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Research Article

Hubble Diagram Test of Expanding and Static Cosmological Models,

A New Interpretation of the Cosmic Redshift

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Abstract

We compare the observed Hubble diagram compiled from 280 supernovae redshift (RS) data in the range of z = 0.0141–8.1 with theoretical Hubble diagrams calculated on the basis of the Lambda cold dark matter (ΛCDM) model, the slowly expanding flat universe (SEU) model that expands according to equation (1) with $\Omega_M = 1$, and the static universe model. We show that the Hubble diagram clearly follows the exponential tired light RS formula as expected for static and for slowly expanding universe models.

The tired-light RS theory is re-examined in connection with astronomical observations and novel theories of the physical properties of the quantum vacuum by assuming thermalization of starlight into a homogeneous blackbody energy distribution. Our results support the assumption that the RS of the spectral lines is composed of a velocity $H_{0,\ \text{expansion}}$ and a superimposed RS $H_{0,\ \text{tired light}}$ component of as yet unknown origin.

Keywords: Tired-light theory, redshift, Hubble constant, energy equilibration, quantum vacuum, cosmic microwave background, diffuse background radiation, energy conservation.

1. Introduction

The interpretation of the RS of atomic spectral lines emitted by distant galaxies as recession velocity was probably the most important contribution leading to the conception of the Big Bang Theory; a highly successful theory for explaining the origin and expansion of the universe, the abundance of light elements, and the existence of the 2.7K cosmic microwave background (CMB), demonstrating that its basic assumption-i.e. the expansion of the universe-is a legitimate global concept.

At the same time, however, we have to bear in mind that, as the counterpart to its great success, this interpretation was the most compelling evidence for introducing the elusive "dark" components-dark matter (DM) and dark energy (DE)-into cosmology. Nearly all the major problems of modern cosmology have their origin in this hypothesis. To mention only a few:

Firstly: Accurate observations of the CMB anisotropy show, that the universe is flat [1]. Following the paradigm of the Big Bang Theory, *kinetic energy = ½ gravitational energy*, the critical mass for a flat universe $\rho_{cr} = \frac{3H^2}{8\pi G}$ (H_0 = 72.6 km s^{-1} Mpc^{-1}) corresponds to a mass density of $\approx 10^{-29}$ g cm^{-3}. In contrast, the density of matter which has been observed so far only amounts to a few percent of the critical value.

Secondly: A further problem is related to the age of the universe which nearly corresponds to the age of its oldest stars. The problem is that galaxy formation in a purely baryonic universe does not work. It is impossible for baryonic matter to form galaxies and large scale structure in a time as short as 10-20 billion years. Estimates show that the time necessary for the formation of galaxy clusters amounts to roughly 200 billion years [2].

Thirdly: Another problem with the cosmological expansion relates to the loss of energy associated with the RS. Contemporary big-bang cosmology ignores this problem and often, this loss of energy is explained by some physically questionable arguments such as the universe is an open system to which, on the cosmic scale, energy conservation does not apply; or using the statement that the redshifted energy disappears in the quantum vacuum.

An alternate answer to the problems described above might be found in the hypothesis, that RS of spectral lines is composed of a velocity and a superimposed RS component [3, 4] of as yet unknown origin and the rate of expansion is much lower, namely, the universe expands according to the Friedmann equation with $\rho_{M,\,obs} \approx 10^{-31}$g cm^{-3}, $\Lambda = 0$, $k = 0$.

Contemporary Big Bang cosmology adheres to the velocity interpretation and surmises DM and DE for explaining the missing mass and age problems. Many cosmologists consider the postulate of DM and DE as the main finding of present astrophysics. Speculations about the physical nature of these unknown particles and energy are numerous but not successful as yet. If a search for DM and DE turns out to be unsuccessful, the whole construction will break down and we shall face the unavoidable question of what is the real mechanism that produces the observed values of the RS.

2. The Slowly Expanding Universe Model

When GR is applied to the universe as a whole it turns out that space should either be contracting or expanding. On the assumption that expansion is governed by the gravitational attraction of the observable mass density $\rho_{M,\,obs.}$ against the outward impulse of motion the solution of the field equation ($k=0$; $\Lambda=0$) leads to

$$\left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi G}{3}\rho_{M\,,obs.} \qquad (1)$$

Surprisingly, this simple model that naturally follows from the Einstein equation and from the observable mass density was not considered in literature as a possible alternative to the static- and the big-bang-model at all, although when it is compared with the ΛCDM and static universe models, its advantages is obvious; for example:

(i) Inferring the Hubble constant from the observable mass density of some 10^{-31}g cm^{-3} (instead of ~ 10^{-29}g cm^{-3} as calculated on the basis of the still controversial interpretation of

RS as recession velocity) leads to $H_0 = \sqrt{\frac{\rho_{obs} \times 8\pi G}{3}}$ ~ 5-15 km s^{1} Mpc^{-1} and the missing mass problem on the cosmic scale does not arise.

(ii) Inferring the age of the universe from 1/H$_0$ with H$_0$ ~ 10 km s^{-1} Mpc^{-1} yields ~ 100 billion years, and with this, galaxies may have been evolved over time in some regular way without the need for DM or DE.

(iii) In comparison with the ΛCDM and static universe models the SEU model is simple and follows from GR without additional free parameters like the elusive dark components DM and DE or, in case of a static universe, the cosmological constant Λ of unknown physical nature.

(iv) SEU is exclusively based on observable quantities, i.e.: $\rho_{M,\, obs.}$, the experimentally measured RS distance relation, and the experimentally confirmed Euclidean geometry of the universe, instead of introducing unknown particles and energy.

3. Is the Slowly Expanding Universe Model in Agreement with Observational Data?

In favor of the SEU model we can present the following reasons:

3. 1. The Hubble Diagram Test

In a previous paper [5] we compared the observed Hubble diagram compiled from 171 supernovae RS data in the range of z = 0.0141–8.1 with theoretical Hubble diagrams calculated on the basis of the ΛCDM and SEU model that expands according to equation (1) with Ω_M = 1 and the static universe model. We expected that in the high RS range (i) it should be possible to check more precisely whether the Hubble diagram follows a linear, $z = H_0 D_C/c$ or the exponential

$$z = e^{H_0 \frac{d}{c}} - 1 = e^{H_0 t_S} - 1 \tag{2}$$

relationship-an effect which is only slightly perceptible in the z < 1 region and (ii) the fitting of the calculated t_S/RS diagrams to the observed RS data would, as predicted by different cosmological models, set constraints on alternative cosmological models. On the basis of our results we concluded that the best fit function derived from the observed RS/magnitude (μ) data corresponds to the exponential energy depletion according to Equation (2).

In order to ensure and refine our previous results in this paper we present an extended t_S/RS data analysis including 280 data points.

3. 1. 1. Data Collection and Processing

In our analysis we have included data obtained by Wei [6] from 59 calibrated high-RS gamma–ray bursts (GRB) (Hymnium data set) from the 557 Union 2-compilation and 50 low RS GRBs, and 171 gold–set data [7].

For conversion of the RS/μ data points into the t_S/RS representation Equations (2), (3) and (4) were used.

The photon flight-time t_S was calculated from

$$t_S = \frac{Dc}{c} = \frac{10^{\frac{\mu+5}{5}}}{(z+1)\times 3\times 10^{10}} \times 3.085\times 10^{18} \tag{3}$$

In Equation (3) t_S means the flight time of the photons from the co-moving proper distance D_C to the observer that should not be confused with the photon travel time (t) in an expanding universe according to the ΛCDM model. t_S means the flight-time of photons between emission and reception, $t_S = D_C/c$, which is proportional to the D_C that goes into the linear Hubble law.

The photon flight time for the ΛCDM model was calculated with H_0 = 72.6 km s^{-1} Mpc^{-1}, Ω_M = 0.266, Ω_Λ = 0.732 and k = 0 [8]. Excel and Excel Solver were used for data refinement and data presentation.

3. 1. 2. Results

Since the RS/μ data are plagued by considerable scatter, similar to the procedure described in (1) the potential $\mu = a\times z^b$ function was used to perform a global fitting over the RS range of z = 0.0141–8.1.

The best fit curve is shown in Figure 1:

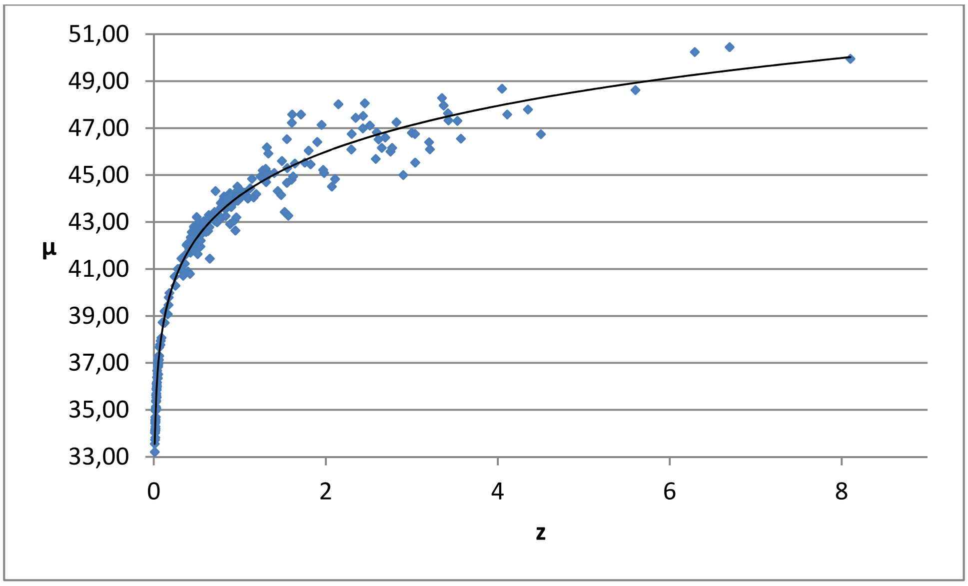

Figure 1: Solid line: potential best fit, diamonds: observed RS/μ data

The goodness of fit was characterized by the corresponding R-square and χ–square values. The potential–fit curve is represented by

$$\mu = 44.11888 \pm 0.032 \times z^{0.05986 \pm 0.00066};\ R^2 = 0.984;\ P_{\chi\text{-test}} = 1 \qquad (4)$$

The results differ only slightly from the parameters derived from 171 data points.

Since differences between the different cosmological models become more pronounced only in the linear t_S/RS data representation using Equation (3) and (4) the potential best-fit data were converted into a t_S/RS data set.

Comparison between the best-fit data, the static universe, SEU and ΛCDM cosmological models is shown in Figure 2:

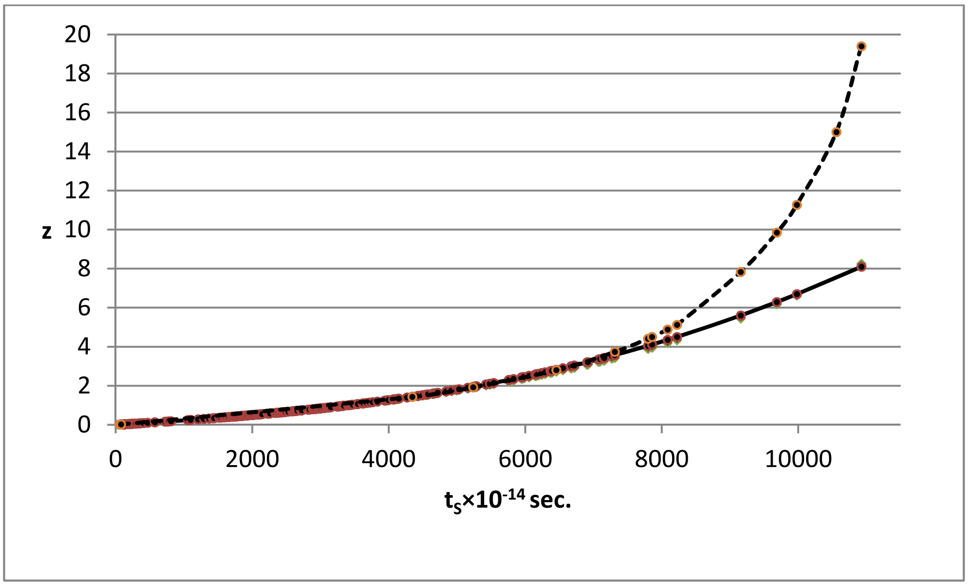

Figure 2: Redshift of type Ia supernovae as a function of $t_S = D_C/c$. Solid line: t_S/RS relation inferred from the potential best–fit curve of the RS/μ diagram. Diamonds: The exponential t_S/RS relation with $H_0 = 1.97\times10^{-18}$ Hz s^{-1} Hz $^{-1}$. Circles: RS for the SEU with $H_0 = 1.94\times10^{-18}$ Hz s^{-1} Hz $^{-1}$+RS resulting from expansion with 5 km s^{-1} Mpc^{-1}. Short-dashed line: t_S/RS relation derived from the distances D_C obtained from the ΛCDM model with $H_0 = 72.6$ km s^{-1} Mpc^{-1}

3. 1. 3. Analysis of the z < 1 region

At RSs z < ~ 0.3 the t_S/RS curves derived from the different cosmological models can also be fitted with a linear function. The linear approximation, however, is deceiving. At higher RSs, the best-fit curve obeys the exponential energy depletion relationship.

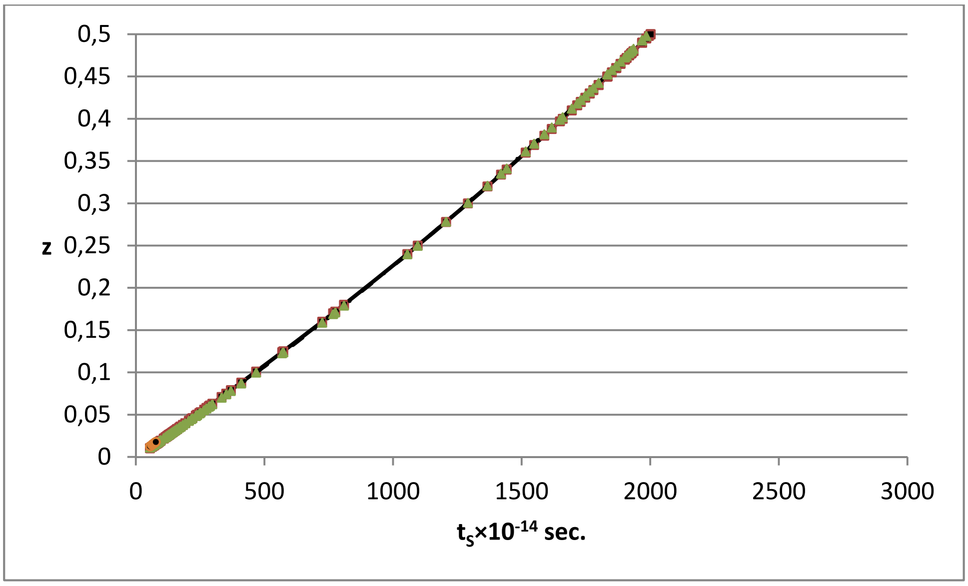

Figure 3: The "linear" t_S/RS relation in the low RS region for the static universe, SEU and ΛCDM cosmological models

3. 1. 4. Analysis of the z > 2 region

For data analysis 41 equidistant RS/μ data were converted into a t_S/RS data set and compared with data calculated from the static universe, SEU and ΛCDM models.

Data are summarized in Table 1.

Table 1: tS/RS data for the potential best fit, static universe, SEU and the ΛCDM model

$t_S \times 10^{-14}$	Potential fit	static universe	SEU	ΛCDM
6000	2.39	2.26	2.32	2.54
6125	2.48	2.34	2.40	2.65
6250	2.57	2.43	2.48	2.74
6375	2.66	2.51	2.57	2.88
6500	2.75	2.60	2.66	3.00
6625	2.85	2.69	2.74	3.13
6750	2.95	2.78	2.84	3.26
6875	3.05	2.87	2.93	3.40
7000	3.15	2.97	3.02	3.55
7125	3.26	3.07	3.12	3.71
7250	3.38	3.17	3.22	3.87
7375	3.47	3.28	3.33	4.04
7500	3.59	3.38	3.43	4.22
7625	3.70	3.49	3.54	4.41
7750	3.81	3.60	3.65	4.60
7875	3.93	3.72	3.76	4.81
8000	4.05	3.84	3.88	5.04
8125	4.17	3.96	4.00	5.27
8250	4.30	4.08	4.12	5.52
8375	4.42	4.21	4.24	5.78
8500	4.55	4.34	4.37	6.07
8625	4.69	4.47	4.50	6.37
8750	4.82	4.61	4.63	6.67
8875	4.96	4.75	4.77	7.02
9000	5.10	4.89	4.91	7.37
9125	5.24	5.04	5.05	7.76
9250	5.38	5.19	5.20	8.17
9375	5.53	5.34	5.35	8.62
9500	5.68	5.50	5.50	9.10
9625	5.82	5.66	5.66	9.59
9750	5.98	5.83	5.82	10.15
9875	6.13	6.00	5.99	10.75
10000	6.30	6.17	6.16	11.37
10125	6.45	6.35	6.33	12.10
10250	6.62	6.53	6.51	12.83

10375	6.78	6.72	6.69	13.67
10500	6.94	6.91	6.87	14.56
10625	7.12	7.11	7.06	15.56
10750	7.29	7.31	7.26	16.62
10875	7.46	7.52	7.46	17.80
11000	7.64	7.73	7.66	19.10

Figure 4 shows the graphical representation of the data at z > 3

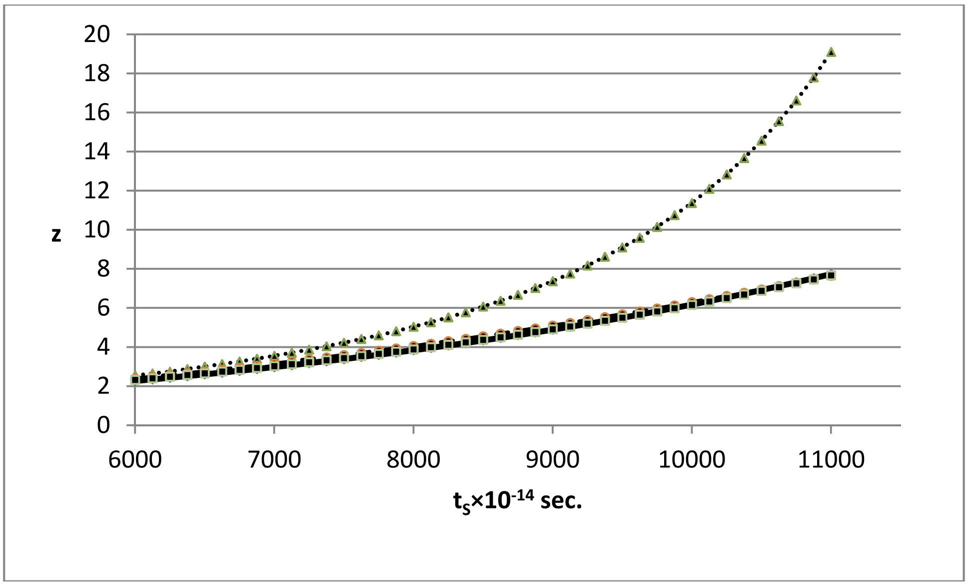

Figure 4: t_S/RS curves for the best fit data (circles), the static universe model (diamonds, H_0 = 1.97×10^{-18} Hz s^{-1} Hz^{-1}), for SEU (squares, H_0 = 1.94×10^{-18} Hz s^{-1} Hz^{-1} + RS resulting from expansion with H_0 = 5 km s^{-1} Mpc^{-1}) and the ΛCDM model (triangles, dotted line) in the high RS range

Goodness-of-fit indicators are summarized in Table 2.

Table2:

Z > 3	**X test**	**X squared**
Static universe	1	1
SEU	1	1
ΛCDM model	0,058	0,046

The most impressive result of the Hubble diagram test is that the t_S/RS relation obtained from the potential best-fit data can be expressed exactly by the exponential formula $z = e^{1.97\times10^{-18} t_S} - 1$ (diamonds) over the whole range of z.

Also the slowly expanding universe model (circles) with $H_0 = 1.93\times10^{-18}$ Hz s^{-1} Hz^{-1}, plus the RS resulting from the expansion with 5 km s^{-1} Mpc^{-1} shows a similarly good fit and the two models become nearly identical.

The long-dashed line in Figure 2 stands for the t_S/RS relation, derived from the ΛCDM model with $H_0 = 72.6$ km s^{-1} Mpc^{-1}, $\Omega_M = 0.266$, $\Omega_\Lambda = 0.732$ and $k = 0$ [8].

One can see from Figure 4 that RSs calculated on the basis of the ΛCDM model show a poor agreement with the observed data. Many data points lie outside of the error boundaries and show a systematic (non-statistical) deviation from the best-fit line. The χ-square test leads to a statistical significance between the observational potential fit and the calculated ΛCDM data of $P \approx 0.05$, indicating that from the statistical point of view the two models are essentially different.

The Hubble diagram clearly follows the exponential tired light RS formula as expected for static and for slowly expanding universe models.

3. 2. The Local Velocity Anomaly

Measuring the clustering of bright galaxies has shown that the 3-dimensional distribution of luminous matter has a SB-like appearance with the visible galaxies on the surface of the soap bubbles [15, 16]. The galaxies are situated in walls, filaments and dense nodes, forming a network which surrounds huge voids. The voids occur on scales of 100 Mpc and are free of matter. In the following discussion we regard a single void as a representative part of the infinite universe and describe the universal expansion by the example of this isolated but representative sample. It is assumed that all voids of the universe expand in the same way.

The Local Void was identified in the Nearby Galaxies Atlas [17]. The empty region begins at the edge of the Local Group and our Milky Way lies on the surface of the Local Void. The size of the void is poorly defined, because much of it lies behind the plane of the Milky Way. It nearest part may have a diameter of ~ 45-65 Mpc [18, 19] and the south and north extensions have diameter of 140 and 160 Mpc, respectively.

The local velocity anomaly was first noticed by S. M. Faber and D. Burstein [20] and R. B. Tully [21] and has been discussed subsequently by several authors [22-24]. Recently, a comprehensive study on this topic was published by R. B. Tully [25]:

The observation is the following [25]: The Sun orbits in our Milky Way Galaxy at 220 km/s. The Milky Way is falling toward the Andromeda Galaxy at 135 km/s. The neighborhood of our galaxy is retarded from the cosmic expansion by the Virgo Cluster by 185 km/s. These velocities correspond to the expected gravitational attraction by the mass of the neighboring galaxies.

However, after subtraction of the velocity components caused by the nearby galaxies, the residual pattern of motion reveals an extra component: The Milky Way moves away from the Local Void with a velocity of 260 km/s in a direction close to the supergalactic South Pole. This movement is not toward anything substantial, but is directly away from the Local Void, orthogonal to the disk of the Local Sheet [25].

For an average void with a radius of 50 Mpc the expansion velocity of 260 km/s leads to a Hubble constant of 5.2 km s^{-1} Mpc^{-1} in good agreement with the expansion rate inferred from the SEU model with $\rho_M \approx 10^{-31}$ g cm^{-3}, $\Lambda = 0$, $k = 0$.

This result could have far–reaching consequences for our understanding of the universal expansion. Regarding voids as the dynamical component of the expansion, the large scale structure can be thought of as a close packing of expanding spheres of different sizes and the linearity of the individual expansion rates with distance makes it impossible to differentiate local void expansion from a global cosmic expansion.

4. New Interpretation of the Cosmic Redshift

However, the value of the Hubble constant of 5.2 km s^{-1} Mpc^{-1} is far not enough to explain the RS of atomic spectral lines. A resolution of this problem might be found in the hypothesis that the RS of spectral lines is composed of a velocity and a superimposed RS component of as yet unknown origin and the rate of expansion is much lower, that is, the universe expands according to the prediction of the SEU-model.

In the following we describe a new tired light mechanism that explains the observed RS/t_S relation in a static or slowly expanding universe by assuming thermalization of starlight into a homogeneous blackbody energy distribution.

4. 1. Main Hypothesis

We assume thermalization of the energy of atomic spectral photons into the equilibrium blackbody energy distribution.

This idea is not really new. Its conceptual origin can be traced back to early ideas of Eddington, Regener, Nernst, and Finlay-Freundlich [10, 11] predicting a temperature of the interstellar space of ~ 3 K. The proposed mechanism, explicitly the loss of energy of starlight by photon-photon scattering was widely criticized [26] and because no convincing mechanism could be identified at that time the tired light model for explaining intergalactic RS was discarded. This lack of knowledge, however, cannot be used as a decisive argument against the tired-light theories. The cosmologically more important issue is to decide, whether the Hubble diagrams follows a linear or exponential relationship. The presented t_S/RS - test clearly favors the static and SEU models.

In extension of previous ideas mentioned above we further assume that energy equilibration is a natural quantum mechanical process, inherent in the energetically excited quantum vacuum itself and thus, equilibration does not require any material mediator for transfer of energy from the starlight into the CMB.

With this interpretation, of course, H_0 does not represent the velocity of expansion, km s^{-1} Mpc^{-1}, but the rate of energy transfer from starlight into CMB and has the dimension Hz s^{-1} Hz^{-1}, according to the presented energy equilibration theory.

4. 2. Thermalization of Starlight into Blackbody Radiation

In favor of the presented theory we can support the following reasons:

4. 2. 1. The Missing Diffuse Background Radiation

Beside the CMB the universe also contains a considerable amount of radiation not belonging to the blackbody spectrum, called diffuse background radiation (DBR). DBR is expected to arise from cumulative emissions of pregalactic, protogalactic, and evolved galactic systems over the history of the universe, assuming that star formation is the major source of the observed background [9].

It is to be expected that similar to CMB, DBR would also establish a certain radiation temperature of the interstellar space. There are numerous estimates to determine this temperature. A compilation of these results is shown in Table 3.

Table 3: Estimates of the temperature of the interstellar space (K). Data are taken from [10, 11]

Guillaume	5-6
Eddington	3.18
Regener	2.8
Herzberg	2.3
Nernst	2.8
Finlay-Freundlich	1.9-6

It is a surprising fact that all these unanimous estimates deviate considerably from experimental data. Sky brightness measurements by COBE, DIRBE, and FIRAS have permitted the first quantitative results of the diffuse cosmic background (DBR) at all wavelengths showing that infrared radiation in the range from 0.3 to 200 μm is the major contribution to the total DBR energy. It amounts to only 10 % of the expected value [12–14].

Thus, it is legitimate to ask if all these careful estimates carried out by notable physicists are really so much in error, or as is a more likely explanation, the lack of DBR energy is to be seen as an indication in favor of the presented theory; namely, as a steadily flow of energy from the starlight into the CMB by the proposed energy equilibration process.

4. 3. Supporting Physical Theories

In order to give a supporting physical basis for the proposed energy equilibration it is necessary to answer the following question:

Is the transfer of energy from starlight into CMB without any material mediator a physically acceptable concept?

To answer this question we can present the following reasons:

(1) Theories that support energy equilibration of starlight into CMB without material mediator are described by Opher and Pelinson [27] and Lima and M. Trodden [28]. They describe the possible decay of vacuum energy into CMB photons. The process corresponds to a continuous flow of energy from the vacuum to the created CMB radiation field. It leads to a Planckian type form of the spectrum, which is preserved in the course of evolution. Further literature supporting the theory of energy equilibration can be found in [29–35].

In generalization of these theories we claim, that similar to the decay of vacuum energy into black body radiation, the energy of the excited vacuum state also has the tendency to equilibrate into the Planckian blackbody distribution.

(2) Energy equilibration also follows from the principle of maximum entropy, which states that the probability distribution has the largest entropy and herewith the thermodynamically favored distribution of energy. For photons (the excited quantum vacuum), the equilibrium state is the well-known Planckian blackbody energy distribution [36].

(3) In quantum field theory the vacuum state is defined as the ground state of interacting quantum fields that can exist in various excited states. The vacuum is described as a quantized, fine grained, evolving, dynamical medium; waves propagating in this medium can be described as excitation of specific quantum states. Photons, for example, are interpreted as elementary excitations in a fine grained space whose ground state is the vacuum [37]. Since all constituents of the excited vacuum, photons, virtual particles, and also possible

space and time are quantum mechanical, it is consequent to assume that between these constituents energy exchange will occur and, furthermore, that the equilibrium state of these energetically intimately interacting fields is the probability energy distribution, i.e. the black-body energy distribution.

We assume that Planck's formula continues to be valid in every quantum system, in atomic, solid state systems and also even in the excited quantum vacuum itself. Thus, energy equilibration is an inevitable physical process rather than a theoretically unfounded physical assumption.

5. Conclusions

We have discussed here the Hubble diagram test for expanding and static universe models and shown that the exponential energy depletion $z = e^{H_0 t_S} - 1$, characteristic for static and also for slowly expanding universe models, fits the experimental data with high accuracy while the RSs calculated on the basis of the ΛCDM model are in poor agreement with observation.

We have shown that the slowly expanding universe model unifies the advantages of expanding and static models by avoiding their problems: namely, the DM, DE problem of the ΛCDM model, and, in case of the static universe the problem of the cosmological constant and gravitational instability.

On the basis of the results presented in this paper we feel that the SEU model represents a promising alternative to the ΛCDM and static universe models that could possibly be verified by studying the effect of the lower expansion rate on the big bang nucleo-synthesis (BBN). It is known that the relic abundance of the light elements depends on the expansion rate which determines the temperature and nucleon density in the early universe which in turn has a strong influence on the elements abundance pattern. As a consequence, BBN could set further constraints on the discussed cosmological models.

We have presented theories supporting our assumption, which shows that the proposed equilibration process might take place without any material mediator. The equilibration follows from the interaction between quantum states of the excited space-time entity and therefore, energy equilibration has to be looked at as a natural quantum physical process rather than as being physically unlikely.

In the presented theory, at least, there is no real loss of energy; the energy of the redshifted photons is merely converted into CMB energy and the total energy ($E_\lambda + E_{CMB}$) has not changed.

The theory makes provable predictions: the energy equilibration theory predicts RS of spectral lines even inside non-expanding galactic systems. Thus, in experiments similar to the Pioneer mission the validity of our theory could be proved experimentally.

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