On a Heuristic Point of View about Newton's Laws, Mach's Principle and the Theory of Relativity

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Abstract

It will be shown that Newton's theory already implies a maximum velocity with which a massive particle can travel if the universe is included into the consideration (according to Mach's principle). The resulting formulas for the velocity dependence of the particle's mass and it's energy are identical with those of SR. The constancy of the speed of light does not have to be postulated for this purpose, but comes rather as one of the results. The results suggest also that the speed of light (in "vacuum") is not a natural constant. One can also conclude that the "action at a distance" – property of Newton's law of gravity is not in contradiction to the local character of nature as described by the theory of relativity.

Key words: action-at-a-distance, Mach's principle, Newton's laws and the universe, non-conventional derivation of SR, variable speed of light

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1. Introduction

With his astonishing paper in 1964 John Stewart Bell showed us a way to determine experimentally whether a theory describes local realism.[1] The numerous experiments performed since then on quantum entangled states have revealed that certain measurements are incompatible with the assumption of locality. Local realism as a fundamental property does not seem to exist in nature.

With the following consideration we are not aiming to find out the reasons behind the non-local character of quantum mechanics, but we take this experimental finding as a fundamental property of nature and investigate, whether this property can also be found in the fundamentals of classical mechanics. Thus, we are not following Newton, who did surprisingly not believe in an "action on a distance" principle, though his law of gravitation is based on it.[2]

However, if we are looking carefully to Newton's theory (if we understand it to mean both the law of inertia and the law of gravity), we see that only gravity is described as non-local: the gravitational force acts instantaneously at every point of the universe.[3] But the universe is not payed attention to when describing a moving mass in the framework of Newton's mechanics. In the following consideration we will abolish this nonobservance in Newton's mechanics.

We proceed from Newton's laws of inertia and of gravity and view them as one unit for describing all classical properties of masses, and we take the action at a distance (or long range) principle substantially seriously: all masses in the universe are instantaneously interconnected by the force of gravity! In contrast to Newton, we also want the description of the **motion** of a mass point to take all the masses actually existing in the universe into account from the start. And so we go along with the notion of Ernst Mach that the motion of a mass point should depend on all other masses in the universe.[4] We therefore base our considerations on the mass distribution of the universe as the given and experimentally measurable starting point. We of course immediately run into the fundamental difficulty that our knowledge of mass distribution in the universe is naturally uncertain and becomes more uncertain the farther away the masses are from Earth. But in contrast to 100 or even 300 years ago, we have today a wide range of experimental data, and it is possible to make physically justifiable assumptions on this basis, meaning we can set up an empirically justifiable model of the universe (based upon the classical view of a three-dimensional space and a separate time). We will then have to discuss whether the results of our examination represent progress compared to today's state of theory which is underpinned more by fundamental hypotheses, and so whether the uncertainties of the necessary assumptions are outweighed by the basic problems of the theory of relativity and its current extensions. Our approach focuses on the universe “as it is”, meaning on the most reliable observation data possible about the structure of the universe on the whole. Right from the start we therefore definitely exclude entire classes of abstract models of the universe “as it might also be”. Whether that is an advantage or a disadvantage will have to be discussed later based on the results of our examination.

There were considerations of similar topics within the past decades, but the fundamental causes and relationships as found and described in the following were not discovered in the previous papers. This will be discussed in chapter 5 in more detail (see also the references there).

2. Description of a mass within the universe

We begin by examining a test sample with a mass m. This test sample can be at rest or in motion. It should not be located or move in an empty “absolute” space but rather in the actually existing universe. The universe should be included in the mathematical formulation from the beginning. We initially proceed from the following very simple model of the universe: a three-dimensional finite space stretches out through the distribution of masses. We therefore not proceed, like Newton, from the notion of an absolute space. In contrast to Newton's conception the space in our theory is bound to the existence of masses in the universe, that is: no masses, no space. The space is only formed from the existence of masses in the universe and can be measured section by section: the distance between two masses at rest vis-a-vis other masses in the universe can be determined through comparison with the extent of existing (fixed) masses in the universe.

We have to make a conceptual clarification at this point. The expansion of existing (fixed) bodies, that is, their suitability as a measuring stick, does not depend on their "mass" property but on the "matter" property. The latter is determined by strong, weak and electromagnetic interactions and in today's physical theory is described by the standard model of elementary particle physics. This differentiation is important here and will still be important later on elsewhere.

We can define, for example, the universe's center of gravity as the zero point (origin of the coordinate system) of the space. We initially limit ourselves to the examination of such processes where the expansion or shrinking of the universe can be disregarded. We therefore proceed from the image of a quasi-stationary state in relation to such processes.

We can also build a harmonic oscillator from some of the existing solid bodies whose oscillations determine the unit of time. If this clock is at rest relative to the masses in the universe, we will establish a temporally constant oscillation period that we can define as the unit of time, at least locally, that is, in the immediate environment of the clock. Therefore, just like with Newton, time and space are initially separate entities in our model. At a clock located at the universe's center of gravity, for example, we measure invariable oscillation periods and thus "uniformly flowing" time.

For reasons of mathematical simplicity, we initially place a test sample to be considered with mass m ("sample mass" in short) at the universe's center of gravity, that is, at the origin of the spatial coordinate system. We will have to examine random placements later on of course.

We now make a brief preliminary consideration to make the core of what we wish to work out as clear as possible: The Newtonian gravitational force between two masses, m and m_i, located at distance r_i, is given by

$$F = G \frac{m\, m_i}{r_i^2} . \tag{2.1a}$$

The mass m can be at rest (mass m_0) or can be moving. Whether there is a velocity dependence of m with respect to its gravitational property is open till this step of consideration. We will return later to this aspect (see chapter 3). The question of how the phenomenon of gravity and the force action (2.1a) have come into the universe we leave unanswered at this point, too. We assume that gravity is present everywhere in the universe and satisfies the law (2.1a) at any distance. Referring to the above mentioned experiments with entangled states we are not afraid of using this view of a long-range-order and instant action property of the gravitational force.

If masses m_i and m are initially located at an infinite distance from each other and then approach each other to a distance r_i, the following energy ΔE_i which before the approach was "hidden" as potential energy in the system of both masses is set "free":

$$E_i = - \Delta E_{pot,i} = - \int_{\infty}^{r_i} G \, \frac{m\, m_i}{r^2} \, dr = G \frac{m\, m_i}{r_i} . \tag{2.1b}$$

The potential energy of masses infinitely distant from each other is impossible to determine or measure. It can only be “computed” based on Newton's law of gravity. In contrast, the energy set free during the approach of both masses can be determined and measured. If the two approaching masses, for example, are not decelerated by impact or something else, then the energy set free can initially be identified as the kinetic energy of both masses, which can also be converted to other forms of energy at any time.

Let E_{u1} be the total internal energy of the universe **without** a sample mass at rest m placed at the origin, with the sample mass m in this state infinitely distant from all masses m_i in the universe. An observer at the origin will determine that there is no mass m. **With** a sample mass m this internal energy is greater than E_{u1} due to the sum of all “obtained” energies (2.1b) which the masses m_i have at distance r_i in reference to the location of m, that is, based on our examination, in reference to the origin. The value of this sum is given by

$$E = \sum_i G \frac{m\, m_i}{r_i} . \tag{2.1}$$

This formula applies to completely random distributions of masses in the universe. In order to work out the significant physical aspects and be able to make the simplest possible calculations, we will not examine this fairly general distribution below but limit ourselves to the scenario whereby the masses m_i in the universe (in sufficiently large volume elements) are evenly distributed at (constant) density ρ and up to a distance R_0 from the origin. We know that this is experimentally very well confirmed today.[5] By integrating the volume of the universe we get the following for this scenario:

$$E = G\, m\, \rho \int_0^{\pi} \sin\theta\, d\theta \int_0^{2\pi} d\varphi \int_0^{R_0} \frac{r^2}{r}\, dr = 2\pi\, G\, m\, \rho\, R_o^2. \tag{2.2}$$

The universe's internal energy therefore is greater by this amount vis-a-vis the scenario where there would be no m, which is the same way of saying that m is at an infinite distance from the origin.

You can interpret the existence of this energy in such a way that energy E_{ass} is assigned to mass m. If we select the abbreviation

$$b_0^2 = 2\pi\, G\, \rho\, R_o^2, \tag{2.3}$$

we can write:

$$E_{ass} = m\, b_0^2. \tag{2.4}$$

If we are precise, we must determine that this energy is not only “assigned” to sample mass m but is **existentially** connected to it: It does not exist without the sample mass (E_{ass} = 0 for m = 0) and it must be present if the sample mass exists (at the origin). Energy E_{ass} and sample mass m therefore form one physical unit. They represent inseparable elements of a physical entity which are both detectable and measurable in principle.

Due to the importance of this notion we wish to clarify it once again in another way and perform a thought experiment: We first remove a sample mass m conceived in the origin from this origin, and have it approach infinity. We assume that the mass available in the universe with density ρ up to its edge is so thinly distributed that the sample mass can move without colliding with other masses. The potential energy must first be expended in order to transport the mass to the edge (that is, to radius R_o) of the universe. It is identical to the potential difference between the edge ($R = R_o$) and the center of the sphere ($R = 0$), and for a homogenously filled sphere (that is, ρ = const.) it is:[6]

$$\Delta\tilde{E}_{pot} = \frac{1}{2} G\, m \frac{4\pi}{3} \rho\, R_o^2. \tag{2.5}$$

Based on our notion the universe ends at $R = R_o$. However, there is nothing initially in this notion to prevent the sample mass m from moving even beyond it conceptually if we have already brought it to the edge of the universe. We could, for example, shoot it further beyond with a canon perpendicular to the “surface” of the universe.

The energy needed to bring the sample mass from the edge of the universe to infinity is[6]

$$\Delta E_{pot} = G\, m \frac{4\pi}{3} \rho\, R_o^2. \tag{2.6}$$

The total potential difference between the position of the sample mass m at the origin ($R = 0$) and the position at infinity is then the sum of (2.5) and (2.6):

$$\Delta E_{pot\ tot} = 2\pi\, G\, m\, \rho\, R_o^2. \tag{2.7}$$

This is precisely in line with the energy E_{ass} which we “assigned” to the sample mass m according to (2.2) or (2.4). It is taken successively from the energy reservoir of the universe in order to bring the sample mass from the origin to infinity and is now found as potential energy in the gravitational field between the sample mass and the “remaining universe”, but again it might have to be “attributed” to this sample mass since an observer in the universe “left behind”, including at the origin of course, can determine nothing else experimentally than the fact that there is now no sample mass. The observer cannot perceive its gravitational effect and therefore its potential energy as well and hence cannot measure it. For the observer the sample mass does not exist. He will define the internal energy of the universe at E_{u1}.

If the universe with <u>infinitely distant</u> sample mass m has internal energy E_{u1}, then its internal energy E_{u2} <u>with</u> the sample mass m <u>at the origin</u> is greater by E_{ass}:

$$E_{u2} = E_{u1} + E_{ass}. \tag{2.8}$$

This additional energy is contained somewhere in the environment. However, since it only exists if the sample mass is located (moving or at rest) at the origin (and not outside the universe), then conceptually we can assign it to the sample mass and speak as though the sample mass had energy E_{ass}. In contrast to the universe with an infinitely distant sample mass, we now have a universe with an additional physical "object" that is made up of sample mass m and an "assigned energy" E_{ass}. The sample mass is a "solid", spatially local sub-object, while the "assigned energy" is a "non-solid", non-local sub-object. And to emphasize that both sub-objects form a physically inextricable interconnected unit, it seems appropriate to call this unit a "masson".

Equation (2.4) reveals a formal similarity of the description of the "object" with that of the correlation between mass and energy that Einstein discovered in his SR. We of course immediately ask whether there is more to this than just a purely formal relationship or whether b_0 is perhaps not identical to the speed of light. The quantities going into (2.4) - G, ρ and R_o - can basically be determined experimentally, and there are also measured values for them but they are of widely varying accuracy. While G can be measured very precisely, the value for ρ is fairly uncertain, and there are only estimates for R_o. For the visible part of the universe, values for R_o of about 1.3×10^{28} cm to approximately 10×10^{28} cm are indicated. If we now arbitrarily assume a value of 2.07×10^{28} cm, which lies within the range of values found in the literature (cf. for example[7]), then we find ourselves at

$$G = 6.674 \times 10^{-8} \frac{cm3}{g\ sec2} \text{ and } \rho = 5 \times 10^{-30} \frac{g}{cm} :$$

$$b_0 = \sqrt{2\pi G\rho}\ R_o = 3 \times 10^{10} \frac{cm}{sec}. \tag{2.9}$$

Then b_0 would really be identical to the speed of light c. Naturally (2.9) is still by no means evidence of the correctness of our assumption because the values given in the literature for ρ and especially for R_o are expressed with considerable caution and must still be considered uncertain today (perhaps even in principle) . But the value of b_0 at first glance appears to lie very much within the order of magnitude of c, and we can at least take (2.9) as an encouraging sign to explore the idea further that there is more to it than a formal relationship between (2.4) and Einstein's $E = mc^2$ formula.

Before we do this, we should note at this point that in our thought experiment involving the removal of a sample mass from the universe (or the introduction of one into the universe) we have disregarded the time between the beginning and end of the respective experiment. Provided masses could only be moved with finite velocity (SR!), this would raise the question as to whether such a thought experiment could have physical relevance at all due to the very long time needed for it given finite velocities. If we assume that it would certainly be feasible in principle given enough time, then the masses of the cosmos of course would move in this time, indeed as is actually the case (expansion of the universe since the Big Bang). For ρ and R_o the time averages to be determined over the length of the experiment would have to be (must) be considered. However, this does not appear to call our basic model of the universe into question.

And one more thing: Naturally our considerations invariably apply both to a universe with an inhomogeneous density distribution and to an unlimited, infinitely vast universe. For a density function that decays fairly strongly from a specific radius R_1 we get similar relations such as (2.3) and (2.5), of course with another value R_0' instead of R_0. But we shall stick to the very simple model of the universe chosen above because the easiest way to study and clarify basic relationships mathematically is with this model.

3. Velocity dependence of a mass in the universe

We again consider a sample mass (or better still: a solid test sample) placed at the origin but we now proceed from the aforementioned notion of a masson. This masson exhibits the following features:

It is characterized by a gravitational mass: m_g (3.1)

and by an "assigned energy": $E_{ass} = m_g b_0^2$. (3.2)

The mass is at the location of the solid body (the matter). Let us first leave open the question of where the "assigned energy" is located and in which form it exists.

Any change of the energy of the masson is given by

$$dE_{ass} = dm_g \, b_0^2 \, . \tag{3.3}$$

Let now an **external** force F (for example an electrical force, not the gravitational force of another mass!) act on the solid body. The energy transferred to the mass along a path element ds is then, according to Newton's law of inertia, given by:

$$dE_{in} = F\,ds = \dot{p}\,ds = (m_{in}\dot{v} + \dot{m}_{in}v)ds\,. \tag{3.4}$$

The mass m_{in} appearing in (3.4) is the inert mass associated with the solid body (matter). For what follows we now make use of experimental experience that inert and heavy mass always turn out to be proportional to each other when measuring their quantity, that is, they are "identical" when the right units of measurement are chosen. This means the two types of mass are indistinguishable both at rest and in motion, i.e. $m_g = m_{in} = m$. This assumption is the same as that underlying the principle of equivalence, an essential principle of GR. However, it takes its strong form there, namely in the sense that one cannot distinguish (locally) whether a sample mass under consideration is located in an accelerated reference frame or in a system in which gravity is working. For the theory formulated here, it is enough to assume the indistinguishability of both types of mass (weak principle of equivalence).

Let us again imagine the masses in the universe as homogenously distributed and as individual masses so far distant from sample mass m that we can disregard their direct gravitational effect on mass m in relation to force F. We therefore do not need to consider a direct force action of other masses in (3.4).

The amount of dE_{ass} and dE_{in} in (3.3) and (3.4) must be equal, and thus we find (with $m_{in} = m_g = m$):

$$dm\, b_0^2 = (m\dot{v} + \dot{m}v)\, ds\ , \tag{3.5}$$

and with ds = v dt we finally arrive at

$$\frac{dm}{m} = \frac{v\, dv}{b_0{}^2 - v^2}\ . \tag{3.6}$$

For v = 0 the mass m has to be equal to m_0 (= “rest mass”). And the Integration of m = m_0 to m and of v = 0 to v leads to

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{b_0{}^2}}}\ . \tag{3.7}$$

The total “assigned” energy of the masson is thus given by

$$E_{tot} = \frac{m_0}{\sqrt{1 - \frac{v^2}{b_0{}^2}}}\, b_0{}^2\ . \tag{3.8}$$

For v = 0, E_{tot} merges into rest energy $E_0 = m_0\, b_0{}^2$.

From (3.7) we get the following for momentum

$$p = mv = \frac{m_0}{\sqrt{1 - \frac{v^2}{b_0{}^2}}}\, v. \tag{3.9}$$

We know this expression from relativistic mechanics as the generalization of the relationship between momentum and velocity.

Using (3.9), (3.8) of course can also be written in the following form:

$$E_{tot} = \sqrt{(m_0 b_0^2)^2 + p^2 b_0^2}\ . \tag{3.10}$$

(3.9) and (3.10) represent the form conventionally used in SR for describing a moving mass by means of energy and momentum.

Equation (3.7) or (3.8) arises exclusively from Newton's law of gravity for a solid body in its (distant) environment and from Newton's law of inertia for this solid body (but with $m \neq \text{const.!}$), provided we set identical values for both of the solid body's properties of inert mass and gravitational mass. The initially undefined dependence m = m(v) in (3.2 to 3.4) must then clearly follow from both Newtonian laws (and the masses of the universe).

All prior relations in which the abbreviation b_0 appears were derived without referencing the speed of light. Equation (2.9) gave an initial indication that b_0 could be identical to the speed of light based on experimental quantities. And so now relation (3.7), which was also derived entirely without reference to the speed of light but has been fully verified experimentally for $b_0 = c$, is likewise strong evidence that b_0 really corresponds to the speed of light. And more than that: The mathematical description of a well-defined physical phenomenon has to be clear without ambiguity and must not depend on the way it has been derived. Therefore, we must conclude, that b_0 and c are identical. And it seems that the constancy of the light velocity in different inertial frames is caused by the remote masses of the universe (see also chapter 4.2).

What we gather from our previous considerations is that it is possible without running into contradictions to view a solid test sample, both at rest and in motion, as a masson and therefore as a quasiparticle whose environment is also admitted into the mathematical description. The masses in the universe here can be viewed as rigidly fixed, at least in the short time period in which the sample mass is considered. On this basis we find the correct description of experimental experience for both a masson at rest and a masson in motion. If there are no other masses nearby, its kinematics is determined by the “distant” masses of the universe following the action-at-a-distance principle. The speed of light is not included in the physical derivation.

The physical concept of a moving masson shows similarity with the concept of a polaron where a phonon cloud moves around an electron and produces an effective mass for this polaron. This image of a quasiparticle seems to allow us to describe a solid body in the environment in an adequate physical sense, and it seems to fulfill Mach’s requirement.

Of course, we will have to examine modifications of our model assumptions (for example, non-homogeneous mass distribution, or non-abrupt and uniform density reduction at the edge of the universe). Some elementary considerations in this respect are to be found within the subsequent chapter 4.

4. First consequences, evaluations and new questions

4.1 Short-range/long-range interaction– local/non-local

Since the theory expounded here is based on Newton's law of gravitation, it recognizes that all masses in the universe constantly and instantaneously interact with each other. Therefore, the theory developed is also an action-at-a-distance theory. On the other hand, it yields the result that masses evidently cannot be accelerated beyond b_0 because the energy would otherwise approach infinity according to (3.8). Hence the existence of an action - at - a - distance and simultaneously of a maximum velocity for masses seems not to be a contradiction (see further remarks under 4.2)).

4.2 Transformation properties

If $b_0 = c$, then equations (3.7) and (3.8) are identical to those that Einstein discovered in SR. He derived these equations from two experimental experiences, namely the constancy of the speed of light in reference frames moving relative to each other and the requirement that natural laws in reference frames moving uniformly relative to each other must be transformable into each other by means of linear coordinate transformation (principle of relativity). His goal in this approach was to resolve the different transformation behaviors of electrodynamics (Lorentz-invariant) and mechanics (Galileo-invariant). It was shown that this is only possible if both spatial coordinates and time simultaneously are transformed in all physical laws. Lorentz transformation supersedes Galilean transformation for spatial coordinates and a non-transformed universal time, transforming space and time simultaneously. Relations (3.7) and (3.8) then arise from the transformation relations in a mathematically explicit way. Tolman physically illustrated this in his elegant thought experiment.[8] Here he assumes, apart from the validity of the Lorentz transformation, only the third axiom of Newton, namely the conservation of total momentum.

We have arrived at relations (3.7) and (3.8) in an entirely different way. Since Tolman's experiment only involves elastic collisions with ideally smooth balls, these steps can be performed in reverse order. Consequently, vice versa the Lorentz transformation also follows from the validity of relations (3.7) and (3.8) for test samples moving uniformly relative to each other.

In our derivation the principle of relativity does not have to be assumed. It is already in Newton's equations of motion which we in fact have taken as the starting point of our considerations. The constancy of the speed of light in moving light sources also does not have to be assumed. It is shown rather that moving light sources and light receivers – like all masses – are subject to Lorentz contraction. This result is in line with the image that Lorentz proposed in 1892 in a purely formal way without any physical justification in order to describe moving bodies correctly in the context of Maxwell's theory.[9] We have found the physical justification here. The variable b_0 defined by the environment goes into the contraction formula and is equated with the speed of light.

We can then very much take the view that there is a prevailing proper time in every reference frame moving uniformly relative to another, as it happens in SR. However, this representation seems like a phenomenological description which has deeper underlying causes. Based on the theory developed here, space and time are linked to each other by Newton's laws in the actually existing universe. Minkowski's theory of four-dimensional spacetime can be retained and used for the elegant description of motion in space and time. And it now has a deeper underlying cause. The inertia of mass and the laws of motion for a mass point are not attributed to properties of spacetime (as with Einstein/Minkowski) but are rather a consequence of Newton's laws in the actually existing universe. “Spacetime” is derived from more fundamental quantities in our theory. The “actually existing universe” is included in our theory with the model representation of a finite, spherical, homogeneous mass distribution.

Further assumptions are unnecessary. However, in this interpretation the universe with all its masses represents a preferred reference frame relative to which other frames can move. Based on the special form of the Lorentz transformation (group property), one can view reference frames in uniform motion relative to each other or relative to the universe as (mathematically!) equivalent or not preferred among each other. Therefore, it follows also for light sources (having always a mass) that the description of their motion is Lorentz invariant. This explains the constancy of the speed of light in all inertial systems. In this paper, therefore, we have found something similar to a luminiferous “ether” for the propagation of light, without having to look for it, but in a way entirely different from the approaches employed from the time of Lorentz to this day. We arrive at it completely naturally from Newton's laws alone, without any auxiliary hypotheses or model representations. The universe with all its masses represents a kind of “ether”!

Our finding is identical with Einstein’s finding within his SR: The mass-related phenomena of mechanics are subject to the same Lorentz’ transformation properties, which Maxwell’s equations have to obey. This fact leads immediately to the question, whether there are deeper interrelations between gravitational and electro-magnetic phenomena. Or, referring to our derivation above: Are the remote masses of the universe also causative or co-determining for Maxwell’s laws? There will be a basic approach to this question in another paper.[29]

We have to mention another aspect related to all physical phenomena underlying Lorentz transformation properties: One can show (see e.g. [26] p. 30) that for those phenomena information transfer is only possible with a transfer velocity $v_s < c$ (= b_0), otherwise causality would be violated. Therefore, it seems that we should better speak on a “force-at-a-distance” rather than on an “action-at-a-distance” principle when considering Newton’s law of gravity. And we have also to mention that, up to now, it is unfathomed whether and how there is a relationship between this “force-at-a-distance” phenomenon and the nonlocal character of quantum phenomena mentioned in the introduction.

4.3 Local dependence of the speed of light

The relations discovered almost necessarily suggest that the speed of light coincides with the variable b_0 introduced here. If this is correct, the speed of light would not be a universal constant but a variable derived from several parameters of the universe.

Relation (2.3) or (2.9) only applies in the event the test sample is located at the origin. If on its way from infinity it has not yet arrived at the origin but is (presently) at rest, for example, at distance r from the origin, then it has until then emitted only a part of its potential energy to the environment, namely (cf. e.g. Demtröder[6])

$$\Delta E_{pot \infty r} = \Delta E_{pot\ ges} - \Delta\tilde{E}_{pot}(r) = 2\pi\ G\ m_0\ \rho\ R_o^2 - \frac{1}{2}\ G\ m_0\ \frac{4\pi}{3}\ \rho\ r^2$$

$$= 2\pi\ m_0\ G\ \rho\ (\ R_o^2 - \frac{1}{3}\ r^2\ ). \qquad (4.1)$$

The remaining potential energy $E_{mro} = \frac{1}{2}\ G\ m_0\ \frac{4\pi}{3}\ \rho\ r^2$ we assign to the test sample at position r. It does not appear in the test sample's environment.

We can also write equation (4.1) as

$$\Delta E_{pot \infty r} = m_0\, b^2 \qquad (4.2)$$

where

$$b = \sqrt{2\pi\ G\ \rho\ (\ R_o{}^2 - \frac{1}{3} r^2\ )}\ . \qquad (4.3)$$

Our previous results suggest that b is identical to the speed of light c, and equation (4.1) or (4.3) demonstrates that b is not a universal constant but depends rather on the position of the light speed observer within the universe (i.e. his distance from the origin of the universe). This is different to what Einstein had discovered during his way from the special to the general theory of relativity (GR), because (2.9) and (4.3) are caused by the “distant” masses of the universe, whereas Einstein considered “local” or “near” masses.[10,11] (see also[12] and section 5). However just recently there was a publication possibly confirming (4.3).[13]

4.4 Expansion of the universe

The speed of light can be measured today in the laboratory with a relative accuracy of approximately 10^{-9}[14]. If we develop (4.1) into a series, for $r \ll R_o$ we can write:

$$b \approx \sqrt{2\pi G\, \rho}\ R_o\ (1\ -\ \frac{1}{6}\ \frac{r^2}{R_0^2}). \qquad (4.4)$$

To enable us to determine in a measurement at position r a deviation from the measured value compared to a measurement at the origin, the following must then apply:

$$\frac{1}{6}\,\frac{r^2}{R_0^2} > 10^{-9} \qquad (4.5)$$

or

$$r^2 > 10^{-9}\ 6\ R_o^2. \qquad (4.6)$$

If R_o takes the value 1.3×10^{28} cm, then r must at least be around 10^{24} cm, allowing us to measure in a laboratory a deviation at position r compared to a measurement at the origin. This corresponds to a distance of about a million light-years.

If we are observers at the origin, then we of course cannot install a laboratory a million light-years away in order to measure a different speed of light that might exist there. However, the local dependence of the speed of light would basically yield an interesting consequence: The redshifts of light sources at different distances from the origin and of the spatially varying speed of light differ from the redshifts that would result if the speed of light were assumed to be locally independent. For the recession velocity v the redshift z is given by

$$z = \sqrt{\frac{c+v}{c-v}} - 1 \tag{4.7}$$

At delay difference Δt between the beginning and end of a signal period, the following applies even to stars that emit light signals at very precise and consistent time intervals τ (so-called standard candles):

$$\frac{\Delta t}{\tau} = \frac{v}{c} \tag{4.8}$$

We obtain an increased redshift compared to (4.7) or a greater delay difference compared to (4.8) not only when the light source moves at higher velocity but also when the speed of light, at which the light travels from the light source to the observer, is on average less than c. This is exactly the case according to (4.3) if the comparison light source is farther away from the observer (conceived at the origin) than the reference light source. The effect is currently not measurable for $r < 10^{24}$ cm. However, the farther beyond the light sources are, the clearer the effect. The obvious question here is whether the escape velocities measured against distant standard candles and assuming the same value for the speed of light everywhere are not in fact smaller. This could be verified if new calculations were done taking (4.3) into consideration and were compared with existing experimental results. This potentially could affect the hypothesis of an accelerated expanding universe. (See also chapter 4.7)).

4.5 Extent of the universe

The velocity-dependent increase of a moving mass according to (3.10) can be observed experimentally[15]. Consequently, the value of b_0 is also determined experimentally. G is known. If the value of ρ can be measured or estimated in a plausible manner, then by virtue of correlation (2.3) the extent R_0 of the universe can also be determined or estimated.

If we assume, that the edge of the universe can proceed with the maximum velocity b according to (4.3), the radius of the universe expands with

$$R_0(t) = b\,t = \sqrt{2\pi\, G\, \rho\, \frac{2}{3}\, R_o{}^2}\; t = \sqrt{G\, \frac{M}{R_0}}\, t$$

or

$$R_0(t) = \sqrt[3]{GM}\; t^{2/3}\,. \tag{4.9}$$

This proportionality between R_0 and $t^{2/3}$ has already been proposed by Dirac in 1939[16].

4.6 Origin of the universe

If the universe were to have developed from an originally very small point (with an "early" diameter r_0), then at the initial phase of birth the maximum propagation speed at the edge of a spherical initial point would be given by (cf. (4.3))

$$b' = \sqrt{2\pi\, G\, \rho\, \frac{2}{3} r_o^2} = \sqrt{G\, \frac{M(t)}{r_0}}\,. \qquad (4.10)$$

M(t) here is the total mass of the universe at time t after the Big Bang. Depending on the rate of formation of masses during the initial phase of the universe, the maximum possible propagation speed at the edge could have been different from today's speed of light. This has been studied theoretically recently[13] and the authors have concluded that the speed of light in the early phase after the Big Bang was very much higher than what it is today. Their theory yields calculable and in principle also measurable values. Through comparison with it we have another possibility of confirming or rejecting the theory presented here. Moreover, there are indications that the fine-structure constant in the early development phase of the universe could have been less than what it is today[17], and this would also be compatible with a higher value for b'.

4.7 Rest energy of the universe and dark energy

At first view it seems, that we can write for the rest energy of a volume element dV at any distance r from the origin of the universe (see (4.3)):

$$dE'(r) = m_0(r)\, b^2(r) = \rho(r)\, dV(r)\, 2\pi\, G\, \rho\, \left(R_o^2 - \frac{1}{3} r^2 \right), \qquad (4.11)$$

and for a homogeneous mass distribution $\rho(r) = \rho_0 = \text{const.}$:

$$dE'(r) = \rho_0^2\, 2\pi\, G\, \left(R_o^2 - \frac{1}{3} r^2 \right) \sin\theta\, d\theta\, d\varphi\, r^2\, dr. \qquad (4.11a)$$

Integration over $d\theta$ and $d\varphi$ yields the rest energy of a thin shell at distance r:

$$dE(r) = 8\, \pi^2\, \rho_0^2\, G \left(R_o^2 - \frac{1}{3} r^2 \right) r^2\, dr. \qquad (4.12)$$

If we integrate (4.12) from r = 0 to r = R_0 we find for the "rest energy of the universe":

$$E_{u0} = G\, \frac{4x8\, \pi^2}{3x5}\, \rho_0^2\, R_0^5. \qquad (4.13)$$

But the formulas (4.11) to (4.13) are based upon the consideration of a specimen mass m_0 within the universe as it exists today. The process of its formation has not been taken into account, but this is necessary when calculating the total rest energy of the universe. This can be seen, if we investigate the “reverse process”, i.e. if we start from the universe as it is today and remove then step by step the outmost shells of it and transport it to infinity. The mass of the outmost shell (at radius R_0) is given by

$$dm(R_0) = 4\,\pi\, R_0^2\, \rho_0\, dr \,. \tag{4.14}$$

To move this mass from R_0 to ∞ against the gravitation field of the remaining mass of the universe we need the energy

$$dE'' = G\,\frac{4\pi}{3} R_0{}^3 \rho_0 \int_{R_0}^{\infty} \frac{4\,\pi\, R_0^2\, \rho_0\, dr}{r^2} \tag{4.15}$$

or

$$dE'' = G\,\frac{4\pi}{3} R_0{}^5\, \rho_0^2\, \frac{4\,\pi}{R_0}$$

And if we repeat this removal for all shells from r’ = R_0 to r’ = 0 we find the total energy, which is needed to remove the total mass of the universe to infinity:

$$\Delta E = \mathrm{I}\ G\,\frac{4\pi}{3} \rho_0^2 \int_{r'=R_0}^{0} 4\,\pi r'^4\, dr'\ \mathrm{I} = \mathrm{I}\ G\,\frac{16\,\pi^2}{3\mathrm{x}5} \rho_0^2\, R_0{}^5\ | \,. \tag{4.16}$$

In the reverse process the potential energy of all masses being transferred from infinity into the finite universe is transformed into internal energy of the universe. According to the considerations of the above chapters 2 and 3 this energy is identical with its “rest energy”.

The value of (4.16) is half of the value of (4.13). Accordingly, the corrected value of the rest energy of a thin shell dE’(r) amounts to half of the value of (4.12).

Let us now consider a force F(r) acting on a mass element dm = ρ_0 dV(r) along a path element dr. The energy of the mass element is then increased along dr by

$$dE_F = F(r)\, dr \,. \tag{4.17a}$$

Since dE_F has to be equal to dE’(r), the force between adjacent shells (if ρ_0 = const(r) and dr $\ll$ r) is thus determined and given by

$$F(r) = \frac{dE'(r)}{dr} \,. \tag{4.17b}$$

Referring the force (4.17b) to the surface area A(r) of the shell we find for the pressure:

$$p(r) = \frac{F(r)}{A(r)} = \pi\ \rho_0{}^2\, G\, \left(R_o{}^2 - \frac{1}{3} r^2 \right). \tag{4.18}$$

Obviously, this pressure forces the universe to expand. Is it fallacious to assume, that the rest energy of the universe as defined by (4.18) might be connatural to the “dark energy" widely assumed in present physics as cause for the expansion of the universe found by measurements? This, of course, is a speculation and has to be investigated in detail, including possible revisions of the recession velocities as discussed under chapter 4.4).

4.8 Inhomogeneous mass distribution

In the preceding chapters we assumed a homogeneous distribution of masses in the universe, i.e. a constant mass density ρ_0, and we were considering only the influence of remote masses onto a specimen mass m_0. These assumptions are not necessary, and a complete generalization to a non-homogeneous and arbitrary distribution is possible, but not intended here; it would by far exceed the frame of this paper. However, we will have a first look onto the special case of a single mass M, which is added to the homogeneous distribution with density ρ_0, having the distance R to a specimen mass m at the center of the universe.

Instead of (2.1) we find for the internal energy of the (static) universe with respect to a specimen mass m_0 in rest:

$$\Delta E_{pot,o} = \sum_i G\frac{m_o m_i}{r_i} \;\rightarrow\; \Delta E'_{pot,o} = \sum_i G\frac{m_o m_i}{r_i} + G\,\frac{m_o M}{R}\,, \tag{4.19}$$

and instead of (2.3) and (2.4):

$$E_o = m_0\, b_0'^2 \quad \text{with} \quad b_0'^{\,2} = 2\pi\, G\, \rho\, R_o^2 + G\,\frac{M}{R}\,. \tag{4.20}$$

Let us now consider a moving test mass m close to the origin of the universe exactly as in chapter 3, but now with the additional mass M at distance R from this origin. In this case the gravitational force of the mass M has to be added to the external force F, and (3.6) has to be changed in:

$$dE'_{F'} = \mathbf{F}d\mathbf{s} + G\frac{Mm}{r^2}\,\mathbf{e}_r\, d\mathbf{s} = (m\dot{\mathbf{v}} + \dot{m}\mathbf{v})\, d\mathbf{s}\,. \tag{4.21}$$

This nonlinear differential equation cannot be integrated as easily as (3.8). But for a first exploration of basic properties, we can arbitrary choose the direction of **F** towards the center of the mass M, i.e. d**s** = d**r**, and we find

$$F dr + G\frac{Mm}{r^2}\, dr = (m\dot{v} + \dot{m}v)\, dr. \tag{4.22}$$

Before we are going to solve this equation, we are considering the change of the potential energy of the mass m when approaching the mass M (the mass m shall be in rest at the beginning and end of the change):

$$dE_{pot,M} = G\frac{Mm}{r^2}\, dr. \tag{4.23}$$

We integrate from r = R to r = R_1:

$$\Delta E_{R,R1} = \int_R^{R1} G\frac{Mm}{r^2}\,dr = -G\frac{M<m>}{RR1}(R - R_1), \tag{4.24}$$

whereas $< m >$ is the mean mass between m(R) and m(R_1). The loss of the potential energy of the mass m in the gravitational field of M according to (4.21) obversely elevates the internal energy of the universe, i.e the energy of the “masson” (see chapter 3):

$$\Delta E_u = -\Delta E_{R,R1} = G\frac{M<m>}{RR1}(R - R_1). \tag{4.25}$$

We can write (4.25) in the form

$$\Delta E_u = \frac{<m>}{R1}(R - R_1)\frac{GM}{R} = \Delta m\frac{GM}{R}, \tag{4.26}$$

i.e. we can interpret the energy gain of the universe to be proportional to the increase of the mass

$$\Delta m = \frac{<m>}{R1}(R - R_1) = \frac{<m>}{R1}\Delta R. \tag{4.27}$$

For infinitesimal changes in the vicinity of R the relation (4.27) merges into

$$dm = \frac{m}{R}\,dr, \tag{4.28}$$

and we can write (for r close to R)

$$dE_u = dm\frac{GM}{R}. \tag{4.29}$$

Based on this previous consideration of the change of the potential energy we can solve equation (4.22). Embracing (4.29), we have to write instead of (3.5):

$$dE'_{ges} = dm\, b_0'^{\,2} + dm\frac{GM}{R} = dm\left(b_0'^{\,2} + \frac{GM}{R}\right) = dm\, b_0''^{\,2}. \tag{4.30}$$

with $$b_0''^{\,2} = b_0^2 + 2\frac{GM}{R} = b_0^2\left(1 + 2\frac{GM}{Rb_0^{\,2}}\right). \tag{4.31}$$

As in chapter 3 one has also to stipulate here:

$$dE'_{F'} = dE'_{ges}, \tag{4.32}$$

and we find in close analogy to (3.9):

$$\frac{dm}{m} = \frac{v\,dv}{b_0''^2 - v^2}. \tag{4.33}$$

or

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{b_0''^2}}}. \tag{4.34}$$

The rest energy is given by

$$E_0' = m_0\, b_0'^2 + m_0 \frac{(R-R_1)}{R_1} G \frac{M}{R} \tag{4.35}$$

or, if $\frac{(R-R_1)}{R_1} \ll 1$: $E_0' = m_0\, b_0'^2$. (4.36)

Eventually we find approximately

$$E' = \frac{m_0\, b_0'^2}{\sqrt{1-\frac{v^2}{b_0''^2}}} . \tag{4.37}$$

On the basis of (4.20) to (4.37) the trajectory of a mass m moving around the mass M (whereas **F**, $\mathbf{e}_r$ and d**s** do not point into the same direction) can be calculated (e.g. for mercury around the sun). The formulas contain terms with the Schwarzschild radius $r_s = 2\frac{GM}{b_0{}^2}$, leading to trajectories, which are not closed for one loop, and therefore leading to a perihelion precession. It has to be examined, whether the results are in accordance with the results of GR or whether there will be deviations. This shall not been carried out within the framework of this paper and is left to future investigation.

5. Comparison with previous considerations and theories

In sections 2 and 3 we have seen, how the masses of the universe determine the inertia of a single mass. The derivation leads to the same formulas as they result from SR, but with a parameter b_0 instead of the velocity c of light. Because of the fact that one and the same phenomenon must be described by one and the same formula, irrespective of the way it has been developed, we conclude, that b_0 must be identical with c. Our derivation is based upon the influence of all masses of the universe on the mass considered, i.e. our derivation is fulfilling Mach's requirement. Einstein's derivation of the SR is based on the constancy of light velocity, which is in line with experimental findings (e.g. Michelson's experiment), but nevertheless is a postulate, and there is (at least directly) no connection to the masses of the universe. The light velocity c is considered to be a universal natural constant. In this method of approach the SR is not related to Mach's requirement. Gravitation and the masses of the universe are not included directly in the SR. But the conformance of the theory developed here and the SR suggests itself, that there is a "hidden" interconnection between light and gravity. Within the framework of the SR this interconnection is interpreted as a fundamental property of space and time, Minkowski's "space-time". The derivation given here in sections 2 and 3 do not support this interpretation, on the contrary: The Lorentz transformation is found without any reference to light and is directly determined by the masses of the universe. The constancy of light velocity is not involved and might have causes not understood up to now.

This hidden interconnection between light velocity and the masses of the universe was first discovered by Dicke.[18] He investigated the property of a light beam when passing the sun and found a relation between the dielectric “constant” of the vacuum and the mass of the sun:

$$\epsilon \cong 1 + \frac{2GM}{r}, \tag{5.1}$$

where G is the gravitational constant, M is the sun’s mass, and r is the distance from the sun.

His derivation was based upon the assumption that gravitation should be electro-magnetic in origin and that the “vacuum” has the effect of a polarizable medium on a hydrogen atom. With further assumptions he calculated the variation of the refractive index about the sun, which is “required to obtain a deflection of light of the amount expected and observed”. This way he found (5.1). He stated that the second term is clearly associated with the presence of the sun, and then he put the question: “What about the first term? Does it have its origin in the remainder of the matter in the universe?”. To investigate this possibility he formed the integral

$$2G \int_0^R \frac{4\pi\rho r^2}{r} dr = 4\pi G\rho R^2. \tag{5.2}$$

Then he inserted the appropriate value for G and assumed $R = 5.4\text{x}10^{27}$ cm, $\frac{\rho}{c^2} = 4 \text{ x } 10^{-29}$ g/cm^2 and thus found (5.2) to be equal to unity (with the units choosen by him). This result is similar to our result in (2.3) if it is assumed, that $c = b_0$. Dicke did not derive his finding from basic laws, and he described it himself as an “interpretation”. In any case it stems from light properties, and it is open, which physical mechanism would be responsible for the correlation between light (i.e. an electro-magnetic phenomenon) and gravity. But in spite of the number of assumptions not justified by first principles he “discovered” the relations (5.1) and (5.2), giving a hint on the interconnection between light and the masses of the universe.

Such an interrelation was first described by Einstein on his way from special to general relativity by postulating his principle of equivalence between a system with a gravitational field and a uniformly accelerated system, which should apply for **all** laws of physics.[10,11] Applying the results of the SR he found for the light velocity within a gravitational potential Φ :

$$c = c_0 \left(1 + \frac{\Phi}{c^2}\right). \tag{5.3}$$

Referring to Huygens principle he concluded that a light beam should be bent in a gravitational field in the same way as in an accelerated system. The potential Φ must not be caused by the distant masses of the universe and therefore the second term in (5.3) is not indicating Mach’s principle, but according to Dicke, the first term could. Einstein was apparently not aware of this “hidden” property. In his early years Einstein considered himself as “follower of Mach”, but later on he seemed not to consider Mach’s principle “as a useful fundament for a new theory”.[19]

After Einstein (1908/1911) and before Dicke (1957) at least two other scientists were considering this topic, namely Schrödinger and Sciama:[20,21]

Schrödinger tried to find a physical law in order to explain inertia in line with Mach's principle. He established an ad hoc Ansatz in a certain analogy to Newton's law of gravity and some "heuristic" requirements. Based upon the relation found he calculated the perihelion precession of a planet and compared the result with the respective result of the GR for Mercury and thus determined a parameter γ contained within his ad hoc formula to be $\gamma = \frac{3}{c^2}$. Eventually he found the following relation:

$$c^2 = 4\pi\,\rho\,G\,R^2. \tag{5.4}$$

This is quite similar to (2.3), but the physical meaning of R was open. He concluded, that R has to be much larger than the diameter of our galactic system, because otherwise the inertia of a mass would show anisotropy, whereas if the masses of the universe would be contained within a sphere of radius R one could expect c^2 to be isotropic.

One can see that he also "discovered" an interrelation between c and the masses of the universe, but he did not derive this from basic physical laws and he also needed the GR for "calibrating" his ad hoc formula. Therefore, his result was a consequence of the GR in which the interconnection with c is "hidden".

A similar attempt was independently undertaken also by Sciama.[21] He tried to develop "the simplest mathematical scheme to describe that matter has inertia only in the presence of other matter" and established an ad hoc formula for the description of gravitational effects in a formal analogy to Maxwells equations. In his book of 1969 he simplified his approach and "assumed that the inertial action has a similar structure as the Coulomb law".[22] He needed to introduce "the c^2 factor for dimensional reasons". With some further considerations he found the formula

$$G = \frac{c^2}{2\pi\rho\,R^2}\,, \tag{5.5}$$

which is formally identical with (2.3). He stated that "the gravitational constant at any point is determined … by the distribution of the matter in the universe", assuming that the light velocity is a natural constant. Also in this case the derivation was not based upon basic laws but on an analogy, and the light velocity was introduced through this analogy (Maxwell's laws).

The physical essence behind all these considerations is the question to which extent Mach's principle is contained or not contained in the GR. This question was the topic of a long lasting "controversy" between Einstein and de Sitter,[23] and was treated afterwards at length on several occasions, e.g.[24,25] Till this date this question seems not to be completely answered (see e.g.[26] p.181/182). It has been examined also recently, see e.g.[27]. Here a fifth dimension has been introduced into the framework of GR in order to explain inertia. Therefore, also this author like all the others mentioned above relies on light properties contained in SR, GR or Maxwell's equations. It seems that the possibility of the derivation as described here in sections 2 and 3 was not noticed by all of them.

Our considerations and calculations show that the impact of all "distant" masses of the universe on a specimen mass m is included already in the SR, i.e. Mach's principle is contained in it. The postulate of the constancy of the light velocity is not required for the derivation. Instead, a particle approach and the principle action-at-a-distance are used for the description of the influence of the masses of the universe. The derivation and the results do not contradict neither SR nor GR. As far as Einstein's deliberations from SR to GR are valid, these deliberations can also be used to transfer the theory presented here to GR, which also admits calculation of motions of masses in locally very inhomogeneous mass distributions. However, extending the derivation in chapter 3 to inhomogeneous mass distributions, that is, consideration of masses located near the sample mass m in equations (2.1), would result in (nonlinear) equations of motion for the local masses, deviating from Newton's description, where the distant masses are not taken into account. In this case Einstein's (strong) equivalence principle is not required as a postulate, but possibly will arise as a consequence. Whether the equations of motion in GR (or alternatives to it) will result in this manner must of course be studied. However, this exceeds the established framework of this paper.

6. Gravitational waves and light

The quantities b_0 and b (cf. (2.3), (2.4), (3.10), (3.11) and (4.3)) have the dimension of speed and very much appear to coincide with the speed of light. But light and the speed of light do not appear at all in the derivation of the equations. The natural question therefore is what physical nature does "speed" b_0 have and how can a possible relationship with the speed of light emerge. It is definitely related to gravity. If a physically meaningful and measurable speed value can be found for b_0, then according to (2.3) this must be related to the gravitational constant G and the universal variable ρ, as well as depend on the extent of the universe R_0. The latter requirement appears odd at first glance, but it implies that a physical variable at a certain location, that is, a local variable, should depend on the overall extent of the universe. On the other hand, however, this is just not surprising because this paper is based on Newton's action-at-a-distance theory of gravity: gravity acts instantaneously and everywhere, even across the greatest distances. Schrödinger alluded to this feature ("action in distans"), but was in doubt whether it could be harmonized with the finite velocity of propagation resulting from the SR.[20]

If b_0 must now be identical to the speed of light, on the one hand, and be related to gravity, on the other, then evidently we must look for a resonating system that is gravitationally and electromagnetically defined. We will describe this in detail in another paper.[29] Here, we only give an overview with the most important considerations.

We first move away from the previous very simplified model representation where we viewed the universe as static, that is, with spatially fixed masses (“fixed stars”). We want to see it more as a structure in which individual volume elements can move relative to each other, as it is indeed the case in reality, reminding us of the properties of the simplest resonating object made of mass points, namely a linear chain. In its familiar form such a chain consists of individual punctiform masses located along a straight line, each at distance a from each other. They are usually linked in linear fashion by springs with spring constant D.

If you consider only longitudinal deflections and force action only between the closest neighbors, then the nth mass with deflection s_n is subject to spring forces

$$F_{n,n+1} = D\,(s_{n+1} - s_n) \tag{6.1}$$

$$F_{n-1,n} = D\,(s_{n-1} - s_n), \tag{6.2}$$

producing the equation of motion

$$m\,\ddot{s}_n = D\,(s_{n+1} + s_{n-1} - 2s_n). \tag{6.3}$$

We find wave solutions with the approach

$$s_n = s_0\, e^{-i(kan-\,\omega t)}. \tag{6.4}$$

The dispersion relation is expressed by

$$\omega(k) = 2\sqrt{\frac{D}{m}}\,\left|\sin\left(\frac{ka}{2}\right)\right|. \tag{6.5}$$

Let us now consider a chain whose masses, in turn, are lined up in a row (for the moment, at the beginning) at distance a from each other. They do not exert spring forces on each other but attract each other according to Newton's law of gravity. If we, in turn, only consider the closest neighbors and longitudinal deflections, then we have (for the moment) the gravitational forces on mass n:

$$F_{G\ n,n+1} = G\,\frac{m^2}{(a+ s_{n+1}- s_n)^2} \tag{6.6}$$

$$F_{G\ n-1,n} = -\,G\,\frac{m^2}{(a+ s_n- s_{n-1})^2}\,. \tag{6.7}$$

Let us assume that (longitudinal) deflections are very much smaller than the distances a, then the following applies approximately

$$F_{G\ n,n+1} = G\,\frac{m^2}{a^2}\left(1 - 2\left(\frac{s_{n+1}- s_n}{a}\right)\right) \tag{6.8}$$

$$F_{G\ n-1,n} = -\,G\,\frac{m^2}{a^2}\left(1 - 2\left(\frac{s_n- s_{n-1}}{a}\right)\right). \tag{6.9}$$

And with the abbreviation $D_1 = 2G\frac{m^2}{a^3}$ we arrive at the equation of motion

$$m\,\ddot{s}_n = -\,D_1\,(s_{n+1} + s_{n-1} - 2s_n\,). \tag{6.10}$$

Compared with (6.3), we see the negative sign before the coupling constant, and approach (6.4) in this case leads to purely imaginary values for ω(k):

$$\omega(k) = i\,2\,\sqrt{\frac{D}{m}}\,\left|\,\sin\left(\frac{ka}{2}\right)\right|. \tag{6.11}$$

Longitudinal wave propagation is obviously impossible on such a chain.

Next, we want to consider transverse waves of a linear chain whose mass points exert gravitational forces on each other and we, in turn, only consider the closest neighbors.

We again designate deflections of the nth mass perpendicular to the chain line (for example, in the z direction) with s_n. The gravitational attraction between neighboring masses is then:

$$F_{G\,n,n+1} = G\,\frac{m^2}{a^2+(s_{n+1}-s_n)^2} \quad \text{and} \quad F_{G\,n-1,n} = -\,G\,\frac{m^2}{a^2+(s_{n-1}-s_n)^2}. \tag{6.12}$$

For the z components of these forces we get

$$F_{G\,n,n+1,z} = G\,\frac{m^2}{a^2+(s_{n+1}-s_n)^2}\,\frac{s_{n+1}-s_n}{\sqrt{a^2+(s_{n+1}-s_n)^2}}$$

and (6.13)

$$F_{G\,n-1,n,z} = G\,\frac{m^2}{a^2+(s_{n-1}-s_n)^2}\,\frac{s_{n-1}-s_n}{\sqrt{a^2+(s_{n-1}-s_n)^2}}.$$

If we disregard terms of order s^2 and higher, we find the following equation of motion:

$$m\,\ddot{s}_n = D_2\,(s_{n+1} + s_{n-1} - 2s_n\,) \tag{6.14}$$

with

$$D_2 = G\frac{m^2}{a^3}. \tag{6.15}$$

In terms of form, this equation is identical to equation (6.3) for a chain whose elements are bound to each other by spring forces. If we now stack these chains beside and above each other, we get a lattice that should allow transverse oscillations as described in the lattice theory of solid state bodies.

In a forthcoming paper [28] we describe a homogeneous universe with mass density ρ (constant everywhere) through such a lattice model whereby we view a snapshot in which distance a between lattice points is constant. In this paper we also consider interactions not only between next neighbors, but between all neighbor mass points.

Such a model appears to admit plane “gravitational waves” which exhibit the universal expansion R_0 perpendicular to the direction of propagation and as a good approximation travel at the following propagation speed

$$\frac{d\omega}{dk} = \sqrt{2\pi G\rho R_0^2} \ . \tag{6.16}$$

This propagation speed coincides with the variable b_0 (cf. (2.3)). We do not want to call these waves “gravitation waves” because this name is reserved today for waves in space-time, which result from the general theory of relativity. The extent to which a relationship exists between both types of gravity-related waves still needs to be clarified. And, there is another interesting relationship certainly to be investigated: If such gravitational waves as described above are existing anywhere in the universe, they will interact with every test mass in the universe wherever it might be located. Therefore, any test mass must necessarily show some wave properties. Is there a fundamental link to quantum mechanics?

In another paper [29] we examine a further aspect, namely how plane, universally expanding “gravitational waves” can link with plane electromagnetic waves. This is possible through the existing plasma in the universe made of electrically charged particles, and leads to a situation where the direction and propagation speed of electromagnetic waves must coincide with the direction and propagation speed of “gravitational waves”.

7. Summary and conclusion

It seems as if the results of the special theory of relativity can be derived solely on the basis of both Newton's laws for inert and heavy masses and on the equivalence of inert and heavy mass. Light and its properties play no role in the derivation. We likewise do not need to examine reference frames (inertial systems) moving relative to each other. It is clear that the fundamental property of Newton's law of gravity, namely that gravity is to be understood and described as an action-at-a-distance, is not inconsistent with a maximum speed at which solid bodies can move. This maximum speed can be calculated from fundamental quantities of the universe, namely the gravitational constant, its density and its extent. It is not a universal natural constant but depends rather on the position of the moving body in the universe, among other things, and appears to be identical to the speed of light.

The reason for this is that in the theory presented here Newton's law of inertia is related to Newton's law of gravity, whereby all masses in the universe interact instantaneously (action-at-a-distance) with each other, right up to the edge of the universe. Everything interacts with everything at every moment! This nonlocality appears to be included in quantum theory, whereas the theory of relativity does not reproduce it under the current interpretation. The theory developed here is non-local but nonetheless yields the results of the special theory of relativity. It therefore seems conceivable that both theories are entirely valid and the previous contradictions of action-at-a-distance/nonlocality (Newtonian and quantum theory) against local action/locality (theory of relativity) disappear. The particle approach and the principle action-at-a-distance seem to be reasonably applied to the “distant” masses of the universe being at rest.

The distant masses of the universe build up a preferred reference frame, and our theory yields the Lorentz transformation for masses being uniformly moved against this preferred frame (or against any other inertial frame). This is also valid for light sources (having always a mass), and explains the constancy of the speed of light in all inertial systems.

This paper is based on the model of a homogeneous universe with very low mass density. In this case, its results contradict neither the special nor the general theory of relativity. A generalization to non-homogenous mass distributions can be performed but is studied in the work presented here only on a very elementary level.

Acknowledgements

The author is grateful to the Professors Dr. H.P. Büchler, Dr. Nicolas Gisin, Dr. Gerd Schön, Dr. Ulrich Steiner, Dr. Ulrich Weiß and Dr. G. Wunner for their valuable comments and their encouraging support.

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