The Application of the Theory of Variable Speed of Light on the Universe

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By applying the theory of variable speed of light, the galactic red-shift can be described as a phenomenon, which only SEEMS to be a movement and it can be explained by the variation of the cosmic gravitational potential. An alternative concept of the universe is developed, whereas only very general assumptions about the properties of the universe are made. The worldview arising from that is simpler than the Standard Model. The theory of variable speed of light is able to describe the Hubble diagram consistently in a new way, nevertheless, without having to introduce any parameters.

Contents

1 Introduction

In 1912, Vesto Slipher discovered a red-shift in the spectra of galaxies for the first time [1]. More and more, a systematic relationship between red-shift and distance became apparent with the successful determination of the distances of galaxies by Edwin Hubble, done from 1925 [2]. Based on this relationship, Georges Lemaître first presented in 1927 a dynamic world model with a well defined beginning [3].

Since that time, most of the physicists did not consider a stationary cosmos without temporal development to be a likely scenario. It was seen as a validation of Albert Einstein's General Relativity Theory, which was difficult to be brought in line with a static universe, anyway. The red-shift was interpreted as escape velocity of the galaxies unanimously, even if Lemaître emphasized from the beginning that the galaxies are not moving away from each other but only "the space is expanding". There were attempts to compensate the escape speed of the galaxies by creation of matter and to ensure a static universe in this way, but the vast majority of cosmologists committed themselves to the Big Bang model, whose exact properties continue to be the topic of perpetual research and discussions.

Even the Friedman-Lemaître solutions with cosmological constant Λ were not able to explain the basic properties of the universe coherently [4]. Today, the so called Cosmological Standard Model in form of the ΛCDM model includes in addition to that a phase of inflation, so called Dark Energy and Dark Matter, whose existence has not been proven so far. The number of necessary parameters has increased over time more and more and has reached a quasi unlimited amount, in which the observed flatness of the universe in the Standard Model nonetheless appears as an unexplained unbelievable coincidence.

It is the authors opinion, that there is something, that we do not understand correctly, if an extremely unlikely coincidence is necessary for the theory to be valid. Indeed it is the question, whether the Standard model fulfills the criteria of a good theory. It shall not be misunderstood: the Standard Model is the best theory we have. Still it is the time to challenge essential, generally accepted viewpoints in cosmology and to search for better ways.

In [5], a theory of variable speed of light was introduced, which is based on Special Relativity Theory and the equivalence principle, but it disregards the covariance principle. With the assumption, that gravitation can be explained by a variable polarizability of vacuum, the classical tests of General Theory of Relativity can be reproduced, which means all effects in weak fields.

In strong gravitational fields, however, the differences between the theory of variable speed of light and General Relativity are of fundamental nature. Instead of refusing the theory of variable speed of light due to that, however, it is regarded as serious alternative for the description of gravitation.

In the following, the theory of variable speed of light is developed further by applying it to the universe as a whole.

2 General Properties of the Gravitational Field

We assume a point-like mass M in free space and consider for now the situation as static, meaning, as time independent. A second assumption is the gravitational energy to be a preserved quantity. From that, it follows, that the gravitational energy is independent of the path of movement equivalent to an irrotational field of gravity $\vec{\nabla} \times \vec{g} = \vec{0}$. Thereby, $\vec{g}$ is the acceleration in a gravitational field.

The classical derivation of Newton's law of gravity with the law of Gauss requires additionally, that the gravitational field disappears at infinite distance, $\vec{g}(r = \infty) = \vec{0}$. The differential form of Gauss's law of gravitation is

$$\vec{\nabla} \cdot \vec{g} = -4\pi G \varrho(\vec{r}) \tag{1}$$

Thus, the gravitational field in vacuum, where the matter density is $\varrho(\vec{r}) = 0$, is source-free: the divergence $\vec{\nabla} \cdot \vec{g} = 0$.

For classical physics, Newton's law of gravity follows from these preconditions with its $\frac{1}{r^2}$-dependence. In its integral form

$$\oint_{\partial V} \vec{g}(\vec{r}) \cdot \mathrm{d}\vec{A} = -4\pi GM \tag{2}$$

it means, that the surface integral across a volume is proportional to the enclosed mass M, which is the volume integral across the density ϱ. Because of the given spherical symmetry, the acceleration vector $\vec{g}$, thus, always points towards the origin, and its absolute value only depends on the distance.

$$\vec{g}(\vec{r}) = g(r)\vec{e}_r \tag{3}$$

If we now integrate across the surface of a sphere around M, the scalar product is reduced to the product of the absolute values:

$$g(r) \oint_{\partial V} \vec{e}_r \cdot \mathrm{d}\vec{A} = -4\pi GM \tag{4}$$

$$g(r) 4\pi r^2 = -4\pi GM \tag{5}$$

and we get Newton's law of gravity in its classical form:

$$g(r) = -\frac{GM}{r^2} \tag{6}$$

An inconsistency of classical physics becomes evident, if one considers a point-like test mass m, which is moved slowly towards the point-like central mass M. Slowly shall mean we regard the situation as a static one. The energy released by this procedure is extracted out of the body m and it is quasi at rest all the time. This can be imagined by the transportation of m in a slow elevator.

The potential energy $E_{\text{pot}} = -\frac{GM}{r}$ of the test body grows beyond all limits for $r \to 0$. The problem arises, because the rest energy of a mass was unknown yet in classical physics and the potential energy E_{pot} represents a separate quantity. It was Einstein, who recognized the significance of the rest energy of mass in his Special Theory of Relativity, and that any kind of energy contributes to the mass and inertia of a body according to $E = mc^2$.

In the Newtonian approach, an unlimited amount of energy is released during the convergence of both (point-like) masses, which even exceeds the rest energy of m. This is obviously wrong in the light of Special Relativity. The rest energy of the body m becomes smaller by approaching M, because potential energy is extracted and accordingly, less potential energy is released as a consequence. Only the entire rest energy of m can be set free at most. Thereby, the problem of unlimited gravitational energy dissapears.

If one accepts the precondition of a variable refractive index of vacuum $k = \sqrt{n}$ being the reason of gravitation, the expression of the refractive index of vacuum discovered in [5] can be reduced also to Gauss's law of gravity in a modified form, which, however, accommodates Special Relativity.

The following relations, outlined in [5], are valid. Starting point is the definition of the speed of light in a vacuum of modified refraction index k.

$$c = \frac{c_0}{k^2} \tag{7}$$

Clocks with frequency ν run slower there by the factor k:

$$\nu = \frac{\nu_0}{k} \tag{8}$$

The wave length of light becomes smaller:

$$\lambda = \frac{c}{\nu} = \frac{\frac{c_0}{k^2}}{\frac{\nu_0}{k}} = \frac{\lambda_0}{k} \tag{9}$$

From the modification of frequencies, the same follows for energy:

$$E = \frac{h\nu_0}{k} = \frac{E_0}{k} \tag{10}$$

As a consequence of Einstein's relation $E = mc^2$, also the mass m is modified:

$$m = \frac{\frac{E_0}{k}}{\frac{{c_0}^2}{k^4}} = m_0 k^3 \tag{11}$$

An acceleration g is decreased, because it is composed of lengths and times, whose modifications we already know. Gravitational forces F stay constant, because the reduction of the acceleration cancels with the increment of inertia:

$$g = \frac{g_0}{k^3} \quad \text{wegen} \quad [g] = \frac{\mathrm{m}}{\mathrm{s}^2} \tag{12}$$

$$F = mg = m_0 g_0 = \text{const} \tag{13}$$

Newton's gravitational constant G, however, decreases in a gravitational potential:

$$G = \frac{G_0}{k^8} \quad \text{because} \quad [G] = \frac{\mathrm{m}^3}{\mathrm{kg\,s}^2} \tag{14}$$

A reference observer at $r = \infty$ sets $k = 1$ for his potential as a reference. From his view, the values from above are modified by a deeper potential closer to the central body M with growing $k > 1$. The quantities with index "0" are values being measured by the reference observer as well as by a local observer at a different potential.

We describe the whole situation from the view of the reference observer, because the constant M of the central body (in opposite to a local observer) remains constant for him indeed. The force $\vec{F}$ is not modified for him in case of a modification of the index of refraction.

$$\vec{F} = m\vec{g} = m_0\vec{g}_0 = -\vec{\nabla}E = -E_0\vec{\nabla}\frac{1}{k} \tag{15}$$

We multiply equation (2) with m_0, then we divide the right side by k, because the rest energy of the test body m is reduced by this factor, when it is moved in the potential. The energy is not preserved here, it is extracted out of the system explicitly by the displacement of m in this quasi static situation.

In this form, Gauss's law of gravity of equation (2) is in accordance with Special Relativity.

$$-\oint_{\partial V} \vec{\nabla}E \cdot \mathrm{d}\vec{A} = -\frac{4\pi m_0 M_0 G_0}{k} \tag{16}$$

Due to the spherical symmetry the energy gradient across the entire surface to be integrated is a vector out of the origin and, thus, parallel to the vector of the surface element $d\vec{A}$. The absolute value of the energy gradient is constant across the entire surface of the sphere.

$$\left|\vec{\nabla} E\right| = \left|\vec{\nabla} \frac{E_0}{k}\right| = E_0 \frac{\partial}{\partial r} \frac{1}{k} \tag{17}$$

The scalar product again is reduced to the product of the absolute values. The integral across the surface element $d\vec{A}$ contributes with the area $4\pi r^2$. Hence, equation (16) can be converted to:

$$-E_0 4\pi r^2 \frac{\partial}{\partial r} \frac{1}{k} = -\frac{4\pi m_0 M_0 G_0}{k} \tag{18}$$

With $E_0 = m_0 {c_0}^2$ we get

$$k \frac{\partial}{\partial r} \frac{1}{k} = \frac{M_0 G_0}{r^2 {c_0}^2} \tag{19}$$

The expression

$$k = \alpha e^{\frac{M_0 G_0}{r {c_0}^2}} \tag{20}$$

fulfills equation (19), because

$$\frac{\partial}{\partial r} \frac{1}{k} = \frac{\partial}{\partial r} \left(e^{-\frac{M_0 G_0}{r {c_0}^2}} \right) = \frac{1}{\alpha} \frac{M_0 G_0}{r^2 {c_0}^2} \, e^{-\frac{M_0 G_0}{r {c_0}^2}} \tag{21}$$

and both exponential terms in the product $k \frac{\partial}{\partial r} \frac{1}{k}$ cancel each other as well as the arbitrary constant α. This constant represents the possibility to choose the reference potential freely.

In this way, the expression found in [5] for the refractive index of vacuum can be reproduced in a very general manner. Solely by regarding the rest energy of a body being decreased in a lower potential, there is a solution for the central potential, which does not exhibit a divergence at the Schwarzschild radius. There are no “Black Holes” according to the theory of variable speed of light. Light is able to escape from any potential.

Newton’s law of gravity of classical physics appears as limiting case of first order, if the force is written as energy gradient:

$$F = -\frac{\partial E}{\partial r} = -\frac{\partial}{\partial r} \frac{E_0}{k} = -E_0 \frac{\partial}{\partial r} e^{-\frac{G_0 M_0}{r {c_0}^2}} \tag{22}$$

By developing the exponential function up to first order in $\frac{1}{r}$ and replacing E_0 by $m_0 {c_0}^2$, Newton’s law of force unfolds for the energy gradient of a mass m_0:

$$F = m_0 {c_0}^2 \frac{\partial}{\partial r} \left[1 - \frac{G_0 M_0}{r {c_0}^2} + ... \right] \approx m_0 \frac{G_0 M_0}{r^2} \tag{23}$$

3 Robert Dicke's Universe

In his paper from 1957 [6] Robert Dicke extended not only the approach of Harold Wilson [7] about the electromagnetic nature of gravitation, but he also designed a visionary picture of the cosmos, including some very bright ideas.

After he had outlined the concept of variable speed of light, he showed that the cosmic redshift does not necessarily have to represent an actual movement of the objects but can be reduced solely to a modification of length scales caused by the temporal variation of the gravitational potential in the universe without the galaxies executing an actual escape movement. He assumes a flat static space of homogeneous density.

According to Dicke the Big Bang is, that the light started to spread in the beginning at the same time in the whole universe. The boundary of the universe is defined by the edge, from where light is reaching us. However, in Dickes approach, the temporal development of the refractive index does not follow directly, but he makes additional arbitrary assumptions describing a temporal evolution.

Alexander Unzicker has enhanced this model and clarified especially the lapse of time for different positions of an observer [8].

According to the theory of variable speed of light in the version suggested by the author in [5], there is a fixed relationship between the potential of the universe, the dispersion of light and the velocity of light. As will be outlined in the following, this leads to a universe, which exhibits qualitative main streaks of Dicke's and Unzicker's model.

4 Preconditions

To be able to come to a consistent world model, at first one has to be clear about the preconditions, which the model shall fulfill. They must, on one hand, enable the representation of all properties of interest, on the other hand they should be as general and simple as possible.

With this in mind, the following most simple assumptions are made:

1. Gravitation can be described by a variable velocity of light.
2. The cosmological principle is valid.
3. The radius of the universe is expanding with the speed of light.
4. The baryon density stays constant for a reference observer.
5. Mach's principle is valid.

The first assumption does claim nothing less than the conjunction of gravitation and quantum physics being a prerequisite. It is not searched for in a second step, but we assume that gravitation is a secondary effect of the electromagnetic interaction between charged particles.

A curved space in the General Theory of Relativity means within our picture, that a light wave front propagates along curved paths caused by a gradient of the refractive index of vacuum according to Huygens' law. To assume a gradient in the whole cosmos, though, violates the cosmological principle, which requests large-scale uniformity. Inasmuch point 2 in our model – the assumption of the cosmological principle – is equivalent to the requirement of a flat space. Therefore, a flat space is no extra demand but a strict consequence of the preconditions of the model. In the Standard Model, however, the flatness of space is a problem, because the measurements suggest a flat space, but the conditions for it have to be fulfilled extremely accurately without an explanation being offered by the standard model.

The present day universe appears as a sphere to us, in which center point we are located. We are receiving light only from distances up to a maximum radius. If we assume space as infinite and flat, request 3 is the only possible version, namely, that the light did start to spread from a fixed point of time in the past, in fact instantaneously in the entire universe. The Cosmological Principle does not allow any other choice here again. Without a starting point in time of the propagation of light, the Newtonian potential of the spatially infinite universe would be infinitely deep since the beginning of time. This does not lead to a meaningful model.

Dicke's approach is able to explain the cosmological red-shift of the galaxies as an effect of the variation of the potential of the universe. This is expressed by the fourth request from above. A fictitious observer, whose potential remains constant, would not notice any movement, the density of matter in his universe would stay constant. The movement of the objects, hence, only appears as such.

Einstein and some other cosmologists even advocated the Strong Cosmological Principle stating, that there should not be a temporal variation of the cosmos. Due to the observations, the idea of a steady state universe is hardly supportable any more, but the assumption of a temporally constant matter density in the universe fulfills one aspect of the Strong Cosmological Principle at least to some extent.

Mach's principle as fifth prerequisite like it is developed in [5] describes, how the (electromagnetic) interaction of matter among each other determines the polarizability of vacuum. The phenomenon of gravitational force then is a consequence of a gradient of the polarizability.

5 Points of view

Also here, it is important to keep in mind, which reference any quantity is related to. The index of refraction n is a relative dependency between spatially or temporally separated locations. In [5], static potentials were examined and only spatial variations of the refractive index were discussed. In case of the universe, however, the interesting topic is about the temporal evolution of the universe as a whole. With the cosmological principle, we assume, that the large-scale matter distribution is homogeneous and we regard $n = k^2$ as constant in space throughout. Thus, it only remains to examine its temporal change. The present lends itself a reference point, at which $n = 1$. All quantities then are represented in relation to present-day values according to fixed rules, see [5], equations (7) – (21).

Essentially, there are two standpoints of an observer to be differentiated. The first observer, let it be called the reference observer, shall be positioned at a stable reference potential of today and he shall remain on this potential for all times. He describes the universe of the past and the future in relation to this reference with the age of the universe being t and the radius being $R(t)$. Today, the age of the universe is t_u and the present radius is $R_u = R(t_u)$. The baryon density stays constant for the reference observer, because his length scale does not change with the potential of the universe. Even if this virtual observer does not exist in the universe, because the background potential of the universe is decreasing steadily, it is rather helpful. The space scale of the reference observer corresponds to the "comoving distance" in the Standard Model.

The second standpoint is consequently local and it is related always to the local time τ and the corresponding potential. The proper time τ represents the "age" of an object.

A today's astronomer, who analyzes light information arriving at us now, essentially takes the standpoint of the local observer.

In the following, the author aims at integrating the measurable basic phenomena of the cosmos into a consistent overall picture. In the simplest possible model, each point in space is surrounded by a sphere of homogeneous density ϱ and total mass M with radius R. The outer space is not yet in the sphere of mutual interaction with the center point. Thus, space has the same potential everywhere because the universe looks identical from every point. Even if matter acts on each other, which leads to local accumulation like galaxies, there is no cosmic acceleration. The gravitational forces cancel each other in the long range and there is no tendency for the universe to concentrate, because the mass distribution is even and space is flat and infinite.

6 Space and Time

To get a correct picture of the universe, first of all, we have to think about, which "distance" is significant for the gravitational interaction at all. It became clear, as soon as we treated a variable index of refraction, that the usual distance in meters is no well defined quantity any more and distance definitions like light travel time distance, angular diameter distance, luminosity distance encounter similar difficulties as in the Standard Model.

We look at a laboratory, in which the polarizability is ε_0 initially. It shall be assembled an experiment in the laboratory, that measures the electrical force F between two charges q_1 and q_2. The distance between the charges shall be r.

$$F_0 = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} \tag{24}$$

Now we consider what happens, if the index of refraction varies. Herein, we distinguish between the views of the reference observer and the local observer, which tries to get a consistent picture of the situation only taking into account locally measured quantities. The distance definition of reference and local observer are identical in the initial state.

Now the index of refraction shall be increased by the factor $n = k^2$. The reference observer now finds $\varepsilon = \varepsilon_0 k^2$. The distance between the charges r remains unchanged because their location is not varied.

$$F_{\text{ref}} = \frac{q_1 q_2}{4\pi\varepsilon_0 k^2 r^2} = \frac{F_0}{k^2} \tag{25}$$

The force, therefore, decreases by the factor k^2.

If the same situation is to be described by the local observer, he notices the measured values in a different way. For the local observer, the refractive index is always equal to 1, $\varepsilon = \varepsilon_0$, but the distance seems to be increased $r_0 = rk$. For the local measured force it means:

$$F_{\text{loc}} = \frac{q_1 q_2}{4\pi\varepsilon_0 {r_0}^2 k^2} = \frac{F_0}{k^2} \tag{26}$$

So both observers come to the same result of the force, though, having a different perception of the structure of the experiment now.

One can ask, why the electrical force between two charges is diminished at all, if "space" is between them. If there is some attenuation already and one doubles the distance, then the force is diminished to a quarter. This is described by Gauss' law adequately.

If the index of refraction ε is increased, it results in a stronger attenuation as well. It can be imagined in a way, that the medium within the space can be polarized. The vacuum is filled with orientated dipoles. These dipoles generate a compensation field attenuating the primary field of the two charges more and more with increasing distance.

Both situations can be regarded as equivalent. It only depends on the "amount" of dipoles located between q_1 and q_2. Herein, both observers agree. But whether the resulting force is counted among the polarizability of the vacuum or among a certain distance, is a pure matter of definition. Space (and time) per se are not defined firmly in a Newtonian sense but only relatively. Each observer can set the index of refraction $k = 1$ and, hence, himself as reference.

If it is respected that clocks run slower by the factor k for the local observer, the distance measurement by means of the light travel time works as well: the local observer measures the distance r_0 by measuring the (proper) time $\tau = tk$ the light needs to cross it.

$$r_0 = \frac{c_0}{k^2} tk = \frac{r}{k} \tag{27}$$

The reference and the local observer, therefore, come to self-consistent measurements of space and time, but having a different interpretation. Because also the reference observer is only an arbitrary choice, every observer is of equal value and can define his view point as reference.

On the ground of a variably polarizable medium, therefore, the structure of a Newtonian space-time can be established. We stay at the assumption, that gravitation as electromagnetic phenomenon has analog properties like the electrical force itself. For Newton, the absolute space and the absolute time were simply given, because the physical measurements at that time gave no reason to have concerns about it. But with the insights of Einstein's Relativity Theories, the naive imagination of a God-given absolute space-time is not supportable any more. There is no absolute space-time. It only can be defined relatively.

Now we go a step ahead and try to describe interactions, if the polarizability of the vacuum varies with time. The variation shall happen in the entire space simultaneously, the polarizability, therefore, shall be spatially constant at all times. For that, we further assume, that all distances stay the same for the reference observer. As a picture, we imagine an electrical charge (transmitter), which sends a spherical wave of photons into the space. Because the polarizability is always spatially constant, the spherical symmetry of the wave field is preserved at all times, even if the refractive index of the vacuum and, therefore, the propagation velocity of the light is modified. Because if a temporal change occurs, it does it simultaneously in entire space. If a spherical wave hits the observer (receiver), several things are of relevance.

The observer interprets the incoming spherical wave straight locally. It is irrelevant for the shape of the incoming wave front where on the way the speed of light has changed. The light travel time being a suitable length scale in a constant medium is not a reliable quantity for the estimation of the strength of the interaction any more.

It is the authors opinion, that it is rather Gauss' law in form of equation (16), which is the accurate approach. If the reference observer is on the same gravitational potential as the receiver ($k_R = 1$), then their length scales match. Hence, a distance measurement to the sender is also the reference distance.

If the index of refraction of the sender k_T at the time of emission is different to that of the receiver at the reception, a red-shift occurs at the receiver ($k_R = 1$) and leads additionally, according to equation (16), to an attenuation of the strength of the interaction by the factor k_T. The distance significant for the strength of the interaction $r_{\text{interaction}}$, therefore, is:

$$r_{\text{interaction}} = \frac{r}{k_T} \tag{28}$$

This can be exemplified with a photon cannon, which dispatches a certain amount of photons in the direction of the receiver per time interval. If the photon cannon has a red-shift compared with the receiver, it is like the cannon moving away from the receiver. The photons arrive from larger and larger distance. Therefore, the rate of the arriving photons is decreased by the factor k_T and the interaction is diminished as well.

The definition of the distance introduced here is not a new arbitrary ingredient to the theory. It follows solely from the laws of Special Theory of Relativity. As in equation (16) noted and carved out in [5], the rest energy of an unmoved body is responsible for the gravitational force. This applies in case of the central potential. Here, the rest energy of a test body is decreased at a location with deeper potential and, hence, the gravitational force is reduced. In case of the universe, we regard the matter as unmoved as well. Only the potential becomes deeper over time. The red-shift effected by that leads to a likewise reduced rest energy. Both situations are equivalent in the frame of the theory of variable speed of light.

We distinguish three points of view from now on: the one of the transmitter (k_T), the one of the local observer or the one of the receiver, respectively (k_R), and the one of the reference observer ($k = 1$).

The similarity with the luminosity distance d_L of the Standard Model is obvious. It is defined with the "comoving distance" d_C:

$$d_L = (z + 1)d_C \tag{29}$$

in the case of a flat space. The red-shift also causes an attenuation of the luminosity by the factor $k = \frac{1}{z+1}$. The "comoving distance" is defined in the Standard Model in a way, that it represents a constant distance scale despite the expansion of the universe. Hence, it is equivalent to the reference distance in the theory of variable speed of light. Furthermore, k is identical with the scale factor a in the Standard Model.

Herewith we state the hypothesis, that the luminosity distance is the length scale, which is significant for the strength of the electrical and the gravitational interaction as well.

It is interesting also to imagine, what happens, if the speed of light decreases at the location of the receiver. Because the length scale is decreased as well, the receiver cuts out a smaller piece of the spherical wave by the factor k_R. The strength of the interaction is attenuated by the factor $\frac{k_T}{k_R}$. For the local observer it means also, that the transmitter now has a red-shift of $\frac{k_T}{k_R}$ and immediately possesses a greater distance by the factor of k_R. This is a completely local phenomenon and there is no time delay related with the speed of light. The red-shift can turn out to indicate a "superluminal velocity" without problems, if it is interpreted as velocity. We will come back to that in connection with the "expansion of space".

Einstein's solution was to define a curved space-time, in which the speed of light is constant. He was able to find a consistent formulation with the Equivalent Principle and the Covariance Principle, which described the gravitational phenomena in the solar system correctly.

The theory of variable speed of light chooses a similar way. The observations are described within an principally flat space-time, but the curved light-paths are taken into account with a variable velocity of light.

The Newtonian space arises in both formulations, if the space-time is flat or the polarizability is constant, respectively.

7 The Structure of the Universe

In the last years the range of the Hubble diagram was extended up to a red-shift of $z > 2$ by the observation of more than thousand supernovae of type Ia and its precision has been improved enormously.

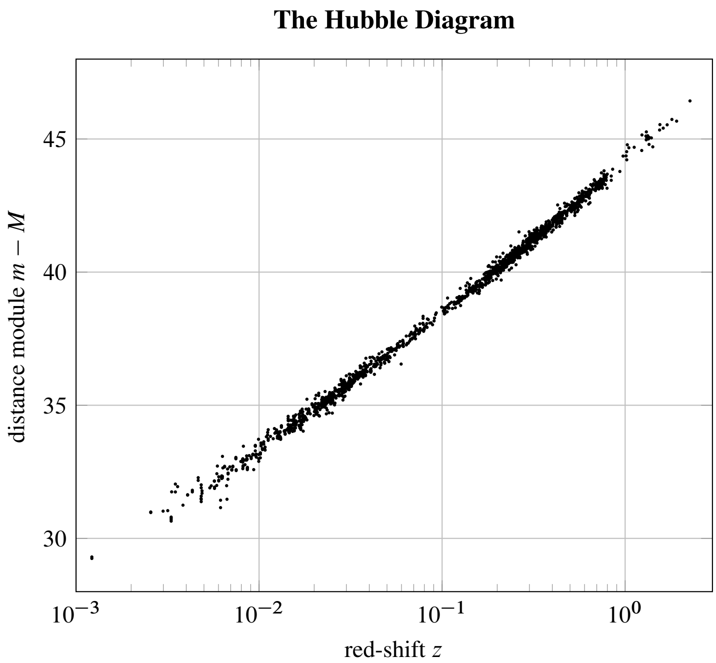

Figure 1: The distance module $m - M$ as a function of the red-shift z

Figure 1 shows the distance module, essentially the distance, as a function of the red-shift of 1700 supernovae type Ia from the Pantheon+ data set [9]. In the Standard Model very specific details about the expansion of the cosmos, vacuum energy and dark matter are deduced.

For the sake of simplicity all absolute brightnesses M were assigned to -19.5 mag, because the model itself influences the close determination of M.

The theory of variable speed of light demonstrated a novel line here. If one follows its arguments, the Hubble diagram has to be looked at with totally different eyes. As Robert Dicke showed already, the red-shift of galaxies can be explained by an increase of the polarizability of the vacuum since the primordial beginning as well. In a thought reference space, in which the gravitational potential remains constant, the galaxies keep their cosmic position. The "flatness problem" does not exist here at all in the first place.

The reference observer perceives, though, the length scale of a local observer shrinking steadily, because his potential declines more and more. Therefore, the galaxies seem to perform an escape movement from the perspective of the local observer. The gravitational potential was zero at the primordial moment, the local scale, thus, infinite, the matter density infinitely large.

We will now regard these properties and are able to gain several details out of the Hubble diagram. We can see from the equation of the luminosity distance (29), that the reference distance r (or the comoving distance, respectively) of a galaxy is contained here:

$$d_L = \frac{1}{k} r \tag{30}$$

If the luminosity distance d_L is divided by the red-shift $z + 1 = \frac{1}{k}$, we directly get the reference distance r of such a supernova. We plot k vs. the reference distance r and get a somehow modified Hubble diagram.

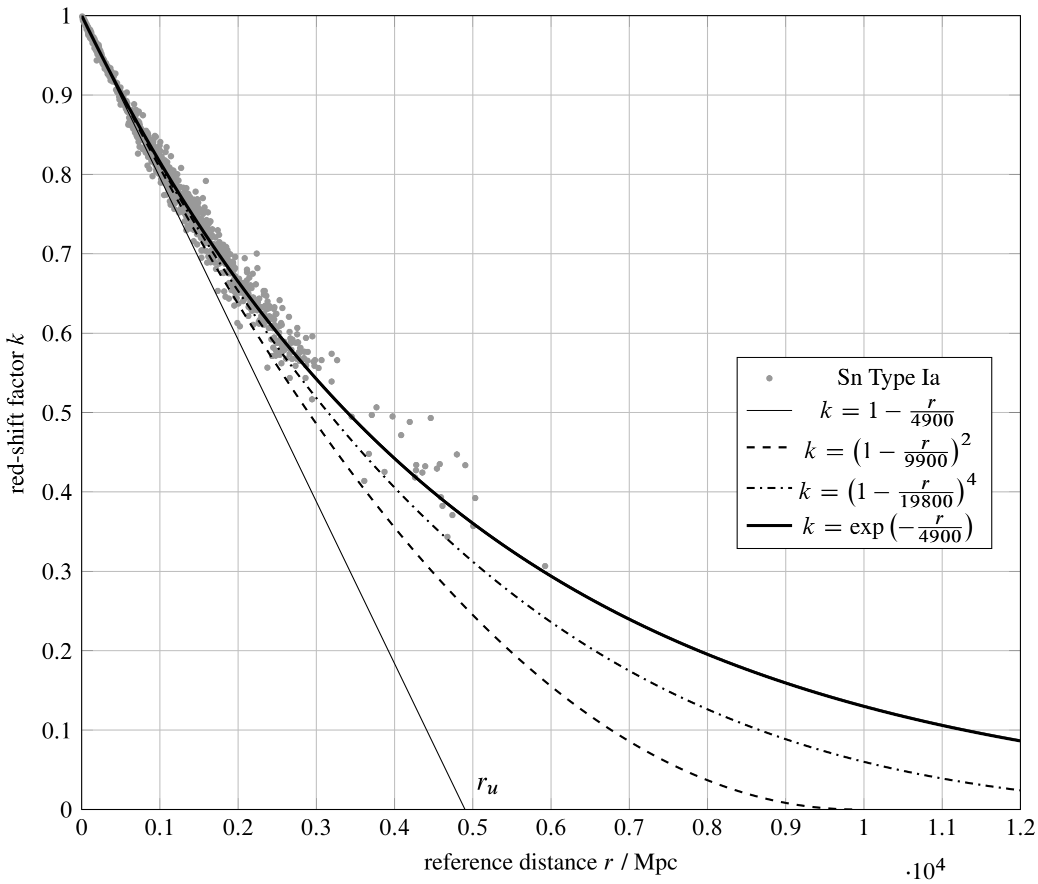

Figure 2: The Hubble diagram represented by the red-shift factor k as a function of the reference distance r

The red-shift faktor k in figure 2 drops with increasing reference distance r of the supernovae. The data set ends at about $k = 0.3$, which corresponds to a reference distance of about 6000 Mpc. If the trend of the red-shift is extrapolated further, the question arises, whether and where the graph touches or cuts the r-axis. This is the size of the universe of today in reference coordinates. Because we assume an infinite speed of light in the initial moment, the r-axis must be a horizontal tangent. Mathematically this is possible, if the graph is a power function with its crest at the touching point with the r-axis. Then the speed of light would have been inifinite, the light would have covered only a finite distance R_u, nonetheless. Light would have reached us up to this distance, light from greater distance still would be underway to us. The universe would have a fixed radius R_u measured in reference scale.

But this does not seem to be the case. The greater the power of a smoothing parabola is chosen, the better the agreement with the measured supernova data. With the additional boundary condition, that the slope at $r = 0$ has to match the data, the radius of the universe R_u increases beyond all limits as well. In the limit we end up at the exponential function

$$k = e^{-\frac{r}{r_u}}, \quad \text{with} \quad r_u \approx 4900\,\text{Mpc} \tag{31}$$

with a characteristic radius r_u. The value $k = 0$ is reached not until an infinite reference distance $R_u = \infty$. Therefore, the Hubble diagram suggests, that the radius of the universe was infinite from the first moment. According to this, we are in interaction with the entire infinite universe since ever. Because the strength of the interaction depends on the red-shift as well, the gravitational potential can begin at zero initially, nonetheless.

At this point, the "horizon problem", which is quite a problem for the Standard Model, is resolved.

The universe seems to have a finite radius R_{u0} for a local observer, anyway. He assumes the speed of light being constant c_0 all the time. The local observer recognizes the initial area, which the light has crossed with very high velocity as a strongly compressed one with increased matter density.

In figure 2, there is included even more, though. The Hubble diagram is a snap-shot of a light packet, which carries temporal, as well as spacial information. The red-shift k describes the speed of light, too, with which the light was sent onto its journey to earth from this specific distance r. Because the speed of light is known on its entire trip on the basis of the Hubble diagram, we can calculate the light travel time from a supernova to us as the integral across the light-path. t is the time of the reference observer.

$$c(t) = \frac{c_0}{k^2} = \frac{\mathrm{d}r}{\mathrm{d}t} \tag{32}$$

$$c_0 \mathrm{d}t = k^2 \mathrm{d}r = e^{-2\frac{r}{r_u}} \mathrm{d}r \tag{33}$$

$$c_0 t = \int e^{-2\frac{r}{r_u}} \mathrm{d}r = -\frac{r_u}{2} e^{-2\frac{r}{r_u}} = -\frac{r_u}{2} k^2 \tag{34}$$

With this it is possible to extract the temporal development of the refractive index at the location of the observer $k_R(t)$ out of the Hubble diagram.

$$k_R(t) = \sqrt{\frac{2c_0 t}{r_u}} \tag{35}$$

At the time

$$t_u = \frac{r_u}{2c_0} \tag{36}$$

it becomes $k = 0$. Thus, t_u is the age of the universe in reference time.

If we want to describe the lapse of time in proper time τ, we have to convert the different clock speeds from one to another. The clock of the local observer runs slower by the factor k_R than that of the reference observer.

$$\mathrm{d}\tau = \frac{1}{k_R(t)}\mathrm{d}t \tag{37}$$

$$\int \mathrm{d}\tau = \int \left(\frac{2c_0}{r_u}t\right)^{-\frac{1}{2}} \mathrm{d}t \tag{38}$$

$$\tau = \sqrt{\frac{2r_u}{c_0}}\sqrt{t}, \tag{39}$$

if the starting points of the integration are placed at the crest of the squaretime function. Therefore, the temporal development of the red-shift k_R is a temporally linear function for the local observer.

$$k_R(\tau) = \frac{c_0}{r_u}\tau \tag{40}$$

And the age of the universe in proper time is:

$$\tau_u = \frac{r_u}{c_0} \approx 16 \text{ Mrd a} \tag{41}$$

The apparent radius R_{u0} of the universe is, thus:

$$R_{u0} = r_u = 4900\,\text{Mpc} \tag{42}$$

The Hubble-constant H_0 is connected tightly with r_u, too. It is the slope of the function $k(r)$ at $r = 0$.

$$H_0 = \frac{r}{r_u}c_0 = \frac{1}{4900}c_0 = 61\frac{\text{km/s}}{\text{Mpc}} \tag{43}$$

The value of the age of the universe significantly deviates from the accepted value of 13.8 Mrd years, as well as the value of Hubble's constant lies far outside the range of secured values of about 67 – 75 $\frac{\text{km/s}}{\text{Mpc}}$. But this shall not trouble us for the moment, because here it is about the rough shape of the universe, in first place. The discrepancy might be caused by the density fluctuations in our cosmic neighborhood. We live in a space area with considerably lower matter density, so deviations from our simple model are to be expected [10], since it is based on the assumption of uniform matter density.

Other than that, there is only one unique free parameter in this simple form of the model. It is not fitted with several parameters in order to match as well as possible to the progression of the Hubble diagram as it is done in the Standard Model, but it has to turn out, that the theory is able to reproduce the observations even with this one parameter. And the deviations from the simple version of the model are not arbitrary, too, they must be calculated from the real distribution of matter.

Still, it has to be shown now, that the shape of the universe as we read it out of the Hubble diagram is compatible with the theory of variable speed of light. The basic idea from [5] is, that the relative change of the potential of the universe is equal to a relative change of the refractive index of the vacuum:

$$\frac{\mathrm{d}\phi}{\phi} = \frac{\mathrm{d}k}{k} \tag{44}$$

We regard the universe as sphere of even density according to the Cosmologic Principle, at which center point we are located. Now we calculate the Newtonian potential of this sphere by integrating the potential contributions across the entire volume. We assume $r_{\text{eff}} = \frac{1}{k_T} r$ according to equation (28) to be the effective distance. k_T is the red-shift of the "transmitter". Thereby, we estimate the situation from the view of the reference observer, which takes the present potential of the universe as a permanent basis.

The infinitesimal mass element $\mathrm{d}m = \varrho\,\mathrm{d}V_u$ with constant density ϱ and volume element $\mathrm{d}V_u$ produces the potential in the center point of a sphere

$$\mathrm{d}\phi = -\frac{G\,\mathrm{d}m}{r_{\text{eff}}} = -\frac{G\varrho\,\mathrm{d}V_u}{\frac{1}{k_T} r}. \tag{45}$$

The total potential in the center of a sphere at the present time t_u is the superposition of all potentials, so we integrate across the entire sphere volume V_u:

$$\phi(t_u) = \int\limits_{V_u} -\frac{G\varrho}{\frac{1}{k_T} r}\mathrm{d}V_u = -G\varrho \int\limits_{\phi=0}^{2\pi} \int\limits_{\theta=0}^{\pi} \int\limits_{r=0}^{\infty} \frac{k_T}{r} r^2 \mathrm{d}r \sin\theta\,\mathrm{d}\theta\,\mathrm{d}\phi = -2\pi G\varrho \int\limits_{0}^{\infty} r e^{-\frac{r}{r_u}} \mathrm{d}r \tag{46}$$

(Be aware that the horizontal angle is also denoted by the symbol ϕ.) The integral is calculable and it converges even for an infinite radius.

$$\phi(t_u) = -2\pi G\varrho \left[e^{-\frac{r}{r_u}} \left(-r r_u - {r_u}^2 \right) \right]_0^{\infty} = -2\pi G\varrho {r_u}^2 \tag{47}$$

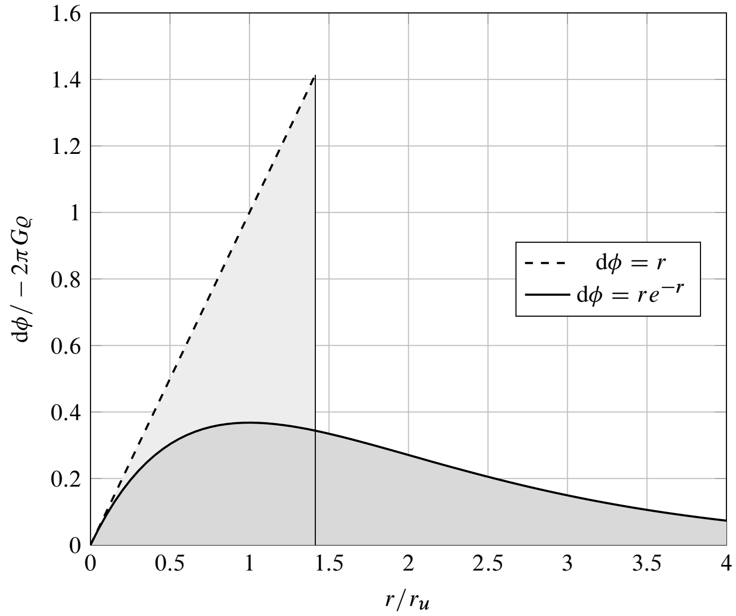

Figure 3: The values each spherical shell of radius r contributing to the potential of the universe. The total potential is equal to the area below the curve. Dashed line: Rigid sphere, solid line: Real universe

The potential contributions at small radius r follow those of an equally dense, unmoved sphere at first, shown as dashed line in figure 3. Its potential contributions rise linearly. They diverge for infinite radius, the integral over them even more. In the real universe their weight declines with increasing distance r due to their rating with the red-shift factor k. The integral across all contributions is finite, too. An unmoved sphere with radius $\sqrt{2}r_u$ would have the same potential as the universe, because:

$$\phi(t_{u,\text{sphere}}) = \int\limits_{V_u} -\frac{G\varrho}{r}\mathrm{d}V_u = -2\pi G\varrho \int\limits_0^{\sqrt{2}r_u} r\mathrm{d}r = -2\pi G\varrho \left[\frac{1}{2}r^2\right]_0^{\sqrt{2}r_u} = -2\pi G\varrho {r_u}^2 \quad (48)$$

Then the areas below the curves are equal.

If we want to calculate the potential at an arbitrary moment, the index of refraction of the observer $k_R(t)$ has to be respected.

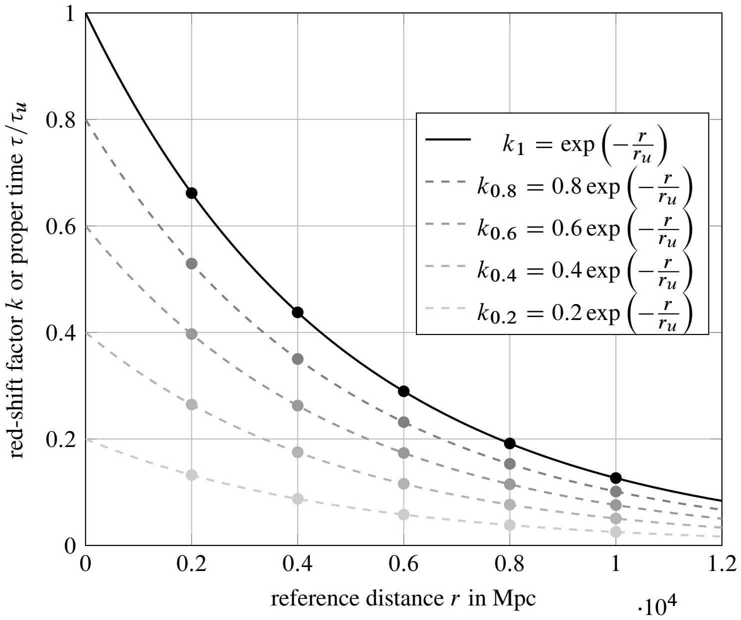

Figure 4: The refractive index k as a function of the reference distance r. The weaker curves are Hubble diagrams of the past from the view of the reference observer (today $k_R = 1$). $k_{0.8}$ means $k_R = 0.8$ and also $\tau = 0.8 \cdot \tau_u$.

The present-day Hubble diagram k_1 in figure 4 is a look into the past. At any distance r one can read the index of refraction k_R of that time and, thus, the speed of light. The speed of light was higher in the past (less slope means more distance per time). The Hubble diagram of the past starts, therefore, at the dedicated smaller k-value. For the reference observer, the galaxies preserve their distance r.

A Hubble diagram from the past is compressed by the faktor k_R in y-direction, but equivalently, it is shifted to the left as well by the distance the light covered during the past time.

$$k(r) = k_R(\tau)e^{-\frac{r}{r_u}} = e^{-\frac{r + r_u \ln k_R(\tau)}{r_u}} \tag{49}$$

The potential of the universe $\phi(t)$, therefore, was smaller by the factor k_R, too, and with equation (35) it is:

$$\phi(t) = k_R(t)\phi(t_u) = -2\pi G \varrho {r_u}^2 \sqrt{\frac{2c_0}{r_u}}\sqrt{t} \tag{50}$$

Because $\phi(t)$ and $k_R(t)$ are proportional to each other, relative changes are equal, too, and, hence, equation (44) is valid. Thereby, it is shown, that the structure of the universe, which we read off the Hubble diagram from the view of the theory of variable speed of light, is consistent with the requirements of the theory.

It is not possible to satisfy (44), if the radius of the universe is finite. The radius of the universe changes with time, because light would arrive at us from greater and greater distance. A horizontal shift in figure 3, thus, is not identical with a vertical stretching by a fixed factor as it is the case for the exponential function. That means from a theoretical point of view, a finite radius of the universe is incompatible with the model as well.

This solves also the problem, which arises with the question, whether the primordial event has started from a single point or whether it had to take place in the whole universe simultaneously.

Only in case of an infinite radius, an event at one single location at the beginning is also at the same time an event in the whole universe.

If somebody puts oneself in the place of a local observer, then the temporal development of the universe appears other than to the reference observer.

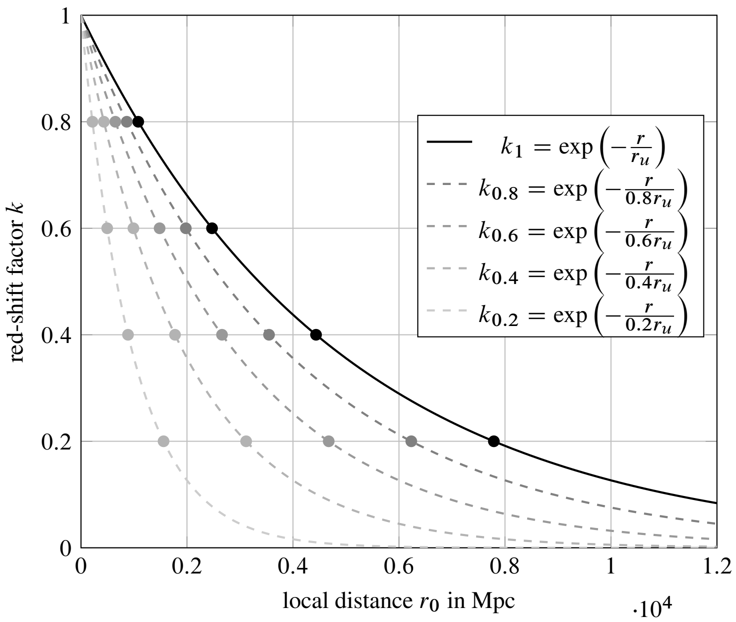

Figure 5: The refractive index k as a function of the local measured distance r_0. The weaker curves are Hubble diagrams of the past from the view of the local observer (always $k_R = 1$). $k_{0.8}$ means the curve $k(r_0)$ at the proper time $\tau = 0.8 \cdot \tau_u$.

A local observer like in figure 5 naturally puts his potential as reference and $k_R = 1$ at all times. The distances of the galaxies apparently grow, because the length scale decreases appropriately. The local measured characteristic radius of the universe r_{u0} increases, too. The red-shift of the galaxies does not change relatively to the particular local observer. Hubble diagrams from the past seem to be compressed in x-direction.

We started with the idea of Robert Dicke of a universe with defined border and landed at a somehow different, infinite model of the universe. We ended up there, however, not by choosing pameters of the model arbitrarily, but led under compulsion by the conditions of nature.

The universe exhibits a high self-similarity. Nonetheless, there is a starting point, which reason can not be given. The question, which was before, remains as sense-less as in the Big-Bang model.

The term “Big-Bang” does not fit very well any more. “Primordial Flash” meets the matter significantly better in terms of the theory of variable speed of light as an electromagnetic theory.

The value of the density ϱ of matter and energy, respectively, drops out, because all relations are defined as relative quantities. There is no initial condition in form of an absolute “density of the universe”. It has to be “something” only and it has to be distributed uniformly to some extent. An astonishing result: A different matter/energy density of the universe would change length scale and lapse of time in a way, that the universe would look exactly the same. Quite contrary to the Standard Model, in which the present shape of the universe demands the compliance of the initial conditions in highest precision.

Additionally that means, that constants of nature, which we regard as fundamental – as the velocity of light c_0 and the field constants ε_0 and μ_0 – are variable from the view of a reference observer and that the values differ indeed dependent on location and time. Measurements executed by a local observer always result in the same values, though. These quantities, therefore, are variable as well as constants of nature according to the particular point of view.

Olbert’s paradox has to be augmented by an additional facet. Olbert argued a static infinite uniform cosmos would be infinitely bright. The present solution of this problem consists of the argument, that light only arrives from a finite space area at us, even the universe may be infinite itself. According to our theory of variable speed of light this is not valid any more. We can see light from the entire infinite cosmos. However, light from large distance is red-shifted to such an extent, that the total arriving light energy, nevertheless, is finite.

Another interesting issue is the development of the matter/energy density in the universe. It is essentially linked with the baryon density at least as of a certain point of time. For the reference observer, the baryon density ϱ_b, thus, the number of baryons N per volume V according to our basic assumptions is constant at all times:

$$\varrho_b = \frac{N(t)}{V(t)} = \text{const} \tag{51}$$

The particle density is decreasing steadily for a local observer, because the measured volume changes along with his length scale.

$$\varrho_{b0}(\tau) = \frac{N(\tau)}{V_0(\tau)} = \frac{N(\tau)}{V(\tau)k^3} \propto k^{-3} \propto \tau^{-3} \tag{52}$$

The particle/energy density at the beginning was infinitely large for the local observer. Because the mass/rest energy of the elementary particles results in the same values all the time, the mass/energy density goes along with the particle density.

The primordial state is characterized by an enormous instability. The evenly distributed matter contains a high potential energy, which is released as gravitational energy at agglomeration and largely is converted into kinetic energy. That represents the motor for all occurring processes in the universe and is the source for any structure building.

Thus, the scenario of the genesis of the universe is essentially the same in the standard model as well as in the theory of variable speed of light. But there can arise great differences in the individual stadia like nucleon synthesis or building or the formation of the galaxies.

The local observer will interpret the red-shift as escape velocity at first glance, the distances to the galaxies seem to increase indeed as well. The reference observer, however, would describe the situation such, that the gravitational/electromagnetic interaction in the beginning had an extremely large range. Thus, the state, which is described here, does have by all means some similarity with the Big Bang in the Standard Model, but it differs in several fundamental aspects, nonetheless.

8 Problems of the Standard Model

In the Standard Model, it is assumed, that the entire matter at the Big Bang was aggregated in one singularity. The further acceleration or slowing down of the matter is determined by the distribution of visible and dark matter as well as dark energy.

Thereby, a number of basic problems arise. The flatness problem was mentioned already. Another one is the horizon problem. When 380 000 years after the Big Bang the temperature has decreased far enough, such that the hot plasma converted into a gas of neutral atoms, the universe became transparent and light rays started to propagate for the most part in a rectilinear fashion through space. The oldest visible remains of the universe date from that point in time and constitute the so called microwave background. Due to the expansion of the universe, space areas were separated so quickly, that they did not come into interaction to this day. This applies to all areas of the microwave background, which are separated by more than 1° in today's viewing angle. Despite of that, a great homogeneity can be observed over the whole angular range. The hypothesis of Cosmic Inflation shall now explain, how these space areas could have exchanged information in order to establish thermal equilibrium.

The essential difference of the model of variable speed of light founded by Robert Dicke is, that matter does not move from the view of the reference observer. Only light propagates and determines the change of the gravitational potential. There is no cosmic acceleration and all forces cancel each other in the long range. The presented model of the universe corresponds to the "empty universe" in the Standard Model. This is compatible with observational data, but was excluded, because it did not appear meaningful in the frame of the Standard Model.

Unlike in the Standard Model the entire universe is in contact since the beginning. There is no mechanism being able to separate them again. The horizon problem does not arise. Andreas Albrecht and João Magueijo show in [11], how the hypothetical assumption of a variable speed of light could solve essential problems.

The Standard Model did not find a consequent representation of variable scales, which are implicitly contained in it, though, as well. Already Lemaître emphasized, that “space is expanding”, not galaxies are “moving away”. Other authors, nonetheless, talk explicitly about the cosmological motion of galaxies. Even cosmologists do not have a clear imagination of what “expansion of space” really means. A varying length scale represents the obvious and self-evident explanation. Moreover, it is much more economic, because it describes the observations just as well without having to set in motion the entire universe.

Despite the excellent numerical agreements with observational data in many areas, the Standard Model has the shortcoming, that it operates with many additional ad-hoc assumptions and parameters. In other words: the Standard Model is full of epicycles, so that in the end, it runs into the problem of nonfalsifiability. The model, with its multitude of parameters, can simply be adapted to any new observation. With that, the theory is degenerated to a pure describing model and thus, has lost its capability of prediction.

9 Comparison with the Observations

The explanation of the Hubble diagram by the theory of variable speed of light is a strong argument in the author’s eyes to take it seriously. Beyond that there are a couple of observations speaking rather in favor of the theory of variable speed of light and against the General Theory of Relativity.

Every prediction in weak gravitational fields – that concerns all phenomena in the solar system – are equivalent, because both theories only differ from the second or third order, respectively. Increasing difference will become evident only with experiments of high precision and including higher order effects, e. g. in strong gravitational fields like Black Holes or concerning the genesis of the universe.

The best proven observations of the General Relativity Theory are observations in weak gravitational fields, altogether. Among them are the four classical tests gravitational red-shift, light deflection at the sun, radar echo delay and perihelion shift of Mercury. Here, both theories agree [12].

Yet another convincing observation is the energy radiation of a double star system by gravitational waves, most prominent of all the double pulsar PSR 1913+16. While Michael Ibison comes to a different energy radiation for the theory of variable speed of light [13], Kris Krogh, on the other hand, confirms the result of General Relativity and the well assured measurement for the theory of variable speed of light as well [14]. The case is not yet closed.

Even if the direct verification of gravitational waves already has been dignified with a nobel prize, it is the author’s opinion, that the sampled data up to now are no crystal clear proof at all. The measurement is extraordinarily challenging and the signal is smaller than the noise by orders of magnitude. In the theory of variable speed of light, gravitational waves arise like in General Relativity. But only longitudinal waves appear, because the theory is – in opposite to the tensorial GRT – a scalar one. Here, a propagation mode for transversal waves does not exist.

The Lense-Thirring effect does not occur in the theory of variable speed of light. The satellite experiment Gravity Probe B should deliver the unambiguous proof here, but the result turned out to be very weak. A clear null result would speak in favor of the variable speed of light.

The direct proof of Black Holes is not accomplished to this day. Direct observation is rather unlikely, because these objects are very small and, naturally, do not emit radiation themselves. The emission spectrum of matter hitting onto the hard surface of a neutron star should differ, however, clearly from that being emitted from matter disappearing in an event horizon of a Black Hole, nevertheless. On the contrary, Stanley Robertson was able to show, that the spectra of neutron stars are not essentially different from those of Black Hole candidates [15]. Actually the only remaining argument for the existence of Black Holes is, that General Relativity does not allow another possibility.

The space mission LATOR would have been able to measure the deflection of light at the sun up to the second order with sufficient accuracy [16]. The General Relativity Theory predicts a deflection decreased by 3.5 μarc seconds, the theory of variable speed of light requests a deflection decreased by 7.4 μarc seconds compared to the deflection in first order [14]. Unfortunately, the mission was not executed. The technical feasibility, still, is present.

The search of Dark Matter turns out to be like the vain quest of the ether a hundred years ago. It was given up not until Albert Einstein made obsolete the concept of an ether as carrier medium of light with his Special Theory of Relativity [17]. In the theory of variable speed of light, Dark Matter is neither necessary nor possible.

In summary, it has to be stated, that anywhere, where clear proofs exist, both theories agree and where the measurement results are weak, the theories differ. There are measurements possible, though, which are able to validate or falsify both theories definitely. However, measurements of effects of higher order are complex and expensive. The hurdle to perform such experiments is appropriately high.

10 Conclusion

The theory of variable speed of light in the version outlined here is able to reproduce the basic structure of the universe according to the observations. Starting point was Robert Dicke's insight, that the red-shift of the galaxies can be explained by the steady decreasing of the gravitational potential of the universe. The Hubble diagram is deduced from the theory with the help of only one free parameter. The imagination of an "expanding space" is replaced by the concept of variable scales. Thereby, many fundamental difficulties of the Standard Model dissolve. Dark Matter, Dark Energy, the flatness problem and the horizon problem count among them. The existence of the universe has begun with a "primordial flash". The primordial state exhibits a large density as in the Standard Model. The theory of variable speed of light abandons the assumption General Theory of Relativity being irrevocably right. Experiments reaching to the second order of space geometry could decide that.

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