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Research Article

Does the Hubble Constant Really Represent Recession Velocity? A New Interpretation of the Cosmic Redshift.

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Abstract

The tired-light redshift (RS) theory in a static or slowly expanding universe is re-examined in connection with novel theories of the physical properties of the quantum vacuum by assuming thermalization of starlight into a homogeneous black-body energy distribution. A new redshift /photon travel time (RS/t) relation is deduced and predictions of the theory are compared with those of the lambda-cold dark matter (ΛCDM) model and with supernovae RS data.

Key words: 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 amounts only to a few percent of the critical value.

For comparison: 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 $H_0 = \sqrt{\frac{\rho_{obs} \times 8\pi G}{3}}$ ~ 7-15 km s^1 Mpc^{-1} and the missing mass problem on the cosmic scale does not arise.
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].
For comparison: Inferring the age of the universe from $1/H_0$ with H_0 ~ 7 km s^{-1} Mpc^{-1} yields ~ 170 billion years, and with this, galaxies may have been evolved over time in some regular way without the need for DM or DE.
Finally: 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 still unexplainable loss of energy is explained by some physically questionable arguments like the universe is an open system to which, on the cosmic scale, energy conservation does not apply, or simply using the fuzzy 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, say, 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 purely 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 search for DM and DE turns out unsuccessful, the whole construction will break down and we shall unavoidable face the question what is the real mechanism that produces the observed values of the RS.

2 Tired – Light Redshift Theories

The tired-light scenario assumes that the photon loses energy due to some unknown process when travels through space. The idea was first suggested by Zwicky [5] to explain the Hubble relation. The major problem with this theory is the identification of a convincing physical process responsible for the observed loss of energy.
Since that time several theories appeared in scientific literature, by which photons in transit might lose energy. To mention only a few: Photon-photon scattering [6 – 9], absorption of starlight by luminiferous ether [10, 11], interaction of photons with vacuum particles [12], with intergalactic matter [13], dispersive extinction [14], photon decay in curved space-time [15] have been proposed but for lack of supporting physical and astronomical evidence not accepted by mainstream cosmology.
In this paper I will describe a new tired light mechanism that explains the observed RS/d (distance) relation in a static or slowly expanding universe by assuming thermalization of starlight into a homogeneous black-body 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 [16, 17] predicting a temperature of

the interstellar space of ~ 3 K for a static universe in thermal equilibrium. The proposed mechanism, explicitly the loss of energy of starlight by photon-photon scattering was widely criticized [18] and because no convincing mechanism could be identified at that time the tired light model for explaining intergalactic RS was discarded.
During the last few decades, however, new theories of the physical nature and structure of the quantum vacuum have become available, so a reconsideration of the tired model in light of these theories appears warranted.

3 New Interpretation of the Cosmic Redshift
3 1 Main Hypothesis

We assume thermalization of the energy of atomic spectral photons into the equilibrium blackbody energy distribution. 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. Supporting physical theories in favor of the proposed energy equilibration without material mediator are discussed in Section 5.
To illustrate the concept let us assume that an emitted photon having energy $h\nu$ travels through the CMB radiation field. According to the proposed energy equilibration there is a transfer of energy from the travelling photon into the CMB radiation field.
The rate of energy transfer is given by

$$d\nu_t/dt = H_0\nu_t \tag{1}$$

where ν_t is the frequency of the photon at time t (sec.) after emission, H_0 is the Hubble constant, and $h\nu = \nu;\ h = 1$).
According to this schema the energy of an emitted photon after a second flight time is $\nu_e - \nu_e H_0 = \nu_e(1-H_0)$, after two seconds $\nu_e(1-H_0) - \nu_e(1-H_0)H_0 = \nu_e(1-H_0)^2$ and after t seconds the observed frequency ν_{obs} is

$$\nu_{obs} = \nu_{em}(1-H_0)^t \tag{2}$$

and with (2) the RS

$$z = \frac{\nu_e - \nu_e(1-H_0)^t}{\nu_e(1-H_0)^t} = \frac{1}{(1-H_0)^t} - 1 \tag{3}$$

Eq.(3) leads to an exponential increase of RS with increasing flight-time *t*. This is essentially the tired light model. For short distances, $z \ll 1$, eq. (3) can be approximated by the linear relation $z \approx H_0 t$.
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.

3 2 The Exponential RS/t Relation

The ΛCDM model with H_0 = 72 km s^{-1} Mpc^{-1}, $\Omega_M = 0.266$, $\Omega_\Lambda = 0.732$ and k = 0 leads to a mathematically correct solution for the evolution of an expanding universe; the universe has expanded from its beginning to the present time to an extent of about D_C = 46 billion ly, where D_C is the co-moving proper distance.

However, the ΛCDM model, though cosmologically important, has by itself no physical basis and requires a choice of free parameters (DM and DE) in order to fit the underlying expansion theory to the observed RS/d data.
An alternative procedure is to choose a static (or slowly expanding) space and analyze cosmological observations exclusively on the basis of 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.
Imagine now that, although the result obtained on the basis of the ΛCDM model is a mathematically correct description of the present radius and distances in an expanding universe, nevertheless, the expanding space interpretation is physically fictitious and the universe is static, or slowly expanding, and infinite, or very large, in extent. In this case, the ΛCDM-model represents only a mathematical fit to the observed RS data, but in reality, the calculated distances represent non-expanding distances between observer and the emitting objects in a static universe. With this assumption the flight-time of photons between emission and reception is $t = D_C/c$.
The resulting RS/t relation, derived from the distances D_C, as obtained from the ΛCDM-model with $H_0 = 68$ km s^{-1} Mpc^{-1} and k = 0 is represented by the solid line in Figure 1 [19].

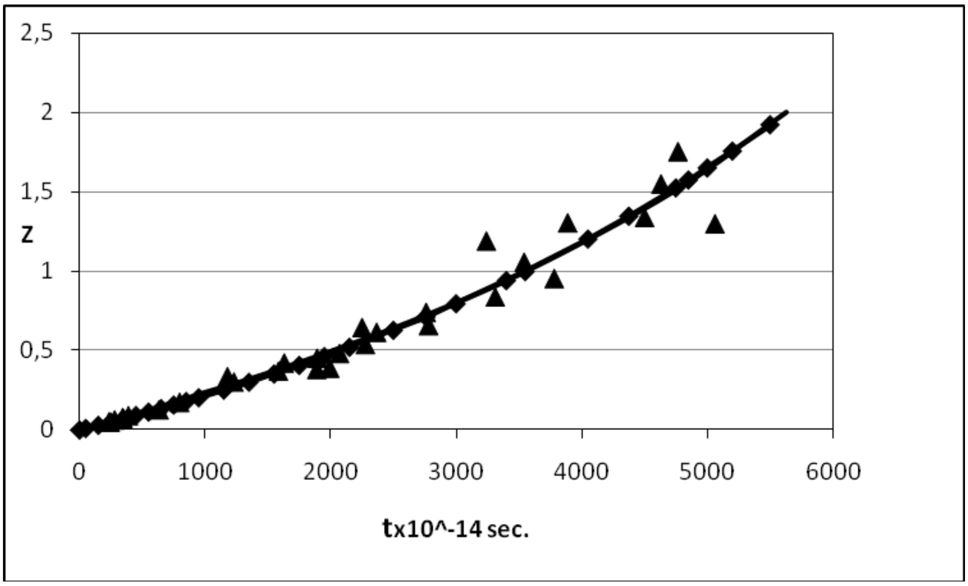

Figure 1: Redshift of type Ia supernovae as function of $t = D_C/c$. Plane line: ΛCDM-model with $H_0 = 68$ km s^{-1} Mpc^{-1}. Diamonds: RS/t relation inferred from eq. (3) with $H_0 = 1.95\times10^{-18}$ Hz s^{-1} Hz^{-1}. Triangles: representative 'gold set' data [20]; luminosity distances were converted into D_C by $D_C = D_L/(1 + z)$.

One can see from Fig. 1 that the two approaches, the ΛCDM-model, supposing expansion, and the static universe model, supposing energy equilibration, although fundamentally different, lead to similar results and show a fairly good fit to the observed redshifts.
An advantage of the equilibration model compared with ΛCDM is that the equilibration model does not require unknown constituents and that there is no real loss of energy associated with this process: The energy of the redshifted photons is merely converted into CMB energy and the total energy ($E_\lambda + E_{CMB}$) has not changed.

4 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 [21].
It is to be expected that similar to CMB, also DBR would 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 1.

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

Table 1: Estimates of the temperature of the interstellar space (K).
Data are taken from [16, 17]

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 [22 – 24].
Thus, it is legitimate to ask, if all these careful estimates carried out by notable physicists are really so much in error, or as 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.

5 Thermalization of Starlight into Black - Body Radiation

The interpretation of RS of atomic spectral lines suffers from the fact that none of the proposed mechanisms, including the expanding space paradigm, can be verified experimentally. Thus, the confidence in each theory must be measured by its success in explaining the observational phenomena. In Section 3.2 we have shown that observed RS date agree well with data inferred from eq. (3).
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 [25] and Lima and M. Trodden [26]. 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 [27 – 33].
In generalization of these theories we claim, that similar to the decay of vacuum energy into black body radiation, also the energy of the excited vacuum state has the tendency to equilibrate into the Planckian black body distribution.
(2) Energy equilibration also follows from the principle of maximum entropy, which states that the probability distribution has the 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 black-body energy distribution [34].
(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 [35]. Because all constituents of the excited vacuum, photons, virtual particles, and possible also space and time are quantum mechanical, it is consequent to assume that between these constituents energy exchange will occur and, further, 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 even also in the excited quantum vacuum itself and thus, energy equilibration is rather an inevitable physical process than a theoretically unfounded physical assumption.
Admittedly, the presented theory remains incomplete to an extent as it does not include explicit physical micromechanism according to portions of energy of the photon can be transferred into the CMB black body energy distribution. However, this lack of knowledge is inherent in the expanding space paradigm, too. Classical physics tells us that the energy of a photon depends on its wavelength by $E = hc/\lambda$. It is assumed that the expanding space stretches the photon's wavelength and consequently, its energy decreases. However, the explanation given above simply describes what will happen to the energy when the wavelengths of photons increase under certain conditions, but similar to the proposed energy equilibration the expanding space hypothesis can neither provide an explicit micromechanism for the energy transfer, nor can it tell us where the redshifted energy has gone.
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_λ + E_{CMB}) has not changed.

6 Conclusions

In this paper we reconsider and extend the tired light theory for the explanation of the cosmic RS by utilizing the principle of energy equilibration between starlight and CMB. We present a new RS/t relation and novel scientific 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 being physically unlikely.
We further show that (i) redshifts calculated with equation (3) are in agreement with the observed supernovae RS data, (ii) the model avoids the missing mass problem on the cosmic scale and (iii) the age problem of galaxy formation by assuming a static or

slowly expanding universe and (iv) explains the RS in accordance with the law of energy conservation.
We do not expect that all the results presented in this paper will turn out to be correct in every detail on closer examination. The theory, however, makes provable predictions: The energy equilibration theory predicts RS of spectral lines even inside of non-expanding galactic systems. Moreover, if the correct form of eq. (1) should turn out to be $\nu_t = H_0(\nu_t - \nu_{CMB})$ a possible blueshift of radio signals as suspected by Anderson et al. [36]. Thus, in experiments similar to the Pioneer mission the validity of our theory could be proved experimentally.

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