of space can be regarded as remaining orthogonal inside a gravitational field. Consequently, from the perspective of an object falling into a gravitational field it appears as if the whole universe is expanding.

3.4 Velocity

A velocity $v = \Lambda f$ can be calculated using a wavelength Λ, which qualifies as a length element, and a frequency f. Subsequently, considering equation 3.2 and 3.7 it can be said that any given velocity scales as follows in the gravitational field of a mass M when assuming no net acceleration influence due to gravity or other forces.

$$v_\Gamma = v_f \frac{1}{\Gamma}\frac{1}{\Gamma} = v_f / \Gamma^2 \cong \left(1 - \frac{2GM}{r\,c^2}\right) v_f \tag{3.8}$$

Since the Γ factors don't cancel out here a velocity which should be constant is effectively getting reduced inside a gravitational field, as observed from outside the gravitational field. This also implies that a moving object which gets very close to a black hole horizon is freezing in its motion, as observed from far away.

The scaling behaviour for velocity is universal and therefore also applies to light rays. Consequently, the scaling behaviour for the speed of light in a gravitational field of a mass M is described as follows, whereby the letter c, without any subscript, still denotes the usual constant speed of light to avoid confusion and to retain the common convention, but c now has to be defined in the absence of a gravitational field to be unambiguous, i.e. $c = c_f$.

$$c_\Gamma = c / \Gamma^2 \cong \left(1 - \frac{2GM}{r\,c^2}\right) c \tag{3.9}$$

Distances measured using light rays will thus change, i.e. they become shorter deeper inside a gravitational field, in accordance with the findings of the previous section. However, since measurement devices

themselves also experience changes in length and time inside a gravitational field it is not possible to measure the slowdown of light locally. For example, imagine a rocket flying at constant speed in a region of space with $\Gamma = 2$, for which special relativistic time dilation is negligible (i.e. $\gamma \cong 1$), to traverse a certain distance measured in meters that is established using a light ray that travels for a certain time duration. The rocket's velocity will be 1/4th compared to the speed it would have outside of the gravitational field, however, a clock inside the rocket is running at a halved rate, compared to outside the gravitational field, and the distance is also half as long comparatively. Thus these effects cancel out for an observer inside the rocket, which should also be the case locally for all other scaling behaviours caused by a gravitational field.
Whilst the slowdown in the speed of light is not measurable locally the bent trajectory of light as it passed by a mass is likely the result of a change in the speed of light. For this purpose the last equation can be easily reformulated into a refractive index n which can be used to calculate said light bending - see section 4.2 for more details.

$$n = \frac{c}{c_\Gamma} = \Gamma^2 \cong \left(1 + \frac{2GM}{r\,c^2}\right) \tag{3.10}$$

A higher refraction index n usually, but not always, denotes a denser medium and the linear approximation of n shows that the refractive index is increasing towards a gravitational source M. If this implies that the energy density of space is increasing towards a mass M is not clear yet and we should be careful to not take the optical analogy too far, as that might be misleading.

The knowledge about a changing speed of light now allows to consider what happens to the size of a spin ½ particle, whose radius inside a gravitational field, as observed from outside of it, must be given by $r_\Gamma = c_\Gamma/(2\pi f_\Gamma)$, which is a logical extension of the special relativistic radius $r_\gamma = c/(2\pi f_\gamma)$. Consequently, the size of a spin ½ particle also scales like a length element as specified by equation 3.7, i.e. it shrinks as observed from outside of the gravitational field it is in.

3.5 Mass

Since mass can be stated as $m = E/c^2$ the scaling behaviour for a mass m inside the gravitational field of a mass M is given as follows under consideration of equation 3.5 as well as 3.9.

$$m_\Gamma = m_f\,\frac{1}{\Gamma}\frac{\Gamma^4}{1} = m_f\,\Gamma^3 \cong \left(1 + \frac{3GM}{r\,c^2}\right)m_f \tag{3.11}$$

Thus objects effectively gain mass as they move deeper into a gravitational field, as observed from outside of the gravitational field.

3.6 Local force

Since Force can be stated as $F = E/\,\Delta d$ the scaling behaviour for a Force F inside the gravitational field of a mass M is given as follows under consideration of equation 3.5 as well as 3.7.

$$F_\Gamma = F_f\,\frac{1}{\Gamma}\frac{\Gamma}{1} = F_f \tag{3.12}$$

Interestingly, force is an unchanging quantity, whereas even energy is changing within a gravitational field. For example, when a space probe is leaving the gravitational field of a planet by using a chemical thruster that can only operate with an unchanging chemical reaction the force of that thruster will remain constant during the space probe's journey, as observed locally as well as from outside of the gravitational field.

However, there is something strange going on with the Newtonian gravitational force $F_g = G\,m_1\,m_2/r^2$, which seems to violate the independence from Γ for a force. This issue can be understood by realizing that the Newtonian gravitational force is calculated with values for the involved masses, and the separation between them, as if they were not affected by a gravitational field so that $\Gamma = 1$ for all involved variables.
Imagining that m_1 and m_2 are located inside an external gravitational field caused by another dominant mass M, whose gravitational field is approximately uniform for m_1 and m_2, they would be affected by the same factor Γ which might deviate noticeably from one. Subsequently m_1, m_2 and r need to be multiplied with this factor Γ to the appropriate power for incorporating the gravitational effect of M. However, the gravitational constant G appears to be an emergent constant which is comprised of the squared speed of light and a kind of (inverse) mass density that is defined by the mass contained in a sphere with a certain radius (2), i.e. $G \cong c^2\,r_H/(2\,m_H)$ whereby r_H is the radius of the observable universe and m_H is its mass. This suggests that for the given scenario G also has to be corrected, whereby a scaling factor of $1/\Gamma^8$ seems to be appropriate. Subsequently, in this example scenario all Γ contributions cancel out so that the gravitational force between m_1 and m_2 is unchanging if r were held constant as the two masses move through the external gravitational field. This scenario is what, for gravity, comes closest to the unchanging force notion which was derived from equation 3.12.

For the special case of m_1 being a central spherical dominant mass M, like in the Schwarzschild metric, a more precise description of the gravitational force acting on m_2 can be achieved by treating m_2 as a variable mass while keeping all other variables unaffected by gravity. In that scenario the resulting gravitational force is not unchanging anymore with respect to Γ and this circumstance is the key to explain Mercury's perihelion precession accurately, as shown in section 4.3.
More complicated cases would require more scrutiny because gravity actually involves two different Γ factors, one caused by m_1 and one caused by m_2. Therefore also the distance r is not identical, from the point of view of a mass m_1 and m_2. Moreover, the same asymmetry issue presumably even applies to G. Subsequently, the Newtonian formulation for the gravitational force might not be suited for being developed into an accurate description for the gravitational attraction between two bodies since it is not clear if and how Newton's third law can be retained.

3.7 Acceleration

Since acceleration can be stated as $a = F/m$ the scaling behaviour for an acceleration a inside the gravitational field of a mass M is given as follows under consideration of equation 3.11 as well as 3.12 when assuming no net jerk influence due to changing gravity or other changing forces.

$$a_\Gamma = a_f/\Gamma^3 \cong \left(1 - \frac{3GM}{r\,c^2}\right) a_f \tag{3.13}$$

This equation, together with the gravitational scaling of mass, implies that objects get more inert as they go deeper into a gravitational field, as observed from outside of the gravitational field.

3.8 Alternative to Γ

Kris Krogh devised an alternative for Γ which uses Euler's number and also applies to a non-rotating non-moving dominant homogeneous spherical mass M (8).

$$\text{exp}\left(\frac{GM}{r\,c^2}\right) = \text{exp}\left(\frac{-\Phi}{c^2}\right) \cong \Gamma \tag{3.14}$$

This alternative to Γ might turn out to be interesting for further research on gravity, as its approximation differs from the approximation of Γ for powers of r beyond one.

4 Tests

4.1 Redshift & blueshift

The gravitational change of a length segment as specified in equation 3.7 matches with the equation for gravitational redshift, i.e.

$$z + 1 = \frac{\lambda_f}{\lambda_\Gamma} = \Gamma \tag{4.1}$$

whereby $\lambda_\Gamma = \Delta d_\Gamma$ denotes the wavelength as sent out by an emission source inside a gravitational field and $\lambda_f = \Delta d_f$ denotes the wavelength received far away from that gravitational field. A photon moving out of a gravitational field will thus obtain a longer wavelength during its journey, i.e. it will redshift.

4.2 Light deflection

The refraction index n can also be calculated by considering the motion of a light ray in a gravitational field by using the line element as specified in equation 2.4 or 2.7 to describe that motion. To simplify the calculation a straight motion can be chosen with an angle Θ such that $\sin^2(\Theta)$ is zero and $\mathrm{d}\phi = 0$, i.e. a radial movement with $\Theta = 0°$. Moreover, considering that for a light ray $\mathrm{d}s^2 = 0$ and using velocity $v = \mathrm{d}r/\mathrm{d}t$ the line element can be reshaped into a refractive index n. Due to the spherical symmetry of the Schwarzschild metric the obtained result must hold true everywhere outside of the Schwarzschild radius associated with a mass M.

$$\begin{aligned} \left(1 + \frac{2\Phi}{c^2}\right) c^2 \mathrm{d}t^2 &= \left(1 + \frac{2\Phi}{c^2}\right)^{-1} \mathrm{d}r^2 \\ \left(1 + \frac{2\Phi}{c^2}\right)^2 c^2 &= \frac{\mathrm{d}r^2}{\mathrm{d}t^2} \\ n = \frac{c}{v} &= 1 \Big/ \left(1 - \frac{2GM}{r\,c^2}\right) = \Gamma^2 \end{aligned} \tag{4.2}$$

This result matches exactly with equation 3.10, which means that the Schwarzschild metric can be regarded as a description of an optical medium with a changing refractive index n and therefore any gravitational light bending calculation based on the refractive index n has to produce results that are equivalent to other calculation approaches which use the framework of general relativity theory. Calculations using the refractive index n thus have to result in the typical gravitational light bending angle θ for light rays moving past a non-rotating stationary homogeneous spherical mass M at a distance r, which is given by the following equation.

$$\theta = \frac{4GM}{r\,c^2} \tag{4.3}$$

The refractive index n was first used by Robert Dicke to correctly calculate the deflection angle for light passing by our sun (6). This is a topic that is covered extensively by Alexander Unzicker, for example in (9). There Unzicker explains that Albert Einstein also attempted to use a refraction index to calculate the amount of light deflection around our sun before he developed his theory of general relativity (12). Einstein's result using a refraction index was exactly half of the correct value that he predicted later on by using general relativity, which was because Einstein only took light's gravitational frequency change into consideration but missed the change in wavelength. Thus his expression for the reduced speed of light in a gravitational field was slightly off, i.e. $[1 - GM/(r\,c^2)]\,c$. Today, however, it is pretty much forgotten that Einstein was taking the notion of a variable speed of light due to gravity very seriously. There are also lots of other papers available which calculate the refractive index using general relativity, but these derivations are usually more complicated than the derivation done here in equation 4.2 and their respective authors are usually not willing to interpret the refraction index as evidence for space being a physical medium with substance to it.

4.3 Perihelion precession

The precession of Mercury's perihelion stands as one of the most significant tests of Einstein's general theory of relativity. While that theory explains an otherwise unexplained amount of Mercury's perihelion precession through space-time curvature, an alternative mathematical approach is presented in this section which achieves the same prediction by incorporating the notion of a variable mass in the function for the gravitational potential energy between our sun and Mercury.

The relevant properties and definitions used for Mercury's perihelion precession calculation are as follows:
Distance between our sun and Mercury: r
Mass of our sun: $M = 1.988\,841\,6 \times 10^{30}\,\mathrm{kg}$
Mass of Mercury: $m = 3.30 \times 10^{23}\,\mathrm{kg}$
Eccentricity factor of Mercury: $e = 0.20563069$
Semi-major axis of Mercury: $a = 0,387$ au $= 5.789 \times 10^{10}\,\mathrm{m}$
Mercury's number of orbits per century: $N_m = 365.25/88.00 \times 100 = 415.057$
Conversion factor for radians to arcseconds: $rad2arcs = 206\,265\,''/\mathrm{rad}$
Please note that in this section the letter e is used to denote eccentricity instead of fundamental charge, to comply with the common notation for calculating elliptic orbits.

Since Mercury moves in a plane, and thus $\dot{\theta} = 0$, its kinetic energy T is given by

$$T = m(\dot{r}^2 + r^2\dot{\phi}^2)/2 \tag{4.4}$$

in polar coordinates. Its gravitational potential energy V with respect to our sun and is given by

$$V = -GM\Gamma^3 m/r \tag{4.5}$$

when also considering a variable mass $\Gamma^3 m$ for Mercury. Using these last two expressions the Lagrangian $L = T - V$ can be obtained.

$$L = m(\dot{r}^2 + r^2\dot{\phi}^2)/2 + GMm\Gamma^3/r \tag{4.6}$$

Applying the Euler-Lagrange equations to it we get the following equation,

$$\begin{aligned} \frac{\mathrm{d}}{\mathrm{d}t}\frac{\partial L}{\partial \dot{\phi}} &= \frac{\partial L}{\partial \phi} \\ \frac{\mathrm{d}}{\mathrm{d}t}\left(mr^2\dot{\phi}\right) &= 0 \end{aligned} \tag{4.7}$$

which means that the angular momentum of Mercury is constant because the product of these variables doesn't change with time, and another equation for Mercury's radial motion

$$\begin{aligned}
\frac{\mathrm{d}}{\mathrm{d}t}\frac{\partial L}{\partial \dot{r}} &= \frac{\partial L}{\partial r} \\
\frac{\mathrm{d}}{\mathrm{d}t}\left(m\dot{r}\right) &= \frac{\partial}{\partial r}\left(mr^2\dot{\phi}^2/2 + GMm\Gamma^3/r\right) \\
\frac{\mathrm{d}}{\mathrm{d}t}\left(\dot{r}\right) &= \frac{\partial}{\partial r}\left(r^2\dot{\phi}^2/2 + \frac{GM}{r}\left[1 + \frac{3GM}{rc^2}\right]\right) \\
\ddot{r} &= \frac{\partial}{\partial r}\left(r^2\dot{\phi}^2/2 + \frac{GM}{r} + \frac{3G^2M^2}{r^2c^2}\right) \\
\ddot{r} &= r\dot{\phi}^2 - \frac{GM}{r^2} - \frac{6G^2M^2}{r^3c^2}
\end{aligned} \tag{4.8}$$

which is an equation of motion extended by an additional 3rd term with a $1/r^3$ dependency compared to the classical Newtonian case. Hereafter it is shown that this additional term is explaining the perihelion precession of Mercury.

Using $u = 1/r$, Kepler's second law in the form of $r^2\dot{\phi} = h$ and $\mathrm{d}/\mathrm{d}t = \dot{\phi}(\mathrm{d}/\mathrm{d}\phi) = hu^2(\mathrm{d}/\mathrm{d}\phi)$ it is possible to obtain a standard differential equation from equation 4.8.

$$\begin{aligned}
-h^2u^2(\mathrm{d}^2u/\mathrm{d}\phi^2) &= h^2u^3 - GMu^2 - 6G^2M^2u^3/c^2 \\
-u^2(\mathrm{d}^2u/\mathrm{d}\phi^2) &= u^3 - GMu^2/h^2 - 6G^2M^2u^3/(h^2c^2) \\
(\mathrm{d}^2u/\mathrm{d}\phi^2) + u &= GM/h^2 + 6G^2M^2u/(h^2c^2) \\
(\mathrm{d}^2u/\mathrm{d}\phi^2) + [1 - 6G^2M^2/(h^2c^2)]u &= GM/h^2
\end{aligned} \tag{4.9}$$

Using the relationship $h^2 = GMa(1-e^2)$ for elliptical orbits the last equation can be reformulated as follows:

$$\frac{\mathrm{d}^2u}{\mathrm{d}\phi^2} + \left(1 - \frac{6GM}{c^2a(1-e^2)}\right)u = \frac{GM}{h^2} \tag{4.10}$$

This is a standard differential equation of the form $u'' + k^2u = C$ where $k = \sqrt{1 - 6GM/[c^2a(1-e^2)]}$. The general solution for equation 4.10 is given by

$$u(\phi) = A\cos(k\phi + \sigma) + \frac{C}{k^2} \tag{4.11}$$

and Mercury must thus advance by $2\pi/k$ to complete one orbit. Since $1/k$ can be approximated as follows

$$1/k \cong 1 + \frac{3GM}{c^2a(1-e^2)} \tag{4.12}$$

the perihelion precession of Mercury per orbit is given by

$$\Delta\phi = 2\pi/k - 2\pi \cong \frac{6\pi GM}{c^2a(1-e^2)} \tag{4.13}$$

which, when expressed in arcseconds per century, evaluates to

$$\Delta\phi \times N_m \times rad2arcs = 42.98''/\text{ century} \tag{4.14}$$

This result matches perfectly with the one obtained by doing a perihelion precession calculation for Mercury using the framework of general relativity. It should also be emphasized that the calculation carried out here did not require the concept of space curvature.

Special relativistic contributions were not included in the calculation done here, since they would cancel out in the equation of motion 4.8 anyways together with Mercury's mass m. However, the same argument could be made about the Γ^3 factor for Mercury's mass m which was only applied in V but not in T and there needs to be a reason for this unequal treatment. Since T as well as V denote energies they both are subject to the same $1/\Gamma$ factor which would also cancel out in equation 4.8 and therefore that factor wasn't needed in equation 4.4 and 4.5. This omitted $1/\Gamma$ factor already accounted for all of the gravitational influence on the individual variables in T due to the gravity of the mass M, but in the case of V it cannot because the gravitational potential energy formula involves different locations in the overall gravitational field. Judging from the final result the next best approximation seems to be to also incorporate a variable mass for Mercury's mass m in V besides the omitted $1/\Gamma$ factor. In plain words: the quantity of energy is changing with the distance of Mercury from our sun but still the amount of gravitational potential energy between our sun and Mercury requires considering a variable mass m. The influence on our sun's mass M by the gravitational field of Mercury can be neglected in V since our sun's gravitational field is by far the dominant factor here.

5 Newtonian gravity reexamined

5.1 Gravitational potential energy

The following equation states the gravitational potential energy that is released when a test mass $m_t = 1.000\,\mathrm{kg}$ is moved inside the gravitational field of earth, with $m_E = 5.972 \times 10^{24}\,\mathrm{kg}$ being the mass of earth and $r_{near} = 6371\,\mathrm{km}$ being the radius of earth, from a position $r_{far} = r_{near} + 10.000\,\mathrm{km}$ to the surface of the earth.

$$\Delta E = \frac{-G\,m_E\,m_t}{r_{far}} - \frac{-G\,m_E\,m_t}{r_{near}} = \left(\frac{1}{r_{near}} - \frac{1}{r_{far}}\right) G\,m_E\,m_t = 98.043\,\mathrm{kJ} \tag{5.1}$$

So roughly 100 kilojoules of energy are released according to Newtonian gravity as the test mass is moved to a lower gravitational potential, i.e. the surface of earth. To make the connection to general relativity the last equation can also be written as follows:

$$\Delta E = \left[\frac{G\,m_E}{r_{near}\,c^2} - \frac{G\,m_E}{r_{far}\,c^2}\right] m_t\,c^2 = \left[\left(1 - \frac{G\,m_E}{r_{far}\,c^2}\right) - \left(1 - \frac{G\,m_E}{r_{near}\,c^2}\right)\right] m_t\,c^2 \tag{5.2}$$

Using the following linear approximation

$$1/\Gamma = \sqrt{1 - 2GM/(r\,c^2)} \cong 1 - GM/(r\,c^2) \tag{5.3}$$

it is possible to rewrite ΔE as

$$\Delta E = \left[\frac{1}{\Gamma_{far}} - \frac{1}{\Gamma_{near}}\right] m_t\,c^2 = 98.046\,\mathrm{kJ} \tag{5.4}$$

whereby Γ_{near} denotes Γ for $r = r_{near}$ with $M = m_E$ and Γ_{far} denotes Γ for $r = r_{far}$ with $M = m_E$. It can be seen that the results of equation 5.2 and 5.4 are quite close and they get even closer for larger separation distances. Moreover, the results also get closer when treating m_t as a variable mass in the Newtonian calculation, as it was done for the mass of Mercury in section 4.3. The remaining deviation between the result of equation 5.1 and 5.4 is presumably largely due to the linear approximation in equation 5.3.

The calculation presented in this section is based upon a related example in John A. Macken's work where he claims that time dilation is responsible for the gravitational potential energy (4), which can be said rightfully so since frequency f as well as energy E both scale with $1/\Gamma$ and they are directly related via $E = hf$. This effectively means that when a spin ½ particle is moving towards the earth's surface it looses mass energy, due to the reduction in its frequency f_Γ, and since this change in its mass energy is not directly detectable locally that change is accounted for as a lowered gravitational potential energy in classical physics calculations. In case that this particle is in free fall its lost mass energy will be converted to kinetic energy and thus the overall energy remains conserved. This notion also provides a simple explanation for the origin of gravitational potential energy which cannot be accounted for satisfactorily in Newtonian physics otherwise, because contrary to electric fields the potential energy here is not linked to an energy in the field.

5.2 Normalized potential gradient

Another fascinating example from John A. Macken shows that Newtonian gravity calculations contain concealed gradient calculations, akin to the maths of space curvature. For a similar example we consider the gravitational force between earth's mass $m_1 = m_E$ and a proton with mass $m_2 = 1.672\,62 \times 10^{-27}\,\mathrm{kg}$ at a distance r_{far}, which is given by:

$$-G\frac{m_1\,m_2}{r_{far}^{\;2}} = -2.487 \times 10^{-27}\,\mathrm{N} \tag{5.5}$$

The minus sign here just explicitly indicates that the force is attractive. Next it will be shown that the same force can be calculated with a totally different approach. However, the alternative approach requires at least one spin ½ particle and thus the alternative approach cannot be applied to arbitrary situations without some tweaks.

A classical gravitational potential at r can be normalized by dividing it through $-c^2$ since $-c^2$ is the presumed gravitational potential limit in our universe (2). Macken called such a normalized gravitational potential the gravitational magnitude ß which can be written in the following ways for a mass M and a distance r.

$$ß = -\Phi/c^2 = \frac{GM}{r\,c^2} \cong \Gamma - 1 \tag{5.6}$$

This dimensionless parameter will always have a value between 0 and 1. Calculating it for our example situation with $M = m_1$ and $r = r_{far}$ gives the following concrete value:

$$ß_1 = \frac{G\,m_1}{r_{far}} \times \frac{1}{c^2} = 2.709 \times 10^{-10} \tag{5.7}$$

It is also possible to calculate how the gravitational magnitude changes at r, which is simply the gradient of the gravitational magnitude ß at r. The gravitational magnitude has a $1/r$ factor in it whose derivative with respect to r is simply $-1/r^2$ and therefore $\mathrm{d}ß/\mathrm{d}r = -ß/r = -GM/(r^2c^2)$. In our example this evaluates to:

$$\mathrm{d}ß_1/\mathrm{d}r = -ß_1/r_{far} = -1.655 \times 10^{-17}/\,\mathrm{m} \tag{5.8}$$

Using this gradient it can be estimated by how much the gravitational magnitude $ß_1$, which is caused by the earth's gravitational field in our example, is changing over the confines of our example proton. As already mentioned in section 2.1 the reduced Compton wavelength $r_c = \lambda_c/2\pi$ is used as a measure of a spin ½ particle's size in this paper. More correctly r_c describes half of its size, since it denotes a radius, but incidentally this is the appropriate measure for the calculation in this section. The change in the gravitational magnitude at a distance r caused by a mass m_j over the confines of a spin ½ particle's mass m_k can then in general be approximated as follows whereby r_{ck} denotes the reduced Compton wavelength of the mass m_k.

$$\Delta ß_j = -\frac{G\,m_j}{r^2\,c^2} \times r_{ck} \tag{5.9}$$

The reduced Compton wavelength of a proton is $2.1031 \times 10^{-16}\,\mathrm{m}$ and therefore in our example with $j = 1$ and $k = 2$ the approximate gravitational magnitude change caused by m_1 at $r = r_{far}$ over the size r_{c2} of the mass m_2 is given by:

$$\Delta ß_1 = -ß_1/r_{far} \times r_{c2} = -3.500 \times 10^{-33} \tag{5.10}$$

The force that keeps a spin ½ particle together can be estimated by multiplying its mass with its centripetal acceleration, whereby its centripetal acceleration is assumed to arise from an equatorial perimeter rotation which occurs at light speed c. For a proton, which in our example is associated with mass m_2, this approach gives the following force:

$$F_{s2} = m_2 \times c^2/r_{c2} = c\hbar/{r_{c2}}^2 = 7.148 \times 10^5\,\mathrm{N} \tag{5.11}$$

In case of a proton the strength of this force closely matches with the expected strength of the strong force, which is why the subscript letter s was used to refer to this force. Moreover, as discussed in (1) and (3) the strong force seems to be the near field behaviour of gravity and therefore it makes sense that this force appears in the calculations done here.

Finally, multiplying F_{s2} with $\Delta ß_1$ results in the gravitational force of equation 5.5, whereby this match is symbolically, and not just numerically, since the involved terms cancel out in exactly the right way.

$$F_{s2} \times \Delta ß_1 = -2.487 \times 10^{-27}\,\mathrm{N} \tag{5.12}$$

Macken compares this congruence with a mirror effect, i.e. a spin ½ particle experiences a physically real change in its surrounding space which leads to a kind of reflection, comparable to incoming light being partially reflected by a mirror that it encounters. The strength of the reflection by a ½ particle seemingly depends on the force that holds the affected particle together and the gravitational magnitude change over the particle's size. However, the problem with the mirror analogy is that it suggests a repulsive force.

Macken also suggested that $\Delta ß$ quantifies a change in the rate of time, i.e. masses move towards regions with slower time and indeed in our example $\Delta ß$ is approximately equal to the difference of two approximated $1/\Gamma$ factors, i.e. $[1 - Gm_1/((r_{far} + r_{c2})\,c^2)] - [1 - Gm_1/(r_{far}\,c^2)] \cong \Delta ß_1$ (note: the small value of r_{c2} and the relatively large value of r_{far} can lead to precision problems with the used calculation software). Since $E = hf$ this can be rephrased as masses moving towards states of lower energy, which is a common scheme in physics and in accordance with the findings of section 3.2 and 5.1. Admittedly, this line of thought is not elaborated enough yet to quality as a satisfactory explanation for the attractive nature of gravity in the presented model.

6 Quantum forces

The previous sections were portraying a very dynamic behaviour of physical quantities in a gravitational field and the question that follows from this is what mechanism could provide such dynamics? Curved space-time, as envisioned by general relativity theory, does not seem to fit, or at least it does not yet provide a mechanism to explain the presented couplings. One viable candidate could be a wave based quantum gravity approach as proposed by John A. Macken in (5)(4), whose fundamentals will be presented and assessed in the following sections. Macken uses two main starting points in his works, one is an analogy of matter to light waves trapped between two mirrors and the other is the equation for the intensity of a planar gravitational wave. It should be noted, though, that some of Macken's claims differ from what was presented here before, in particular the scaling factors for the various physical quantities due to gravity, but that does not invalidate what gets presented from his work hereafter.

The starting point for examining quantum gravity in this paper is also the equation for the intensity of a planar gravitational wave as derived from general relativity theory, which can be defined as follows

$$I_{gw} = \frac{1}{8\pi}\, l_l^2 \left(\frac{\Delta L}{L}\right)^2 \omega^2\, Z_s \tag{6.1}$$

whereby ω is the angular frequency of the gravitational wave and the term $\Delta L/L$ is a dimensionless factor that accounts for the stretching of space due to a gravitational wave. Here L denotes a reference length transverse to the wave's propagation direction and ΔL refers to the change of that length due to the wave. The usual formulation for the intensity of gravitational waves does not contain an explicit amplitude, since the impedance term c^3/G, that is appropriate for strain amplitudes, is normally used (11) instead of the unacquainted "acoustic" gravitational impedance Z_s. As shown in the upcoming sections gravity might be transmitted by a sea of "background" waves whose natural amplitude is the Planck length l_l. Therefore, equation 6.1 contains the Planck length l_l as the unstretched amplitude and the effective amplitude is thus given by $l_l\,(\Delta L/L)$. Another small difference to the usual equation for the intensity of a planar gravitational wave is the proportionality constant, which here is $1/8\pi$ instead of $1/16\pi$, in order to yield identical results between the different formulations.

6.1 Strong force

Previously, in equation 5.11 a force was calculated which presumably holds the proton together. The used formula can be generalized to a strong force F_s for spin ½ particles which possess a Compton wavelength λ_c. This force can be written in the following ways:

$$F_s = m^2 c^3/\hbar = m \times c^2/r_c = G m_l^2/r_c^2 = e^2/(4\pi\epsilon_0 \alpha r_c^2) = c\hbar/r_c^2 \tag{6.2}$$

Interestingly, one variant involves the Planck mass m_l, but the meaning of this occurrence is not the focus here. The relationship between a spin ½ particle's mass m and its radius r_c is given by

$$r_c = c/(2\pi f_c) = \lambda_c/2\pi = \hbar/(mc) \tag{6.3}$$

whereby the relativistic cases, and their relation to frequency, were already stated before, i.e. $r_\gamma = c/(2\pi f_\gamma)$ and $r_\Gamma = c/(2\pi f_\Gamma)$. Doing a simple comparison of forces reveals that F_s matches quite closely with the nuclear strong force for the proton and neutron, since F_s is approximately 10^{38} times stronger than Newtonian gravity. For example, a calculation for the proton, with m_p being the proton's mass and r_{cp} being the proton's radius, yields

$$\frac{G m_l^2}{{r_{cp}}^2} \bigg/ \frac{G m_p^2}{{r_{cp}}^2} = \frac{m_l^2}{m_p^2} = 1.69 \times 10^{38} \tag{6.4}$$

Thus F_s really deserves its name and this result even indicates that the strong force is the near field behaviour of gravity when a particle's rotational effects on space are included too (1). Another calculation reveals that using the Planck length l_l as radius r_c the strong force F_s evaluates to the gigantic Planck force $F_l = c\hbar/l_l^2 = c^4/G = 1.21 \times 10^{44}\,\mathrm{N}$, which will play an important role in the upcoming sections and which the physicist Salvatore Pais calls the super force. For reasons touched upon in appendix B the Planck force can also be regarded as the primordial force or pristine force of our universe.

Analogous to the equation for the intensity of a planar gravitational wave the Planck force can be defined as the force caused by a planar wave with Amplitude $A_o = l_l$, a proportionality constant $k_s = 1$, an angular frequency $\omega = \omega_l = c/l_l = 1/t_l$, which is the inverse of the Planck time t_l, and the "acoustic" impedance of space Z_s (equation 2.3). Additionally, the propagation velocity v of the wave in space is assumed to be light speed c and the relevant cross section is assumed to be $A = 2l_l^2$, due to reasons presented in (1) where a possible geometric structure of space was discussed. This then leads to the following force equation:

$$F_l = k_s\, A_o^2\, \omega^2\, Z_s\, A/\, v = l_l^2\, \omega_l^2\, \frac{c^3}{2G\, l_l^2}\, (2l_l^2)/\, c = c^4/G \tag{6.5}$$

It is assumed here that the last equation describes the base layer of space, i.e. that space is composed of tiny oscillators which are also responsible for the so called zero point energy of quantum physics. Moreover, these oscillators are assumed to form standing waves in the observable universe.
Curiously, spin ½ particles also seem to be able to emit similar waves since using $\omega = \omega_c = 2\pi f_c$ and $A = 2r_c^2$ also produces the Planck force, as shown in the following equation:

$$F_l = l_l^2\, \omega_c^2\, \frac{c^3}{2G\, l_l^2}\, (2r_c^2)/\, c = c^4/G \tag{6.6}$$

The amplitude is again l_l, but the frequency and the relevant cross section have changed compared to equation 6.5. Subsequently, due to the much lower angular frequency the intensity of waves emitted by spin ½ particles must be much lower than the intensity associated with the proposed fundamental oscillators, which makes sense. The next section will show how the waves described by equation 6.5 and 6.6 are related to gravity as we observe it, as a continuation of the groundwork that has been laid out here.

Equation 6.1 could also be relevant for the waves associated with the proposed fundamental oscillators, but in that case $\Delta L/L$ is not applicable and must therefore be set to 1. Using that stipulation the modified planar wave intensity $I_m = l_l^2\,\omega^2\,Z_s/\,8\pi$ and the Planck force F_l can be related for the relevant cross section area $2l_l^2$ by $I_m \times 2l_l^2/c = F_l/(8\pi) = 1/\kappa$, whereat the symbol κ denotes the Einstein constant $8\pi G/c^4$ which is a conversion factor between space curvature and energy density in the Einstein field equations of general relativity theory. This correlations show that general relativity theory can be connected to the quantum wave model introduced here on at least one level, which provides some first credence to the chosen approach.

6.2 Gravitational force

The starting point point for this section is the classical Newtonian gravity as stated hereafter for two masses m_1 and m_2 at some distance r. The minus sign again denotes the attractive nature of the gravitational force.

$$F_g = -G\frac{m_1 m_2}{r^2} \tag{6.7}$$

Intriguingly, this equation can be formulated in terms of the Planck force F_l in the following way for spin ½ particles.

$$F_g = -F_l\frac{F_{s1}}{F_l}\frac{F_{s2}}{F_l}\frac{1}{r/r_{c1}}\frac{1}{r/r_{c2}} \tag{6.8}$$

Here F_{sn} means F_s for $m = m_n$ and r_{cn} refers to the reduced Compton wavelength r_c of the mass m_n , whereby n is 1 or 2. This equation offers a number of interesting insights into classical Newtonian gravity:

- The reference quantity for the gravitational force is the Planck force F_l
- There is a deeper connection connection between the gravitational force and the strong force.
- The contribution to the gravitational force caused by each of the involved masses, i.e. F_{s1}/F_l and F_{s2}/F_l, is also relative to the Planck force F_l.
- When explicitly stating these force contributions, like it was done in equation 6.8, the strength of the gravitational force does not simply scale with $1/r^2$ anymore, instead it scales inversely with distance measured in multiples of the reduced Compton wavelength of the involved particles, denoted by r_{c1} and r_{c2}, i.e. $1/(r/r_{c1})$ and $1/(r/r_{c2})$.
- Using the same notation as in equation 5.9 it can be inferred for the special case of two spin ½ particles that the change of gravitational magnitude is given by

$$\Delta ß_j = -F_{sj}\,r_{cj}\,r_{ck}/(F_l\,r^2) = -\frac{r_{ck}}{r_{cj}}\,\frac{1}{r^2/l_l^2} = -\frac{m_j}{m_k}\frac{1}{r^2/l_l^2} \tag{6.9}$$

  such that $F_g = F_{sk} \times \Delta ß_j$. Surprisingly, the equation for $\Delta ß_j$ has become pretty simple, especially if the two involved particles are of the same type.

Equipped with that knowledge, and that of the previous section, it is now sensible to switch over to Macken's equations for the gravitational force.

Macken uses a particular notation which utilizes the following two dimensionless factors:

$$A_ß = \frac{1}{r_c/\,l_l} = \sqrt{\frac{F_s}{F_l}} \tag{6.10}$$

$$N = \frac{r}{r_c} \tag{6.11}$$

N obviously quantifies a distance r in terms of multiples of the measure for a particle radius, i.e. the reduced Compton wavelength r_c. $A_ß$ quantifies the relative size of a fundamental Planck oscillator compared to a spin ½ particle, which incidentally is also is a measure for the relative strength of F_s and F_l. Macken's work features different equations for expressing Newtonian gravitational force, whereby the most encompassing and understandable one is the following equation

$$F_g = -\left[\frac{A_{ß1}^2}{N_1}\frac{A_{ß2}^2}{N_2}\right]F_l \tag{6.12}$$

which is structurally comparable to equation 6.8. Here $A_{ßn}$ means $A_ß$ for $r_c = r_{cn}$ and N_n means N for $r_c = r_{cn}$, whereby n is again 1 or 2. Macken claims that the squared $A_ß$ terms are indicative of gravity being a second order effect of the waves emitted by spin ½ particles, inspired by the fact that the upcoming equation 6.19 features a lower power for $A_ß$ - a notion which cannot be judged finally from what was presented so far.

Equation 6.12 is an intriguing way to state the gravitational force, but to get a better understanding of what it might mean physically the terms have to be expanded. Expanding only the F_l part first gives two possible variants:

$$F_g = -\left[\frac{A_{ß1}^2}{N_1}\frac{A_{ß2}^2}{N_2}\right] l_l^2\,\omega_l^2 \frac{c^3}{2G\,l_l^2}(2l_l^2)\frac{1}{c} \tag{6.13}$$

$$F_g = -\left[\frac{A_{ß1}^2}{N_1}\frac{A_{ß2}^2}{N_2}\right] l_l^2\,(\omega_{c1}\,\omega_{c2})\frac{c^3}{2G\,l_l^2}(2\,r_{c1}\,r_{c2})\frac{1}{c} \tag{6.14}$$

Of these two variants equation 6.14 should be the relevant one, since it is highly unlikely that spin ½ particles can emit waves with a frequency of ω_l. Doing an expansion of equation 6.14 gives the following two sensible equations:

$$F_g = -l_l^2\,(\omega_{c1}\,\omega_{c2})\frac{c^3}{2G\,l_l^2}\left[2\frac{1}{r/l_l^2}\frac{1}{r/l_l^2}\right]\frac{1}{c} \tag{6.15}$$

$$F_g = -l_l^2\left(\frac{\omega_{c1}\,\omega_{c2}}{\omega_l}\right)^2\frac{c^3}{2G\,l_l^2}\left[2\frac{r_{c1}}{r/l_l}\frac{r_{c2}}{r/l_l}\right]\frac{1}{c} \tag{6.16}$$

Which of these two equations is the physically relevant one is something that is not fully clear yet. Presumably it is equation 6.16, which incidentally seems to be absent from Macken's work, since its cross section term still contains r_{c1} and r_{c2}. The effective angular frequency of that equation is given by $\omega = \omega_{c1}\,\omega_{c2}/\,\omega_l$. The rather clumsy term $2\ r_{c1}/(r/l_l)\ r_{c2}/(r/l_l) = 2\,r_{c1}\,r_{c2}\,(r/l_l)^{-2}$ likely denotes the reduction of the effective cross sectional area due to the separation between the two objects in gravitational attraction, which is likely describing a loss of intensity since the described wave, or the waves, dissipate with increasing distance d as they spread out over an increasing spherical area. The wave's amplitude and frequency are seemingly unchanged as the wave spreads.

Section 5.2 was exploring how the gravitational magnitude ß changes over the size of a particle, whereby this change is presumably related to a change in the experienced time of the affected particle. The following equation shows several ways to calculate this value using the wave equations that were presented before.

$$\Delta ß_j = \frac{F_g}{F_{sk}} = F_g\frac{c}{\hbar\,\omega_{ck}^2} = -l_l^2\,\frac{\omega_{cj}}{\omega_{ck}}\frac{c^3}{2G\,l_l^2}\left[2\frac{1}{r/l_l^2}\frac{1}{r/l_l^2}\right]\frac{1}{\hbar} = -l_l^2\,\frac{\omega_{cj}^2}{\omega_l^2}\frac{c^3}{2G\,l_l^2}\left[2\frac{r_{cj}}{r/l_l}\frac{r_{ck}}{r/l_l}\right]\frac{1}{\hbar} = -\frac{\omega_{cj}}{\omega_{ck}}\frac{1}{r^2/l_l^2} \tag{6.17}$$

These alternative formulations for $\Delta ß_j$ suggest that a wave based gravity could somehow be causal for gravitational time dilation. Moreover, the term $-(\omega_{cj}/\omega_{ck})\,(l_l^2/r^2)$ suggests that the Newtonian approximation of gravity is applicable as long as each particle's angular Compton frequency ω_c is not affected too much by gravitational time dilation.

In case you want to compare Macken's work with this work it should be noted again that Macken's equations are slightly different since he uses a strain amplitude instead of an explicit amplitude of one Plank length. The equations in question, the ones presented in this paper which explicitly feature the "acoustic" impedance of space Z_s, can be made comparable easily, though, by cancelling out a factor of $2l_l^2$ from the respective equation. This notice also applies to the next section.

6.3 Electric force

To properly classify Macken's equations it is insightful to also look at the classical electric force F_e between two fundamental charges e, which may have different polarity, separated by a distance r.

$$F_e = \pm\frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2} = \pm\frac{\alpha}{4\pi\epsilon_0}\frac{q_l^2}{r^2} \tag{6.18}$$

In his work Macken shows that the electric force can also be formulated in a way that is surprisingly similar to equation 6.12 (4)(5). It is necessary, though, to also insert the Sommerfeld constant α to get the correct calculation results. Macken presents different variants for the electric force in his work, like in the case of gravity, whereby the most encompassing and understandable equation is the following one.

$$F_e = \pm\alpha\left[\frac{A_{ß1}}{N_1}\frac{A_{ß2}}{N_2}\right]F_l \tag{6.19}$$

The last equation is applicable to charged spin ½ particles with a Compton wavelength λ_c, i.e. the proton, electron, positron and muon. Doing some rearrangements the last equation can also be brought into a form that is similar to equation 6.8.

$$F_e = \pm\alpha F_l\sqrt{\frac{F_{s1}}{F_l}}\sqrt{\frac{F_{s2}}{F_l}}\frac{1}{r/r_{c1}}\frac{1}{r/r_{c2}} \tag{6.20}$$

The similarities of the previous two equations to equation 6.12 and 6.8 are highly puzzling as there is no justification in contemporary physics why these similarities should exist. This in turn indicates that the gravitational force as well as the electric force are manifestations of the same underlying phenomenon, which arguably has a wave like nature. Admittedly, equation 6.19 and 6.20 cannot explain the attractive and repulsive effect that electric charges can have, but still the revealed similarities are remarkable. Please also note that the square root of a value smaller than one actually is greater than this value, e.g. $\sqrt{0.5} \cong 0.7071$, which is why in the end the electric force as stated in equation 6.20 is stronger than the gravitational force as stated in equation 6.8 for a comparable situation.

Again, like done for gravity beforehand, there are two ways to expand F_l. Doing that expansions for equation 6.19 results in

$$F_e = \pm\alpha \left[\frac{A_{ß1}}{N_1}\frac{A_{ß2}}{N_2}\right] l_l^2\, \omega_l^2\, \frac{c^3}{2G\, l_l^2}(2l_l^2)\frac{1}{c} \tag{6.21}$$

$$F_e = \pm\alpha \left[\frac{A_{ß1}}{N_1}\frac{A_{ß2}}{N_2}\right] l_l^2\, (\omega_{c1}\,\omega_{c2})\frac{c^3}{2G\, l_l^2}(2\, r_{c1}\, r_{c2})\frac{1}{c} \tag{6.22}$$

whereby equation 6.22 seems to be the physically relevant one as spin ½ particles are presumably not able to emit waves with an angular frequency ω_l. Doing a full expansion for F_e using equation 6.19 gives only one sensible equation since the $A_ß$ terms are to the power of one and subsequently the radius r_c in N and $A_ß$ cancels out.

$$F_e = \pm\alpha\, l_l^2\, (\omega_{c1}\,\omega_{c2})\frac{c^3}{2G\, l_l^2}\left[2\frac{r_{c1}}{r/l_l}\frac{r_{c2}}{r/l_l}\right]\frac{1}{c} \tag{6.23}$$

The last equation is seemingly absent from Macken's work, like equation 6.16.

What was shown so far suggests that the electric force as well as the gravitational force are both wave phenomena, but there must be some telling distinctions in their equations to explain their different behaviour and strength. Comparing equation 6.16 and 6.23 reveals such a difference: in equation 6.16 the resulting angular frequency is always positive, whereas in equation 6.23 a negative overall frequency term is theoretically possible when assuming that ω_c can have positive and negative values. Subsequently, equation 6.23 is able to describe attractive as well as repulsive behaviour, as expected from the electric force.

In Macken's formulation of the gravitational and electric force the primary cause for the difference in their respective strength are the powers of the $A_ß$ terms. As already said previously, Macken therefore claims that the gravitational force is some kind of second order wave effect. If that really can be concluded from the distinct powers of $A_ß$ is not a simple question. Please see Macken's work (4) for more information on that topic. What can be inferred from the presented material, though, is that the strength difference between the electric and gravitational force depends on how the size of a spin ½ particle is associated with the respective force, i.e. when considering equation 6.10 gravity depends on $1/(r_c^2/l_l^2)$ and the electric force depends on $1/(r_c/l_l)$, which in turn suggests that the electric force is inversely proportional to the circumference of a spin ½ particle and gravity is inversely proportional to its surface area. This difference could be a clue for how these two forces operate physically and what makes them different, in case the second order wave effect notion is discarded. In my own previous work I assumed that the fundamental oscillators come in two species (1)(3), which may or may not fit with what was presented here for the electric force. However, this assumption could provide a way to establish different modes of operation and explain what a negative frequency means in the context of a spin ½ particle. Physically seen, positive and negative frequencies could be related to a rotation handedness of spin ½ particles.

The mysterious presence of the Sommerfeld constant α in the electric force equations could have a similar role like it has for hydrogen, where the electron's equatorial perimeter velocity is reduced from a value of c, for a free electron, to αc, as it wraps itself around a proton (1)(3). In the presented equations for the electric force the Sommerfeld constant α can also be applied to a velocity by reducing the angular frequency of a spin ½ particle from $\omega_c = c/r_c$ to $\sqrt{\alpha}\,\omega_c = \sqrt{\alpha}\,c/r_c$, so that the centripetal force of a spin ½ particle and an imaginary electric force for two fundamental charges would be in balance at a particle's radius r_c, i.e. $\alpha F_s = m\,(\sqrt{\alpha}\,c)^2/r_c = e^2/(4\pi\epsilon_0 r_c^2)$, which likely is no coincidence and reminiscent of the situation with hydrogen. Expressing the reduced speed explicitly gives the following equation for the electric force:

$$F_e = \pm\, l_l^2 \left[\frac{c\sqrt{\alpha}}{r_{c1}}\frac{c\sqrt{\alpha}}{r_{c2}}\right]\frac{c^3}{2G\, l_l^2}\left[2\frac{r_{c1}}{r/l_l}\frac{r_{c2}}{r/l_l}\right]\frac{1}{c} \tag{6.24}$$

The physical reason for this frequency reduction may be that the super fast rotation of a spin ½ particle distorts the space around it which subsequently somehow shields the real electric charge from a far away observer in exactly the right amount to achieve the mentioned force equilibrium, for reasons not yet fully understood.

In the case of gravity there seems to be a similar situation: in close vicinity to a spin ½ particle its unshielded mass, which presumably takes into account additional rotational energy, apparently corresponds to the

Planck mass m_l instead of what we consider to be the respective particle mass (see equation 6.4), a circumstance that contemporary physics seemingly interprets as the nuclear strong force to explain what holds a fundamental particle together while assuming a much lower mass than m_l. The shielded mass mass hypothesis is also hinted at by the puzzling mass energy relation $mc^2 = Gm_l^2/r_c$.
Alternatively, the electric charge on the surface of a spin ½ particle might move slower than the overall particle which presumably has a rotation speed of c at its equatorial perimeter, i.e. the electric current lags behind somehow. In any case, the Sommerfeld constant α seems to arise from equilibrium situations, which would explain why this constant exists and what it really means - a topic that is still disputed.

6.4 Inertial mass correction

Phenomena which so far could not be explained by the theory of general relativity, like the rotation speed of galaxies and dark energy, might be explained by changing inertia, as Michael McCulloch advocates for in his works. His approach is also suggesting a wave phenomenon behind these mysterious gravitational anomalies that, according to McCulloch, arise because there is a limit for gravitational wavelength between a mass in space and the cosmic horizon, which in turn has some effects on inertial mass and gravity.

According to McCulloch there is an upper limit to the wavelength between an accelerated object and the horizon of the observable universe, which is given by $2c^2/a$ for an acceleration a. This wavelength limit might be the lowest possible harmonic of the gravitational waves which were proposed before. As a consequence, as McCulloch claims, inertial mass must be modified and the equivalence principle $m_i = m_g$ for the inertial mass m_i and gravitational mass m_g of an object gets violated. The inertial mass correction factor, that I denote here as η, is stated in (10) as

$$\eta = \left(1 - \frac{2c^2}{a\,d}\right) \tag{6.25}$$

whereby d is the distance between a cavity's confines, or strictly speaking two times half of it, which in the absence of an artificial cavity is twice the Hubble radius, i.e. $d = 2c/H_0$. This correction factor is usually irrelevant since it is extremely close to 1, but it becomes relevant as it goes lower for artificial cavities, like two closely placed parallel metal plates, and ultra low accelerations, like at the edges of a spiral galaxy. Moreover, an interesting net effect of the inertial mass correction is that gravitational attraction should exhibit a residual acceleration of $2c^2/d = 2c^2/(2c/H_0) = cH_0 \cong 7.2 \times 10^{-10}\,\mathrm{m/s^2}$, using a Hubble radius of $1.25 \times 10^{-26}\,\mathrm{m}$, as shown in chapter 7.1 of (10).

7 Discussion

Several Γ based factors were provided in section 3 that quantified how various physical quantities scale inside a gravitational field compared to being so far away from the gravitational field that its effects are negligible. The presented supplementary linear approximations of these scaling factors were also obtained by Dehnen, Hönl and Westpfahl in (7) and by Krogh in (8), for those relations that were derived by them using different approaches than the one applied here. Clearly, these agreements support the scaling factors put forward in this paper. Macken, however, derived different factors in his work (4) which presumably should not be able to correctly quantify gravitational light bending and planetary perihelion precession.
The presented scaling factors should work quite well even for stronger gravitational fields, when the respective Γ factor is utilized instead of the associated linear approximation. In case the gravitational field becomes so strong that its influence on Γ even varies over a fundamental particle's confines, the presented scaling factors become inappropriate. That situation should be rather unattainable, though, since it was shown in section 3.2 that gravity actually shrinks fundamental particles so that they become substantially smaller in a strong gravitational field.
What wasn't considered in this paper are the effects that a rotating mass has on space and gravity, in theory, though, it should also be possible to describe these effects using classical physics equations.

As it was already mentioned in section 3.4, the propagation speed of light is claimed to slow down slightly near a substantial mass but a local observer would not be able to measure that effect since any measurement device used is affected too by gravity. This clandestine behaviour of light in general relativity also highlights questions about the validity of special relativity, which too has some inherent undercover issues that are usually brushed aside. Special relativistic time dilation, for example, may actually result from a Doppler effect in a medium which constitutes a unique absolute reference frame that is obscured by the circumstance that we can't measure the one way speed of light. This inability is not merely a technical issue, but a conceptual problem for which no conceptual solution has been found so far. Moreover, special relativity rests on the unproven arbitrary claim that the proper length of an object is measured in any inertial frame, but the measurement of proper length may be reserved for the already mentioned unique absolute reference frame. Special relativistic space-time, i.e. Minkowski space-time, may thus not be physically real, which in turn indicates that curved space-time might not be physically real too, since Minkowski space-time is a special case of it. Intelligible video lectures on the issues with the theory of special relativity can be found on the YouTube channel dialectphilosophy.

One of the main questions addressed in this paper was if space curvature can be avoided in calculations, as curved space might not be physically real. Arguably, this paper showed that calculations can be made without using the concept of space curvature which yield the same results like a full treatment with the framework of general relativity theory. In addition to these calculations a number of other arguments can be brought forward against the existence of space curvature.

- The Schwarzschild radius can be calculated using classical Newtonian escape velocity when also assuming an universal speed limit c, i.e. $c = \sqrt{2GM/r}$ gives the Schwarzschild radius when rearranging for radius r. This is a smoking gun that is hard to dismiss on technical grounds.
- If gravity really means that an object in free fall just follows its geodesic equation, then obstructing that object in its path should eliminate the gravitational effect on it, because there should be no force or pressure that pushes it against the obstruction. Since this is not the case gravity has to be a force, despite what is universally proclaimed nowadays.
- Why and how exactly mass bends space is an unresolved mystery. General relativity theory is incomplete regarding that subject.
- Shrinking particles are conceptually equal to proper volume decreasing inside a gravitational field, which provides an alternative notion for proper volume that does not require curved space.
- The theory of general relativity does not explain the gravitational constant G itself, which may be an emergent constant since it seemingly can be explained in terms of all the masses present in our observable universe (2).
- The observable universe turns out to be a black hole, or at least it is close to being one, when calculating the mass of the observable universe using ordinary Cartesian space and the observed average energy density (2). The fact that we do not observe strong space curvature in our vicinity thus speaks against the notion of a curved space.
- A refractive index for space, which implies a variable speed of light, can be used to explain gravitational light bending and refraction usually implies a physical medium with changing properties.
- The so called Shapiro delay can also be calculated using a refractive index for space, since it has the same causes as gravitational light bending.
- The perihelion precession of planets can be explained as an effect of variable mass alone, as shown in section 4.3. Thus one of the strongest experimental evidence for curved space has an alternative explanation.
- A number of gravitational effects only require gravitational time dilation to be explained, like the gravitational redshift of light and GPS time delay. These effects therefore don't provide support for the notion of a bent space since time dilation can exist independent of curved space.
- The rotation curves of spiral galaxies, and other anomalies, indicate that something is not right with the framework of general relativity theory. The issue at hand might not be to find dark matter or dark energy, but a systemic problem with general relativity theory itself.
- The similarity between Macken's wave equations for classical Newtonian gravity and the electric force are indicating a wave based medium of space.
- Newtonian gravity can be obtained for the surface of a Schwarzschild black hole using the Bekenstein-Hawking entropy, the Unruh temperature and the equipartition theorem (1), as originally shown by Eric Verlinde using a model of a holographic and entropic gravity.
- The equivalence principle, which general relativity rests on, may not hold true in all situations, as discussed in section 6.4.
- There seems to be a link between the strong force and gravity. A side effect of this is that the proton's true mass appears to be the Planck mass m_l from the perspective of classical Newtonian gravity.
- The incompatibility of contemporary quantum physics with general relativity theory may indicate that bent space is not a sensible physical concept.

That list can probably be prolonged, which supports the idea that it is sensible to question the underlying assumptions of general relativity theory and to explore how the gravitational effects derived from general relativity theory can be described without having to assume space curvature or a unified space-time.

Unbeknownst to many people Einstein did not dismiss the notion of an aether, even after introducing general relativity. In a talk that he gave at the university of Leiden in 1920 Einstein focused on the history of the notion of an aether. During the final remarks of that talk he said that special relativity even demands the existence of an aether to enable the existence of light clocks and rulers. General relativity, according to Einstein himself, can also be interpreted as describing an aether. Einstein back then only insisted on the limitation that an aether must not be composed of flowing corpuscles, like it was common with the notions of an aether at that time. The wave based quantum gravity concept presented in this paper fulfils this requirement since the proposed gravity waves are not producing a overall net flow of the medium of space, the idea is rather that of a modulation of the aether's standing wave.

In this paper spin ½ particles are considered to be dynamic self sustaining entities made of space, or made of the substance of space itself, instead of them being something that is merely positioned in space and fundamentally different in its essence from space (1)(3)(4)(5). This notion was not discussed in this paper, as it was not the focus here. However, this unified view on particles and space should fit nicely with the notion of dynamically changing physical properties inside what is commonly called a gravitational field as there must be an immediate relation between particles and space to enable such dynamics. How that mechanism works exactly, and what really constitutes time, is not clear yet, though.

In case space is filled with oscillators and/or waves, as it was discussed in this paper, space is inherently energetic and subsequently it also makes sense to assume that some kind of gravitational temperature exists. Such a measure already exists for the horizon of Schwarzschild black holes in the form of the Hawking temperature and interestingly it is possible to extend that notion to spin ½ particles and gravitational fields, as already discussed in (1) and (3).

8 Conclusions

From what was presented in this paper it can be concluded that it is possible to find an alternative formulation for gravity that does not require a curved space-time by transferring the effects that general relativity describes into the physical quantities of time, length, energy, mass, etc. Subsequently, these quantities become relative in the sense that they are dependent on a position in a gravitational field. It was shown that for a local observer inside a weak gravitational field the shifts in the physical quantities mostly remain clandestine and the physical laws stay invariant. The aforementioned gravitational shifts only become readily apparent when physical processes take place over larger distances or in the vicinity of massive objects, like with the gravitational redshift of light and gravitational time dilation. One local manifestation, though, is the gravitational potential energy that was shown to be an effect of variable mass - something Newtonian physics lacked a concrete physical mechanism before. The gravitational effects of rotating masses were not considered in this paper, but it should also be possible to find classical descriptions for them. The dynamic notion of gravity which was presented in this paper ultimately calls for a dynamic foundation to provide the required variability in the various physical quantities, which might be realizable through the presented wave based quantum gravity, and it indicates the comeback of some kind of aether which can be the substrate for microscopic quantum effects and ordinary macroscopic effects as well as cosmological effects.

For convenience the Γ scaling factors which were derived in this paper for various physical quantities are summarized in the table below.

Quantity	Near ← Far	Approximation
Force (local)	1	1
Time period	Γ	$1 + 1GM/(rc^2)$
Frequency	$1/\Gamma$	$1 - 1GM/(rc^2)$
Energy	$1/\Gamma$	$1 - 1GM/(rc^2)$
Length element	$1/\Gamma$	$1 - 1GM/(rc^2)$
Velocity	$1/\Gamma^2$	$1 - 2GM/(rc^2)$
Acceleration	$1/\Gamma^3$	$1 - 3GM/(rc^2)$
Mass	Γ^3	$1 + 3GM/(rc^2)$

Table 2: Scaling factors

Since the effect of gravity on time is physically real the other gravitational effects must also be physically real.

Appendix A Natural Constants

A.1 Classical expressions

Light speed	$c = 2.9979 \times 10^8\,\mathrm{m/s}$
Planck constant	$h = 2\pi\hbar = 6.6261 \times 10^8\,\mathrm{J/Hz}$
Gravitational constant	$G = 6.6743 \times 10^{-11}\,\mathrm{m^3/(s^2\,kg)}$
Electric field constant	$\epsilon_0 = 8.8542 \times 10^{-12}\,\mathrm{F/m}$
Magnetic field constant	$\mu_0 = 1.2567 \times 10^{-6}\,\mathrm{mT\,/A}$
Fundamental charge	$e = 1.6022 \times 10^{-19}\,\mathrm{C}$
Sommerfeld constant	$\alpha = e^2/(2ch\epsilon_0) \cong 1/137$
Magnetic flux quantum	$\phi_e = h/2e$
Planck length	$l_l = \sqrt{\hbar/c} \times \sqrt{G/c^2} = \sqrt{\hbar\, G/c^3} = 1.6162 \times 10^{-35}\,\mathrm{m}$
Planck mass	$m_l = \sqrt{\hbar/c} \times \sqrt{c^2/G} = \sqrt{\hbar\, c/G} = 21.765\,\mathrm{\mu g}$
Planck time	$t_l = \sqrt{\hbar/c} \times \sqrt{G/c^2} \times \sqrt{1/c^2} = \sqrt{\hbar\, G/c^5} = l_l/c = 5.3912 \times 10^{-44}\,\mathrm{s}$
Planck charge	$\pm q_l = \pm e/\sqrt{\alpha} = \pm 1.876 \times 10^{-18}\,\mathrm{C}$
Planck force	$F_l = c^4/\,G = 1.21 \times 10^{44}\,\mathrm{N}$

A.2 Expressed using the Planck force

Gravitational constant	$G = F_l\, l_l^2/m_l^2$
Electric field constant	$\epsilon_0 = F_l/(4\pi\alpha)\; e^2/l_l^2 = F_l/4\pi\; q_l^2/l_l^2$
Magnetic field constant	$\mu_0 = 4\pi\alpha/F_l\; l_l^2/(e^2c^2) = 4\pi/F_l\; l_l^2/(q_l^2c^2)$

A.3 Expressed as emergent properties

A.3.1 Expressed in base units of quantized spacetime

Light speed	$c = l_l/t_l$
Gravitational constant	$G = c^2\, l_l/m_l$
Sommerfeld constant	$\alpha = e^2/q_l^2$
Electric field constant	$\epsilon_0 = e^2/(2\alpha ch) = q_l^2/(2ch)$
Magnetic field constant	$\mu_0 = 2\alpha h/(e^2c) = 2h/(q_l^2c)$
Planck force	$F_l = c\hbar/l_l^2$

A.3.2 Expressed using cosmological values

Hubble constant	$H_0 \cong 74.3\,\mathrm{km/s/Mpc}$
Hubble radius	$r_H = c/H_0 \cong 1.25 \times 10^{26}\,\mathrm{m}$
Hubble mass	$m_H \cong 8.4 \times 10^{52}\,\mathrm{kg}$
Gravitational constant	$G \cong (c^2/2)\; r_H/m_H$ (note: effectively this is a rearranged Schwarzschild mass equation)
Planck length	$l_l \cong \sqrt{\hbar/c} \times \sqrt{r_H/(2m_H)}$
Planck mass	$m_l \cong \sqrt{\hbar/c} \times \sqrt{(2m_H)/r_H}$
Planck time	$t_l \cong \sqrt{\hbar/c} \times \sqrt{r_H/(2m_H)}\;/\;c$

Appendix B Forces in terms of the Planck force

The main four fundamental forces reveal the following pattern when expressed in terms of the Planck force F_l, aka the super force, for the special case of two spin ½ particles.

Force	Formula
Strong	$F_l\ l_l^2/d^2$
Electric	$\alpha F_l\ l_l^2/d^2$
Magnetic	$\alpha F_l\ l_l^2/d^2\ v_1 v_2/c^2$
Gravitational	$F_l\ l_l^2/d^2\ m_1 m_2/m_l^2$

Table 3: Forces of spin ½ particles

The following notes apply to this table:

- The Planck force seems to be the reference for the main four fundamental forces and to be the strongest possible force. This gives rise to the speculation that the Planck force was the first force in our universe from which the other forces descended in some way.
- The depicted formula for the strong force is an approximation that is applicable in close vicinity to a proton or neutron. Equation 6.2 denoted the special case of $d = r_c$. The strong force may exist for electrons too, but due to a substantially different particle size its effect seems to be practically irrelevant for electrons.
- The relevance of the Sommerfeld constant α for electromagnetism is immediately obvious.
- The stated formulas for the electric and magnetic force do not apply to neutrons.
- The stated magnetic force is for the special case of two fundamental charges e moving in parallel to each other, whereby the sine term of any involved cross product evaluates to 1.
- Distance d counts in multiples of the Planck length l_l, i.e. $1/(d/l_l)$. This circumstance supports the notion that the Planck length is the smallest possible length in our universe.

Appendix C Newtonian gravity in terms of escape speed

Newtons gravitational force $F_g = GM_1M_2/r^2$ for two homogeneous spherical masses M with a distance r between their centres can also be expressed in terms of escape velocity $s = \sqrt{2GM/r}$.

$$F_g = \frac{1}{4} F_l \frac{s_1^2}{c^2} \frac{s_2^2}{c^2} \tag{C.1}$$

This equation highlights the following points:

- Light speed c is the velocity limit in our universe, since s/c normalizes s with respect to c.
- The Newtonian gravitational force can never reach the Planck force F_l because of the factor $1/4$. A gravitational force stronger than $F_l/4$ requires additional gravitational effects not taken into account by Newtonian gravity, like a (rapidly) rotating mass.
- The term s^2/c^2 can be seen as a comparison of gravitational potentials, because the units for squared velocity and a gravitational potential are equal, i.e. m²/s² = J/kg.
- Subsequently, the gravitational potential limit in our universe is given by $-c^2$, as described in more detail in (2).
- The repeated division by c^2 makes it immediately obvious why the gravitational force is relatively weak when used in scenarios which don't involve black holes.

In case that space is interpreted as a flowing medium with actual currents, as some aether theories propose, the escape velocity s should denote the flow of that medium towards gravitational sources, which makes sense since this is the velocity that an object would need to overcome to fully leave the region of influence of a gravitational source. Moreover, a flowing medium could also account for the meaning of Δß as presented in section 5.2. For rotating masses the escape speed should be greater than the static case described by the presented formula for s.

Acknowledgments

The development of this paper has been greatly aided by Andrey Ivashov's SMath Studio (https://smath.com) and Wolfram Alpha's online computation facility (https://www.wolframalpha.com/input).

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