Gravitation as a Secondary Effect of Electromagnetic Interaction

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It has been invested so much vain effort into the unification of gravity and quantum physics, that meanwhile it does not seem to be fallacious any more to estimate the so far pursued way as dead end. Therefore I resume an old approach and start from the precondition, that gravitation can be understood as a secondary effect of electromagnetic interaction. The unification of the forces thus is a prerequisite. Based on that the four classical tests of General Relativity Theory including the shift of Mercury's perihelion can be reproduced. Mach's principle harmonically fits into the presented model. The covariance principle is renounced.

Contents

1 Light in the Gravitational Potential

Einstein himself tried to extend his Special Relativity Theory with the assumption of a variable speed of light in a paper of 1911 [7] to describe the effects of gravitation in this way. His starting point is the principle of equivalence. It says that a uniformly accelerated reference system is equal to a system that rests within a field of gravitation of equal gravitational acceleration. This shall be valid for all physical properties without exception. From that Einstein deduces the deviation of clocks and the red-shift in the gravitational field. He had not done the transition to the geometric interpretation of gravitation in the form of the curved space-time at that time yet. And so he stays for now at the flat Minkowski-space of Special Relativity and he assumes a reduced velocity of light in the gravitational field. His calculation for the deviation of a light beam grazing the surface of the sun by 0.83 arc seconds delivers a value that will be proved to be wrong by a factor of 2. The reason for that is that he silently assumes the spherical potential of the sun to be spatially homogeneous and so he does not respect the curvature of space and the contraction of the wavelength of light respectively. So the preconditions for the correct calculation are not given. But from the wrong result just it does not follow that the access of a variable speed of light is wrong in a fundamental way. Only Einstein's knowledge of gravitation was not matured enough at that time. We take this approach again and try to get a consistent description of gravitation with light along this very path.

We consider a laboratory in space that is freely falling directly towards the sun. An experimenter in the laboratory is directing a laser beam backward from the sun to an opposite receiver. The transmitter laser and the receiver may be positioned fix in the space laboratory. Because there is zero gravity in the laboratory there don't arise gravitational effects (in first order) for the observer. He is measuring the same frequency that is specified on the type label of the laser at the sender side as at the receiver also. He compares the frequency with his atomic clock and doesn't state any deviation. Also he verifies the wavelength of the laser beam with his high precision scale of length and gets the same result.

In the laboratory a second observer shall be, who wants to find out how the gravitation of the sun does affect light. He knows about the acceleration of the lab connected with the gravitational force. Because the receiver is accelerated during the run-time of the light beam in direction of the transmitter, he estimates a blue-shift and a reduction of the wavelength respectively for a measurement located at the receiver due to the Doppler-shift acting on frequency and wavelength. The observer concludes the gravitational field must have exactly the opposite effect to cancel out both, because the experimenter is not able to measure such a Doppler-shift.

We assume without loss of generality that the laboratory and so also the transmitter is at rest at $t = 0$. The receiver though is accelerated during the run-time of the light beam through the lab over the distance h for the time $t = \frac{h}{c}$ to the velocity $v = \frac{gh}{c}$. It should occur a blue-shift of the frequency ω_R, measured at the receiver with respect to ω_T, measured at the transmitter. The potential ϕ within the space-lab can be assumed as homogeneous because the extension of the laboratory compared to the variation of the attracting force in the potential of the sun is small.

$$\frac{\omega_R}{\omega_T} = 1 + \frac{v}{c} = 1 + \frac{gh}{c^2} = 1 + \frac{\phi}{c^2} \quad \text{, with} \quad \phi = gh \ll c^2. \tag{1}$$

So the observer concludes that the frequency of the laser beam is red-shifted for the same amount when leaving the gravitational field. Equitably he states that clocks are running slower by this factor in a gravitational field (at the transmitter).

The same consideration he makes for the wavelengths λ. Because the receiver is accelerated against the sender, he expects a contracted wavelength at the receiver. The observer concludes that the wavelength of the laser beam (in each case measured locally) is stretched for the same amount when leaving the gravitational field.

$$\frac{\lambda_R}{\lambda_T} = 1 + \frac{v}{c} = 1 + \frac{gh}{c^2} = 1 + \frac{\phi}{c^2} \tag{2}$$

thus wavelengths are shorter in a gravitational field.

If now the laboratory is hold in levitation by a rocket drive or is standing onto a planet surface then the compensating Doppler-shift of the acceleration is not there any more. Now a local measurement at the transmitter still delivers the type plate values of the laser frequency and wavelength. But the frequency is reduced at the receiver if locally measured and the wavelength is elongated. Therefore the locally measured velocity of light is unchanged. However the conclusion that the speed of light is a global constant is not yet mandatory.

A laser itself is an excellent time and length scale. For that reason the official definition of time- and length-scales is based on the frequency of an atomic transition of cesium and the distance that light covers in a certain time interval. If we take a laser as reference scale for the measurement of the local speed of light, we must keep in mind that its frequency and wavelength is underlying the same gravitational changes as the laser beam through the lab. Therefore a local measurement of the velocity of light always shows the constant value c, even if the speed of light should vary spatially or temporally. The supposed prove of the universal constancy of the speed of light by means of a local measurement represents a circular argument.

Within these considerations we assume that space-time is flat and time- and length-scales change *indeed*. And we assume that the velocity of light is variable. In opposite to it General Relativity Theory assumes that clocks, length-scales and the speed of light are unchanged, but the curved space-time makes sure that times and lengths seem to be modified. But this is more a question of view than of being. Because both definitions are describing the same observations, they can be counted as equivalent. We are keeping more with a physical view as represented by the variable speed of light because there is a better possibility for energetic considerations. The geometrical representation of the curved space-time more is a mathematical description of an underlying physics. But about this physics in the strict sense nothing is declared.

Now we take the location of the receiver as fixed point of view. He measures a slowed frequency in our thought experiment. Because the potential is temporally constant, he concludes that the light beam was emitted already with the lower frequency. He knows that clocks run slower at the transmitter than his own clocks and the wavelength at the transmitter is contracted besides. From his point of view energy conservation is valid for the light beam and with $E = \hbar\omega$ the frequency stays constant along the beam whereas the wavelength is stretched two times, thus by the factor $(1 + \frac{\phi}{c^2})^2$ to arrive at the receiver with greater wavelength. So he concludes on a change of the velocity of light of

$$\frac{c_R}{c_T} = \frac{\omega_R \lambda_R}{\omega_T \lambda_T} = \frac{\lambda_R}{\lambda_T} = \left(1 + \frac{\phi}{c^2}\right)^2. \tag{3}$$

A complementary situation arises if a light beam is moving through a spatially constant potential but this potential shall change temporally, it is continuously decreasing e.g. The observer is measuring a frequency ω_R and a wave-length λ_R. He knows that ω_T and λ_T were greater at the emission than the standard values because the potential ϕ was higher than at the receiver-side measurement. Because of the temporally variation of the potential the energy is not preserved in this system but the momentum instead. Due to the flat potential $\nabla\phi = F = 0$ there is no change of the momentum $F = \frac{dp}{dt} = 0$. And with the photon momentum $p = \frac{h}{\lambda}$ it follows that the wavelength is not changing along the path of light. This was already recognized by R. Dicke [3]. If we describe a temporal change of the gravitational potential with a variable speed of light then it is:

$$\frac{c_R}{c_T} = \frac{\omega_R \lambda_R}{\omega_T \lambda_T} = \frac{\omega_R}{\omega_T} = \left(1 + \frac{\phi}{c^2}\right)^2 \tag{4}$$

The change of the speed of light is taken here by the modification of the frequency ω. At the emission the frequency is higher than the standard value and lower at the receiver. A red-shift is expected. The reference point is at the receiver as mentioned. Here is the zero point of the potential and we obtain the standard value for the speed of light c_0.

Appropriate to these considerations we can regard the expression

$$n = \frac{1}{\left(1 + \frac{\phi}{c^2}\right)^2} \approx 1 - \frac{2\phi}{c^2} + \ldots \tag{5}$$

as the relative polarizability of vacuum. Thus we will regard c as variable velocity of light and c_0 as the standard value of a local measurement. In General Theory of Relativity the variable speed of light c is called “coordinate velocity”.

$$c = \frac{c_0}{n} \tag{6}$$

2 Former Works about Gravitation as a Light Phenomenon

In the year 1921 Harold Wilson [15] showed that a variable polarizability of vacuum does effect a force onto a charged particle, what can be interpreted as gravitational force. His model included the correct twice deflection of light at the sun. Based on this work Robert Dicke 1957 [3] [4] (not the scalar-tensor theory) extended this insight by explaining three classical tests of General Theory of Relativity by means of a variable refractive index of vacuum. Almost at the same time also H. Dehnen, H. Hönl and K. Westpfahl [2] and later Jan Broekaert [1] demonstrated that the four classical tests including the perihelion shift of Mercury can be described with the model of a polarizable vacuum. All four classical tests are basing on effects of a weak gravitational field. Because General Theory of Relativity as well as the theory of polarizable vacuum have the same solution in weak fields, there is no possibility to decide between both versions. In strong fields however both models differ essentially.

James Evans, Kamal Nandi and Anwarul Islam [9] presented a method that enables the exact calculation of the propagation of light and also the movement of material bodies through a medium of variable index of refraction n. Their method is expression that gravitation and light are of same nature and can be described by a uniform formalism consequentially.

As summarized by Harold Puthoff [12] in an easier readable way many values also become dependent on n within a theory of variable speed of light. Alexander Unzicker is giving a good overview of the state of the theory in [14].

What is missed, is a consequent system of rules how to deal with quantities in a polarizable medium. In this work I will try to connect some of these more or less lose threads to a sustainable network.

Many of the mentioned authors are seeing the formulation with variable speed of light only as a more intuitive and mathematical easier way to General Relativity, which correctness they don't have doubt about. But I want to remind here, that it is not about correctness or falseness of a theory. According this narrow-minded view also Newton's theory is "wrong". Not only because it is inaccurate, but first of all because it is based on conceptions not valid from a today's view any more. Although Newton's theory reliably delivers answers on questions to nature in the area of its validity. One cannot expect any more from a theory. And the question, whether the principles of a theory are "right", only can be judged from the perspective of another theory basing on the assumption of fundamental principles on its part as well. The truth itself is not available.

Naturally there are better and worse models of reality. The criteria though are such as the area of validity, the number of necessary parameters or simplicity. Especially General Relativity Theory can not enter mathematical economy on the credit side. And in strong-field the proofs for the right answers unfortunately are to be described as poor even after a hundred years of research. I would like the theory of variable speed of light to be seen as another possible and powerful model in this sense without associating a claim of "truth" with it.

3 Unit Considerations

The following considerations extend the already found relations to further quantities. It is important to make oneself aware of the index of refraction n being a pure relative quantity. Thus a comparison between an observer, which potential is taken as a reference with refractive index $n = 1$ by definition, and locations with different refractive index, whereas n is describing always the relative difference but not an absolute value.

There must be differentiated basically two situations:

1. A measurement is related to the location itself at which it is conducted (local measurement). Then the index of refraction n is equal one by definition and there the standard values of each quantity are valid, explicitly indicated by index "0".

2. An observer resides at the reference potential and evaluates measurements at a location with different gravitational potential. For him the scales, clocks and reference masses arranged at reference potential look different at the location of the experiment. The local experimenter is taking the modified scales as a reference for his tests. Then following relations are valid.

Starting point is the definition of n on the basis of the speed of light:

$$c = \frac{c_0}{n}$$

As showed above clocks are running slower in a gravitational field, periods are longer, frequencies smaller:

$$\omega = \frac{\omega_0}{\sqrt{n}} \tag{7}$$

The wave-length of light is smaller, lengths are shortened:

$$\lambda = \frac{c}{\frac{\omega}{2\pi}} = \frac{\frac{c_0}{n}}{\frac{\omega_0}{2\pi\sqrt{n}}} = \frac{\lambda_0}{\sqrt{n}} \tag{8}$$

The Planck quantum of action $\hbar$ being unaffected by the gravitational field is an assumption. Dehnen, Hönl and Westpfahl [2] carry out a plausible reasoning. Dicke's argument is that the angular momentum $\hbar$ for a circular polarized photon would not be preserved [3]. From the constancy of Planck's constant we conclude the energy dependency, which varies like a frequency therefore:

$$E = \frac{\hbar\omega_0}{\sqrt{n}} = \frac{E_0}{\sqrt{n}} \tag{9}$$

This relation is valid not only for photons, but also for matter. If a massive body is being moved slowly downwards in the field of gravity, its rest energy is being decreased by detracting gravitational binding energy. This happens in concordance with Special Relativity Theory, whose validity I assume without restriction.

According $E = mc^2$ the inertia of matter is increased threefold by this factor:

$$m = \frac{E}{c^2} = \frac{\frac{E_0}{\sqrt{n}}}{\frac{c_0^2}{n^2}} = m_0 n^{\frac{3}{2}} \tag{10}$$

Planck's constant has the unit J s. If one assumes the modification of all times, lengths and masses according above relations, all variabilities cancel each other. The prior accepted assumption of the constancy of $\hbar$ thus turns out to be consistent.

$$[\hbar] = \mathrm{J\,s} = \frac{\mathrm{kg\,m^2}}{\mathrm{s}} \tag{11}$$

These relations are valid also in strong gravitational fields by definition. Additional relations can be stated by consideration of the units. The fine structure constant α is constant in any case because all units and hence all values, that are changing in the gravitational field, cancel each other.

$$\alpha = \frac{e^2}{4\pi\varepsilon\hbar c} = const \tag{12}$$

Einstein's gravitational constant is independent of a variable polarizability also, because the variabilities cancel each other.

$$\kappa = \frac{8\pi G}{c^4} = const \quad \text{due to} \quad [\kappa] = \frac{\mathrm{s}^2}{\mathrm{m\,kg}} \tag{13}$$

Newton's gravitational constant is decreased in the gravitational potential however:

$$G = \frac{G_0}{n^4} \quad \text{due to} \quad [G] = \frac{\mathrm{m}^3}{\mathrm{kg\,s}^2} \tag{14}$$

Accelerations g are decreased, gravitational forces F_g stay constant, because the decrease of acceleration is nullified by the increase of inertia:

$$g = \frac{g_0}{n^{\frac{3}{2}}} \quad \text{due to} \quad [g] = \frac{\mathrm{m}}{\mathrm{s}^2} \tag{15}$$

$$F_g = mg = m_0 g_0 = const \tag{16}$$

At the electric and magnetic field quantity the unit ampere comes into play:

$$[\varepsilon] = \frac{\mathrm{A\,s}}{\mathrm{V\,m}} = \frac{\mathrm{A^2\,s}}{\mathrm{kg^4\,m^3}} \quad \text{and} \quad [\mu] = \frac{\mathrm{N}}{\mathrm{A}^2} = \frac{\mathrm{kg\,m}}{\mathrm{A^2\,s^2}} \tag{17}$$

If one assumes the elementary electric charge to be a preserved value in the gravitational field, currents must transform inverted to times:

$$I = \frac{I_0}{\sqrt{n}}, \quad \text{then} \quad e = const \quad \text{due to} \quad [e] = \mathrm{A\,s} \tag{18}$$

Then and only then the field quantities of vacuum vary in equal way:

$$\varepsilon = n\varepsilon_0 \quad \text{and} \quad \mu = n\mu_0 \tag{19}$$

Ampere is canceled anyway in the relation of the velocity of light though. The constancy of electrical charge in the gravitational field is no unavoidable choice therefore and lets open the possibility of alternative descriptions.

$$c = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c_0}{n} \tag{20}$$

The electrical force F_e between two elementary charges in the distance d does not show any variability also, although the physical mechanism is different:

$$F_e = \frac{e^2}{4\pi\varepsilon d^2} = \frac{e^2}{4\pi\varepsilon_0 n \frac{d_0{}^2}{n}} = const \tag{21}$$

A couple of elementary physical lengths are compounded out of universal constants and are scaling according these rules like wave lengths with $\frac{1}{\sqrt{n}}$.

$$\text{The Bohr Radius} \quad a_0 = \frac{4\pi\varepsilon_0\hbar^2}{m_e e^2} \tag{22}$$

$$\text{The Compton wave-length} \quad \lambda_C = \frac{h}{mc} \tag{23}$$

$$\text{The classical electron radius} \quad r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2} \tag{24}$$

Moreover in a Lennard-Jones potential e.g. the energy minimum is shifted according the same relation. so that one has a good basis for assuming that all atom- and molecule distances and therefore every material length scale is modified in equal manner like a length scale in form of a laser.

As we mentioned above, these relations present themselves in this way to an observer at the reference location, if the refractive index does not change for the investigated object. If movements in a gravitational field are analyzed or if there are temporal changes, then additional considerations have to be made.

4 Equivalence Principle

How the situation does look like to a local experimenter? Thus a measurement related to the local place as its reference point. Such a measurement is a comparison of a measurement value to a local scale, that however underlies the variabilities of the gravitational field also. At all times $n_{local} = 1$ for a local observer.

An experiment to determine Newton's gravitational constant G would end up as follows e.g.: First of all an experimenter measures the mutual attractive force of two test masses M and m in the distance d at reference potential with $n = 1$ by means of a Cavendish balance.

$$G_0 = \frac{F_{g0}\, d_0{}^2}{m_0\, M_0} \tag{25}$$

He obtains the standard value for G. Now he transfers the experiment to a place with deeper gravitational potential nearer to the sun.

An observer remaining at the reference point evaluates the conduction of the second experiment. He gets the result that the experimenter measures the same force, but the inertia of the test masses has increased, in exchange though the distance of the test masses is less than that at the reference experiment. From his point of view G changes to:

$$G = \frac{F_{g0}\frac{d_0{}^2}{n}}{m_0 n^{\frac{3}{2}} M_0 n^{\frac{3}{2}}} = \frac{G_0}{n^4} \tag{26}$$

From the view of the local experimenter the measurement value did not change however. The Cavendish-balance stayed right the same. The test masses are unchanged from his point of view and all dimensions of the balance are the same in relation to the local measuring equipment as they were at the reference experiment, although they have shortened in the prospect of the reference observer. The force also did not change its value. For the local experimenter the number value of G also stayed unchanged.

$$G_{local} = G_0 \tag{27}$$

These considerations though are working only, because all included values here underlie the same variation of the refractive index n commonly. If the sun is taken as test mass M and we investigate the effects of a spatial variation of n within the solar system onto a test mass m, the mass of the sun M stays at its location, the index of refraction n however changes for m in case of its displacement, but not for M indeed. Later more to that issue.

If we look at the electrical force $F_e = \frac{e^2}{4\pi\varepsilon d^2}$ and the gravitational force $F_g = \frac{Gm_p m_e}{d^2}$ between a proton and an electron, the ratio is independent of the distance and also of the refractive index. It does not change its number value thus.

$$\frac{F_e}{F_g} = \frac{e^2}{4\pi\varepsilon G m_p m_e} = \frac{e^2}{4\pi\varepsilon_0 n G n^{-4} m_{p0} n^{\frac{3}{2}} m_{e0} n^{\frac{3}{2}}} = \frac{e^2}{4\pi\varepsilon_0 G_0 m_{p0} m_{e0}} = 2.3 \times 10^{39} \tag{28}$$

A conclusion to the gravitational potential can not be obtained out of a precision measurement of this ratio.

In general it has to be stated that there are no absolute values in the theory of variable speed of light. Distances, velocities, frequencies can be defined only in relation to a reference at all and have validity only as comparison values. The index of refraction n is only of relative relevance, too. It only does express the difference of the velocity of light for different locations. The space looks locally identical for each observer. That is nothing else than the Equivalence Principle of General Relativity Theory.

At the consideration of units we have transferred the found relations for mass, frequency and length to other quantities compounded of these units like acceleration and force e.g. In order to work well it must be assumed however, that the Heavy Mass is transformed in the same manner as the Inertial Mass. Otherwise the gravitational force would be distinguishable from the inertial force. Hence the Equivalence principle is an implicit request of the theory.

Particularly the number value of the constants of nature does not change at a variation of the gravitational potential for the local observer. Some theories like the "Large Number Hypothesis" of Paul Dirac [5] demand such a temporal variation of Newton's gravitational constant. The previous examinations rather do not indicate a measurable change – for the local observer.

The Equivalence Principle is a basic assumption of General Relativity Theory also but its assumption does not determine the form of the field equations unambiguously. Einstein decided, that beyond that the Covariance Principle shall be valid [8]. Whereas the equivalence principle is a strong argument supported by evidence, the covariance principle only is an argument of mathematical beauty and does not arise from a physical necessity. A dangerous temptation. I guess we should use this degree of freedom in a better way, namely the unification of gravity and quantum physics. In the approach outlined here therefore the basic assumption, that gravitation is an electromagnetic phenomenon, took the place of the Covariance Principle.

A general question is the shape of the law of gravitation. We silently assumed, that Newton's law with a $1/r^2$-dependency is valid in first approximation. The presented dependencies of physical quantities don't deliver a foundation for this circumstance. In the definition of the units of Newton's gravitational constant G the assumption of the validity of the law rather is implicated.

But it can be given a more general justification of Newton's law, that rests on universal properties of fields. For that we only assume the vacuum – outside of matter as source of gravitation – being divergence free and irrotational. Without knowing anything about the physical mechanism, how electromagnetic fields are acting on vacuum, so that the index of refraction n is changing appropriately to reproduce Newton's law, only from zero divergence and zero curl follows in a euclidean space, that the gravitational force is declining inversely to the square of the distance r to a point-like mass. In general the field intensity is $\propto 1/r^{dim-1}$. dim names the number of space dimensions. Furthermore energy conservation, which we rely on throughout, corresponds with a divergence free and curl-free field.

By not agreeing of different observers about the measurement of distance and time the gravitational law becomes an only approximately valid one. The precondition of a euclidean space therefore is only given approximately.

5 Homogeneous Gravitational Potential

We have examined a continuously accelerated laboratory in free space for weak fields. This situation is equivalent to a homogeneous gravitational potential with constant spatial gravity acceleration g, that can be described with $\phi = gh$. h is the height difference in the homogeneous potential. We don't restrict ourselves however on weak fields any more, and we follow Dehnen, Hönl and Westpfahl [2] how to extend the results on strong fields. We start at equation (1).

$$\frac{\omega}{\omega_0} = 1 - \frac{gh}{c^2} = 1 - \frac{\phi}{c^2} \tag{29}$$

That means an observer at the location $h = 0$ does observe a light beam, that propagates from him to h. The frequency there is red-shifted for the receiver, if h is positive. As long as $gh \ll c^2$, ω_0 can be regarded as constant. If we look at the situation more closely, we must incorporate though, that the change of the frequency actually is related to the local frequency ω, which will vary with the propagation of the light beam noticeably against the starting frequency ω_0 sometimes. Then the frequency change does not simply add up linearly, but obeys an exponential law.

$$\frac{d\omega}{\omega} = -\frac{gdh}{c^2} = -\frac{d\phi}{c^2} = -\frac{dk}{k} \tag{30}$$

$$\int_{\omega_0}^{\omega} \frac{d\omega}{\omega} = -\int_0^h \frac{g}{c^2} dh = -\int_1^k \frac{dk}{k} \tag{31}$$

$$\ln \omega - \ln \omega_0 = -\frac{gh}{c^2} = -\ln k \tag{32}$$

$$\frac{\omega}{\omega_0} = e^{-\frac{gh}{c^2}} = e^{-\frac{\phi}{c^2}} = \frac{1}{k} \tag{33}$$

$$n = k^2 = e^{\frac{2gh}{c^2}} = e^{\frac{2\phi}{c^2}}, \quad \text{with} \quad k := \sqrt{n} \tag{34}$$

So far Dehnen, Hönl and Westpfahl. With the introduced redshift factor k is easier to calculate in some opportunities than with n. The index of refraction n and thus also k is equal to one at $\omega = \omega_0$ by definition.

At this point now we must be very careful. We have seen, that almost all values supposed to be sure get into fluctuating at once. They depend on the index of refraction n and we cannot simply insert the reference values without concern any more. We can begin with the reference values g_0, dh_0, c_0^2 for g, dh and c^2 at the starting point. Here is $n = 1$ by definition. But when ω and with it also the index of refraction n has noticeably changed, the observer at the reference point must take indeed the values of the location of the measurement related to the reference point $\frac{g_0}{n^{3/2}}$, $\frac{dh_0}{\sqrt{n}}$, $\frac{c_0^2}{n^2}$. The acceleration etc. indeed is not g_0 any more from the sight of the reference observer at the location of the measurement. The local observer is measuring g_0 further in contrast.

$$\frac{g}{c^2} dh = \frac{g_0 n^{-\frac{3}{2}}}{c_0^2 n^{-2}} dh_0 n^{-\frac{1}{2}} = \frac{g_0}{c_0^2} dh_0 \tag{35}$$

As we can see the variations by the variable index of refraction n cancel each other and the starting values preserve their validity. So a measurement related to the location itself is allowed to calculate also with the same values. This is though not at all a matter of course and as we will see, the exact assignment of the reference values is of significant importance. Here it is successful, because all measurement values are related to the same place. And because the exponent does represent a unit-less quantity, all units cancel each other included their correction factors by n.

Here also a conceptual difficulty becomes evident, namely the definition of distance. As already mentioned I assume a flat space. The reference observer places a coordinate system over the three-dimensional space without regarding the spatial variation of the index of refraction. His location and distance indication is always related to this coordinate system related to reference. The boundary of integration of equation (31) is going until h further, because it is representing the location coordinate of the reference observer. The distance to location h can be defined in a different way also by local scales stringed together. This distance does not agree though to the coordinate distance in the reference system.

This form of the index of refraction has been discussed in the literature several times already. Also Robert Dicke does obtain this form from different reasons in his second paper to that subject [4], as Huseyin Yilmaz [16] and Kris Krogh [10] as well. Even Einstein indicated this form of red-shift in a work of 1907 [6] (on page 457 of the original publication), with the hint that otherwise the zero point of the potential would be exceptional.

6 Central Potential

Now we investigate the field of a point-like mass M instead of a homogeneous potential.

$$\phi = -\frac{GM}{r} \tag{36}$$

So we get for the redshift at $r = r_0$:

$$\frac{d\omega}{\omega} = \frac{d\phi}{c^2} = \frac{GM}{r_0^2 c^2} dr = -\frac{dk}{k}, \tag{37}$$

thus with the gravity acceleration $g = \frac{GM}{r^2}$ at $r = r_0$. Now we let vary r_0 with r in an analogous manner:

$$\int_{\omega_0}^{\omega} \frac{d\omega}{\omega} = \int_{r_0}^{r} \frac{GM}{r^2 c^2} dr = -\int_1^k \frac{1}{k} dk \tag{38}$$

$$\ln\omega - \ln\omega_0 = -\frac{GM}{c^2}\left(\frac{1}{r} - \frac{1}{r_0}\right) = -\ln k \tag{39}$$

$$\frac{\omega}{\omega_0} = e^{-\frac{GM}{c^2}\left(\frac{1}{r} - \frac{1}{r_0}\right)} = \frac{1}{k} = \frac{1}{\sqrt{n}} \tag{40}$$

And so the index of refraction is

$$n = e^{\frac{2GM}{c^2}\left(\frac{1}{r} - \frac{1}{r_0}\right)} \tag{41}$$

This form of the index of refraction does agree in second order also, so the perihelion shift of mercury is described correctly, see [2] or [12].

Newton's law of gravitation now arises as approximation if one develops the force as energy gradient:

$$F = \frac{dE}{dr} = \frac{d}{dr}\frac{E_0}{\sqrt{n}} = E_0 \frac{d}{dr} e^{-\frac{GM}{c^2}\left(\frac{1}{r}-\frac{1}{r_0}\right)} \tag{42}$$

We develop the e-function up to the first order in $\frac{1}{r}$ and and replace E_0 by mc^2, then for the energy gradient the result is Newton's gravitational force on a mass m:

$$F = mc^2 \frac{d}{dr}\left[1 - \frac{GM}{c^2}\left(\frac{1}{r} - \frac{1}{r_0}\right) + \ldots\right] \approx m\frac{GM}{r^2} \tag{43}$$

However there is a complication at the central potential. Like in the case of the homogeneous potential we must take care of the fact here also, that the participating values itself are varying in the gravitational potential. This problem was not treated in the literature yet.

We have to correct the values at the location $\vec{r}$ by the local refractive index n, because we examine the problem from the view of the reference observer. If we execute this as we have done at the homogeneous potential and replace the values by their modified ones, $G = G_0 n^{-4}$, $M = M_0 n^{3/2}$, $c = c_0 n^{-1}$ and $r = r_0 n^{-1/2}$ as usual, then all correction terms by n would cancel as well. But: For the central mass M this procedure is not correct and therefore the gain of the solution of equation (41) in this form is definitely wrong!

The point of the matter is, that the central mass M is remaining at a location with constant n, whereas the other participating quantities at the place $\vec{r}$ join a modification of n along the path of integration.

The solution comes out of the inspection of energy. The actual cause of gravity according Special Relativity is energy and not mass. Namely energy in every form. In the case of matter its rest energy or kinetic energy. Mass is no quantum property but an energetic state. Even heat is contributing to gravity. According $E = mc^2$ mass can be converted into energy 1:1, but in the picture of variable speed of light the conversion factor c^2 is not constant any longer. So we will compare the rest energy of the central mass $E_M = Mc^2$ with the rest energy of the test mass $E_m = mc^2$ and not the inertia M or m respectively. For that the test mass m is being moved slowly in the gravitational field, that means without consideration of kinetic energy. Slowly shall mean that the released or to be expended potential energy is absorbed or spent by an elevator transporting the test mass m. The test mass is quasi at rest all the time. Its rest energy is reduced by this quantity, if it is moved in the gravitational potential nearer to the central mass M.

The reference observer on his fixed potential sees a variation of the rest energy of the test mass $E_m = \frac{E_{m0}}{\sqrt{n}}$ as shown in equation (9), whereas E_M stays constant. **Because the energy is the critical factor for the gravitational action, the central mass M consequently seems to increase in its gravity effect by a factor $\sqrt{n}$ in relation to the test mass m, independent from the point of view.**

Expressed in an equivalent way we must take the speed of light c at the location of the test mass m when converting M_0 into M: $M = \frac{E_M}{c_0{}^2/n^2} = M_0 n^2$. Then $M = M_0 n^2$ is changing in relation to $m = m_0 n^{\frac{3}{2}}$ by the factor $\sqrt{n}$.

Therefore the obtained solution for n in the form of equation (41) is lost for the moment.

7 Mach's Principle

For the further examination we must relieve ourselves at first from a geocentric trap, which confine the view unnecessarily and obstruct the sight onto the greater whole thing.

In the general literature it is assumed throughout at this place, that the zero point of the potential is at $r = \infty$. This determination seems to be plausible, because one is searching for a solution, which migrates into the weak field solution for weak gravitational fields. That solution is believed having found with $\phi = 0$ for $r = \infty$.

The model the Schwarzschild equation is based on is treating the universe as point mass M in an otherwise matter-free space. But this does not agree with reality. If one only looks at the potential of our sun, its influence vanishes in greater distance indeed. We are located though in the potential of our galaxy. If we go even further into the intergalactic space, there is still acting the much deeper potential of the average matter density of the universe.

The gravitational potential outside the solar system obviously is not zero at all like it is included in the model of the Schwarzschild equation. Moreover it is assumed silently, that the rest of the matter in space has no relevant influence on the relationship between masses. This is a perspective I scrutinize.

In any case it becomes obvious, that the interstellar or the gravitational potential on earth respectively is extraordinary in no way, it is only an arbitrary, geocentric point of reference, that wrongly is attributed a special physical meaning to by assigning curvature zero at large distance from the sun.

If we take serious our basic intention, namely that the refractive index of vacuum is able to describe the effect of gravitation correctly, then the cause of gravitation lies in the mutual electromagnetic interaction of matter. There is no direct electrical attraction or repulsion of stars or galaxies, because ordinary matter consists of charged particles throughout, in fact protons, neutrons – which I include here due to its inner structure – and electrons, but mostly it is having balanced charge. Nonetheless all charged particles are in steady exchange with other charged particles in the universe as far as light reaches. This sea of virtual photons I regard as the reason of the polarizability of vacuum and hence also as the cause of the finiteness of the speed of light. Thus the imagination seems to be likely that in a universe that does not contain any matter at all, vacuum would not be polarizable and therefore the velocity of light would be infinite. This I expect as a property of a coherent theory.

How the speed of light would behave at a place, where the gravitational potential vanishes? Thus a location infinitely far separated from any matter. The real universe at most is conforming to a sphere equally filled with mass. With radius R_u and total mass M_u, which center we are located at. And also for any distant observer the universe looks the same in large-scale, only the center point of the universe is shifted from his perspective. The gravitational potential is equally deep all over. To be able to reach a place with vanishing potential we conceptually contract the entire mass of universe M_u in one single point. So we stay at the world model of a central mass and an otherwise matter-free space. The Newtonian potential is $\phi = -\frac{GM_u}{r}$. If we depart from the center, the absolute value of the potential becomes smaller and is vanishing at infinite distance. At first we are searching the distance r_u from the central mass exhibiting the equal gravitational potential as the center point of the homogeneous sphere.

The infinitesimal mass element of a sphere $dm = \rho\, dV_u$ with constant density ρ and volume element dV_u from the center of a sphere has the potential

$$d\phi = -\frac{G\,dm}{r} = -\frac{G\rho\,dV_u}{r}. \tag{44}$$

The potential in the center of a sphere is the superposition of all potentials, thus we integrate over the volume of the sphere V_u:

$$\phi_u = \int_{V_u} -\frac{G\rho}{r} dV_u = -G\rho \int_0^{R_u} \int_0^{\pi} \int_0^{2\pi} \frac{1}{r}\, r^2 dr\, \sin\theta\, d\theta\, d\phi = -2\pi G\rho {R_u}^2 \tag{45}$$

The density ρ also can be expressed with the total mass M_u.

$$\rho = \frac{M_u}{V_u} = \frac{M_u}{\frac{4}{3}\pi {R_u}^3} \tag{46}$$

The potential ϕ_u in the mid point of a homogeneous sphere of mass M_u with radius R_u has the same absolute value as the potential in the distance r_u from a point mass M_u with $r_u = \frac{2}{3}R_u$.

$$\phi_u = \frac{GM_u}{\frac{2}{3}R_u} = \frac{GM_u}{r_u} \tag{47}$$

At the distance r_u we are positioning our reference point the index of refraction becoming 1. Our boundary condition now requests, that the speed of light goes to infinity in infinite distance of the mass center, so as the potential is vanishing and no interaction of matter takes place. That represents the highest possible gravitational potential and thus an absolute point of zero.

Our previous solution for the index of refraction in form of equation (41), applied to this model of the universe

$$n = e^{\frac{2GM_u}{c^2}\left(\frac{1}{r} - \frac{1}{r_u}\right)} \tag{48}$$

does not cope with this demand obviously. If we set $r = \infty$, then n stays finite in any case.

But the solution of the weak field of equation (5) can be interpreted in another way also: **The index of refraction *n* describes the action of a mass *M* onto the vacuum in relation to the action of the entire mass of the universe onto the vacuum.** Therefore in the same manner as we treated the red-shift as relative change against the frequency ω itself. R. Dicke has indicated this on page 3 of his paper from 1957 ([3]), but he did not develop it further.

Again we look at equation (30):

$$\frac{d\omega}{\omega} = \frac{d\phi}{c^2} \tag{49}$$

Now we apply the new interpretation and replace the (fixed) value ${c_0}^2$ with the total potential of all masses in the universe:

$$\frac{d\omega}{\omega} = \frac{d\phi}{-\phi_{abs}} \tag{50}$$

The negative sign in front of ϕ_{abs} comes from setting the zero point of the potential at the reference point. Actually it should be located at the absolute zero point of the potential, but I stay at the convention that the zero point of the potential of a point-like mass is at $r = \infty$.

The notion c^2 and the potential of the universe being essentially the same is not new. What I introduce here additionally is to implement the obtained insight, how quantities have to be treated at modified refractive index.

At the same time it is the simplest possibility to relate the index of refraction to the potential. It straightforwardly equates the relative variations of red-shift, potential and refractive index. This constitutes astonishingly the key to the solution of some other problems. The principally free choice of the zero point of the potential turns out to be an approximation in this respect, at which the variation of the potential is small against its absolute potential.

What I applied on the frequency ω in case of the homogeneous potential, I am extending here to the potential of a point-like mass. In equation (30) we have put the change of the frequency $d\omega$ in relation to frequency ω and modified ω during the integration also and we did not relate it to the starting frequency ω_0 only. The same we make for the potential now: First we interpret the denominator of the fraction $d\phi/{c_0}^2$ as the potential of the universe $-\phi_u$. Second now we relate the potential change ϕ at the integration not to the starting point ${c_0}^2 = \phi_u$ any more only, but to the whole potential of the particular place $\phi_{abs} = \phi_u + \phi$, thus the constant background potential of the universe plus the potential change ϕ evoked by the mass M.

Now again we start with the red-shift for the point-like universe.

$$\frac{d\omega}{\omega} = \frac{d\phi}{-\phi} = -\frac{dk}{k} \tag{51}$$

Because M_u is the only mass in the thought universe, the potential variation in relation to the total potential of the universe looks like this:

$$\frac{d\phi}{-\phi} = -\frac{\frac{GM_u}{r^2}dr}{\frac{GM_u}{r}} = \frac{dr}{r} \tag{52}$$

Only the ratio of radius change to radius does remain and it turns out to be a very simple solution for the point-like universe.

$$\int_{\omega_0}^{\omega} \frac{d\omega}{\omega} = \int_{\phi_u}^{\phi} \frac{d\phi}{-\phi} = \int_{r_u}^{r} \frac{dr}{r} = -\int_{1}^{k} \frac{1}{k} dk \tag{53}$$

$$\frac{\omega}{\omega_0} = \frac{\phi_u}{\phi} = \frac{r}{r_u} = \frac{1}{k} \tag{54}$$

The correction of the quantities with the refractive index n drops out. If we let go here the radius to infinity, the potential vanishes and the index of refraction k with it also. This means the speed of light is diverging. Hence all frequencies and length scales tend to infinity, too. At infinite distance thus space and time is not definable at all.

The approach pursued here meets the conception of Ernst Mach in a perfect manner. It can be regarded as consistent numerical representation of Mach's principle. Mach criticized the imagination of an absolute space like Newton had in mind. For him it was unthinkable that a space would be definable at all in a matter-free universe. Only by the presence of reference objects this would be possible. And the interaction between matter would be influenced definitively by the presence of all other masses [11].

In General Relativity Theory however the (small) dependency of inertia of the gravitational field sometimes is mentioned as implementation of Mach's principle, but it is not worth to be denoted as realization of it because it does not meet Mach's central statement.

Two important consequences result from our assumptions. The first meets the numerical value of the speed of light or the gravitational constant respectively. We identify c^2 (here strictly speaking ${c_0}^2$) with the absolute potential of the universe ϕ_u. The numerical agreement of $c^2 \approx \frac{GM_u}{R_u}$ Erwin Schrödinger 1925 mentioned first [13] and suspected a deeper connection. Before that time one was not conscious of the true dimensions of the universe by far anyway.

Because all quantities in equation (47) are determined independently, the gravitational constant G can be constituted dependently and can be understood as conditional equation of G.

$$G = \frac{\frac{2}{3} R_u c^2}{M_u} \tag{55}$$

If we identify c^2 with the potential of the universe, we are able to contextualize Einstein's most famous equation $E = mc^2$, which has a formally monolithic character:

$$E = -m\phi_u = mc^2 \tag{56}$$

The rest energy of a body is equivalent to its potential energy in the absolute potential of the universe. And so Newton's gravitational potential energy joins with the velocity of light.

8 Central Potential II

The second consequence will restore us the correct dependency of the refractive index we lost above. Again we start with the red-shift. This time we relate the potential variation $\Delta\phi$ not only to the potential of the starting point ϕ_u or ${c_0}^2$ respectively, but to the total absolute potential $\phi_{abs} = \phi_u + \Delta\phi$ at the location we are looking at. ϕ_u represents the constant background potential of the universe. If the potential is increasing, the frequency is increasing.

$$\frac{d\omega}{\omega} = \frac{d\phi}{-\phi} = -\frac{dk}{k} \tag{57}$$

In this model there are two mass portions: The constant background potential of the universe ϕ_u and the central mass M, which potential $\Delta\phi$ is added to to the back ground potential ϕ_u. We start at the reference point $r = \infty$, thus $\phi = \phi_u$,

$$\int_{\phi_u}^{\phi_u+\Delta\phi} \frac{d\phi}{\phi} = \int_1^k \frac{dk}{k} \tag{58}$$

$$\ln \frac{\phi_u + \Delta\phi}{\phi_u} = \ln k \tag{59}$$

$$\phi_{abs} = \phi_u + \Delta\phi = k\phi_u = \phi_u\sqrt{n} \tag{60}$$

Therefore we can represent a variation of the absolute potential by a multiplication with the refractive index $\sqrt{n}$.

Now we start again with equation (37), but we equate c^2 with the variable absolute potential $\phi_u\sqrt{n}$, represent M as energy $\frac{E_M}{c^2}$ and perform the usual corrections of all quantities with the refractive index:

$$\frac{d\omega}{\omega} = \frac{d\phi}{-\phi_{abs}} = \frac{GM}{r^2\phi_u\sqrt{n}}dr = \frac{G\frac{E_M}{c^2}}{r^2c^2\sqrt{n}}dr = \frac{G_0 n^{-4}\frac{E_M}{{c_0}^2}n^2}{{r_0}^2n^{-1}{c_0}^2n^{-2}\sqrt{n}}\frac{dr}{\sqrt{n}} = \frac{G_0M_0}{{r_0}^2{c_0}^2}dr_0 \tag{61}$$

Now the correction of mass M and that of the potential of the universe ϕ_u cancel each other. We integrate from r_0 to r again and receive the original result of equation (41), where we can take the reference values at all places:

$$n = e^{\frac{2G_0M_0}{{c_0}^2}\left(\frac{1}{r}-\frac{1}{r_0}\right)} \tag{62}$$

The result is valid for the potential of a point-like mass M in free space with the constant background potential ϕ_u.

In a notation equivalent to the isotropic Schwarzschild metric the line element can be expressed as:

$$ds^2 = \frac{1}{n}c^2dt^2 - n\,d\vec{r}^2 = e^{-\frac{2GM}{c^2}\left(\frac{1}{r}-\frac{1}{r_0}\right)}c^2dt^2 - e^{\frac{2GM}{c^2}\left(\frac{1}{r}-\frac{1}{r_0}\right)}d\vec{r}^2, \tag{63}$$

which does agree in first approximation with the Schwarzschild solution for $r_0 = \infty$, see [12]. But whereas the Schwarzschild solution exhibits a divergence at a finite distance of the mass center, that leads to the so called event horizon, there is a point of infinity in the refractive index within the solution of the variable speed of light only at $r = 0$, which is physically no problem though. Therefore no "black hole" does appear. An infinite index of refraction n corresponds to a vanishing speed of light. Translated into the Schwarzschild solution this would mean, that the speed of light would be zero at the event horizon and farther inside even "negative". A negative speed of light does not make sense in the picture of a variable speed of light.

9 Conclusion

I believe having demonstrated, that a consistent model of gravitation can be established solely from the assumption, that gravitation can be described as an electromagnetic phenomenon under abandonment of the covariance principle. Mach's principle is not an artificial ingredient, but a natural consequence of very general assumptions.

This theory breaks with the irrevocable believe in the correctness of General Relativity Theory. There arise clear differences in the strong gravitational field. Also the consequences for the physics of the universe are substantial and will be an issue of a further work.

References

[1] J. Broekaert. "A Modified Lorentz-Transformation–Based Gravity Model Confirming Basic GRT Experiments". In: *Foundations of Physics* 35.5 (2005), pp. 839–864.

[2] H. Dehnen, H. Hönl, and K. Westpfahl. "Ein heuristischer Zugang zur allgemeinen Relativitätstheorie". In: *Annalen der Physik* 461.7-8 (1960), pp. 370–406.

[3] R. H. Dicke. "Gravitation without a Principle of Equivalence". In: *Reviews of Modern Physics* 29.3 (1957), pp. 363–376.

[4] R. H. Dicke. "Mach's Principle and Invariance under Transformation of Units". In: *Phys. Rev.* 125 (1962), pp. 2163–2167.

[5] P. Dirac. "A new basis for cosmology". In: *Proc. Royal Society A* 165 (1938), pp. 199–208.

[6] A. Einstein. "Über das Relativitätsprinzip und den aus demselben gezogenen Folgerungen". In: *Annalen der Physik* (1907), pp. 411–462.

[7] A. Einstein. "Über den Einfluß der Schwerkraft auf die Ausbreitung des Lichtes". In: *Annalen der Physik* 340.10 (1911), pp. 898–908.

[8] A. Einstein. "Zur allgemeinen Relativitätstheorie". In: *Sitzungsberichte der Preussischen Akademie der Wissenschaften zu Berlin* (1916), pp. 778–786.

[9] J. Evans, K. Nandi, and A. Islam. "The optical-mechanical analogy in general relativity: New methods for the paths of light and of the planets". In: *American Journal of Physics* (1996).

[10] K. Krogh. "Gravitation Without Curved Space-time". In: (2006).

[11] E. Mach. *Die mechanik in ihrer entwickelung*. F.A. Brockhaus, 1883.

[12] H. Puthoff. "Polarizable-Vacuum (PV) representation of general relativity". In: *arXiv:gr-qc9909037* (1999).

[13] E. Schrödinger. "Die Erfüllbarkeit der Relativitätsforderung in der klassischen Mechanik". In: *Annalen der Physik* 382 (1925), pp. 325–336.

[14] A. Unzicker. "Mach's Principle and a Variable Speed of Light". In: *arXiv:1503.06763v2* (2007).

[15] H. A. Wilson. “An Electromagnetic Theory of Gravitation”. In: *Phys. Rev.* 17 (1921), pp. 54–59.

[16] H. Yilmaz. “New Approach to General Relativity”. In: *Physical Review* 11 (1958), pp. 1417–1426.