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Is the Velocity Interpretation of the Redshift of Spectral Lines in Accordance with Astronomical Data?

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Abstract

Current progress in cosmic microwave background (CMB) anisotropy measurements opens up the possibility of determining Hubble's constant ($H_0 = h \times 100$ km s^{-1} Mpc^{-1}) from the CMB power spectrum radiation temperature anisotropy. The results show that, besides the Lambda cold dark matter (ΛCDM) model, much simpler Einstein-de Sitter (EdeS) models without the cosmological constant can fit the data as well, or even better, than the ΛCDM model. Calculations with EdeS models yield unexpectedly low values for Hubble's constant of $h = 0.30$ and 0.46, respectively. These values are completely inconsistent with the direct determination of $h \sim 0.70$ from the redshift (RS) of spectral lines. In the present paper I consider whether the gap between $h = 0.3$ and $h = 0.7$ could be explained using conventional physics without introducing further hypotheses, or whether the RS of starlight and the RS of the CMB could stem from different physical origins.

Keywords

Redshift, Hubble's Law, CMB Anisotropy, Einstein-de Sitter Cosmological Model, ΛCDM Cosmological Model

1. Introduction

1.1. Hubble's Law

In 1929 Hubble published his famous "… relation between distance and radial velocity among extra-galactic nebulae" [1]

$$z = \text{constant} \times d \tag{1}$$

Equation (1) is usually expressed as a redshift/velocity law:

$$zc = H_0 d \quad \text{or} \quad v = H_0 d \tag{2}$$

where v = expansion velocity, c = speed of light, and H_0 is Hubble's constant.

1.2. The Einstein-de Sitter Cosmological Model

The Einstein-de Sitter cosmological model [2] describes a flat universe expanding with velocity H_0 and having $\rho_B = \rho_{cr}$, $k = 0$, $\Lambda = 0$, and $q_0 = 1/2$:

$$H_t^2 = \frac{8\pi G}{3}\rho_{0,B}\left(\frac{R_0}{R_t}\right)^3 \tag{3}$$

where $\rho_{0,B}$ is the baryon density, ρ_{cr} is the critical baryon density, k is the spatial curvature, Λ is the cosmological constant, and q_0 is the deceleration parameter.

The present value of h lies within the narrow range h = 0.677 - 0.776 with the most probable value being h = 0.726. It is important to remark that the h of 0.726 does not follow from Equation (3); it is derived from the redshifts of atomic spectral lines on basis of Equation (2).

Scrutiny of the astronomical data has revealed significant discrepancies between predictions following from Equation (3) with the fixed value $h \sim 0.7$ and astronomical observation. A few examples of this are the missing mass problem, the age problem, and the fine tuning problem. The missing mass problem arises from the paradigm of the Big Bang theory, *i.e.* kinetic energy = 1/2 gravitational energy. The critical mass for a flat universe, $\rho_{B,CR} = \frac{3H^2}{8\pi G}$ with h = 0.726, corresponds to a mass density of $\approx 10^{-29}\ \text{g}\cdot\text{cm}^{-3}$. In contrast, the density of matter which has been observed so far amounts to a few percent of this critical value. The enormous deficit in observable mass is caused by the high value of H_0. The other problems also have their origin in the velocity hypothesis. Since the expansion of the universe cannot be measured experimentally, whilst the mass density, which is according to Equation (3) the velocity determining parameter, is accessible to direct measurements, at this point, a reconsideration of the velocity interpretation would have been warranted. However, the case that the rate of the universal expansion is proportional to the observable mass density—as predicted by Equation (3)—and consequently, the interpretation of Hubble's constant as a recession velocity being possibly incorrect, was not disputed. Instead, the validity of the velocity interpretation was firmly believed and, henceforth, H_0 was set as a fixed constant.

There are a number of fatal contradictions between observation and predictions of the Big Bang theory. The hypotheses of dark matter (DM) and dark energy (DE) were therefore introduced into Equation (3) in order to overcome these problems.

1.3. Development of the Lambda Cold Dark Matter (ΛCDM) Cosmological Model

The ΛCDM model, which contains variable amounts of DM and DE and has a fixed value of H_0, was developed and improved over time in order to fit observations:

$$\left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi G}{3}\rho_M + \frac{c}{3}\Lambda - k\frac{c^2}{R^2} \tag{4}$$

However, despite the ad hoc introduction of the hypothetical variables DM and DE, a number of problems remained unsolved; the flatness or fine tuning problems and the horizon problem, for example, cannot be explained within the framework of the standard model. A new hypothesis was proposed in order to elucidate these puzzles.

Guth [3] proposed the inflationary theory, according to which the early universe had a brief period of extremely rapid expansion, during which its diameter increased by a factor of perhaps 10^{50}. The inflationary scenario is capable of avoiding the flatness and horizon problems. The discussion of this theory, however, is not within the scope of this paper. Assuming inflation, the ΛCDM model with the free variables $\rho_m \approx 0.286$, $\rho_B \approx 0.07$, $\Lambda \approx 0.714$, $k = 0$ and $h \sim 0.7$ provides an excellent fit to most cosmological observations. However, the price is high: the ΛCDM model rests on a large number of hypotheses, inflation, DM, DE, and negative pressure, which either cannot be proved or though theoretically provable, could not be proved, yet.

"This fact provides a strong incentive to seek alternative explanations that can account for cosmological observations without resorting to dark matter or to Einstein's cosmological constant" [4].

2. Inconsistencies with the Velocity Interpretation of Hubble's Constant: Comparison of Direct and Indirect Measurements Results

1) Hubble's constant is usually determined by direct measurement of the RS of atomic spectral lines emitted by distant galaxies. Depending on the method of distance determination, the observed value of h is in the range 0.677 - 0.776, with the most probable value being 0.726.

2) Another way to determine h involves the CMB power spectrum. It was recently demonstrated that the simpler EdeS model with DM and zero cosmological constant can fit the data as well, or even better, than the concordance model. Calculation of h from various EdeS models without the cosmological constant leads to a substantially lower value of $h_{\text{EdeS}}^{\text{CMB}} = 0.30$ [5] or 0.46 [6] compared to $h_{\text{Spectral-lines(Spl)}} \approx 0.70$.

This result is rather unexpected. A Hubble constant of $h = 0.3$, as derived from the CMB power spectrum, is completely inconsistent with results of the direct determination of $h_{\text{Spl}} \sim 0.70$ and also with the $h_{\Lambda\text{CDM}}^{\text{CMB}} \sim 0.70$. (The $h \sim 0.7$ obtained on the basis of the ΛCDM model from the CMB however, is a more or less constrained target value, adopted from direct measurements).

The most uncompromising answer to explain the disagreement would be that something is wrong with the basic assumptions of the cosmological models, the interpretation of the CMB, or the model itself. Another possible conclusion could be—although this would be likely to seriously undermine faith in the reliability of observational data—that measurement errors in determining the RS are responsible for the discrepancies in the data [6].

Although none of above mentioned grounds can be definitely excluded, such assumptions appear unlikely. The gap between h = 0.726 and h = 0.30 is too wide; it seems unrealistic that it could be bridged by supposing systematic measurement errors. The theoretical background of understanding the CMB anisotropy is conclusive and the experimental data measured with COBA, WMAP, and Planck are consistent.

It seems justified to assume that both the direct measurement of H_0 and the indirect calculation on the basis of the CMB are correct. If so, the disagreement between the two results is real.

3. Possible Resolution to the Problem

As a straightforward explanation for the above disagreement I consider the case that the RS of starlight and the RS of the CMB have different physical origins. The dilemma is that the H_0 from the CMB and the H_0 from the direct RS measurement cannot mean recession velocity within the same theory.

3.1. The Redshift of the CMB Calculated from EdeS Models Is Due to Expansion

1) "Ockham's Razor" or the simplicity principle is one of the key criteria for choosing between rival theories. The principle states that simpler theories should be preferred to more complex ones. A theory is simpler than another if it contains fewer adjustable parameters in order to account for the empirical data. This criterion speaks clearly for the preference of h = 0.3 as the true velocity of the universal expansion.

2) Simplicity can also be understood in terms of the explaining potential of competitor theories.

The $h = 0.3$ with $\Omega_{(\mathrm{DM+B})} = 1$ from EdeS is, not unexpectedly, close to the value that naturally follows from the original Einstein Equation [7]

$$v^2 = \frac{8\pi G}{3}\rho_{B,obs} \tag{5}$$

with $\Omega_B = 1$, $\rho_B \sim 10^{-30}\ \mathrm{g{\cdot}cm^{-3}}$.

With $\Omega_B = 1$ and $h = 0.3$ the missing mass and the age problems would not arise.

3) Low-h models are also consistent with Big Bang nucleosynthesis, cluster baryonic fractions, the large scale distribution of galaxies and the ages of globular clusters, although in disagreement with direct determination of the Hubble constant [5].

4) Different tests based on observational data have been performed to provide evidence for the expansion hypothesis. Recently, Lopez-Corredoira [8] [9] and Crawford [10] critically reviewed the results of these tests and concluded that the

expansion tests do not support models with $h = 0.7$. Static [10] and slowly expanding universe models fit the observational data better than the ΛCDM model with $h = 0.7$ [11], although—without DM and DE—cannot account for the baryonic acoustic oscillations (BAO) and the integrated Sachs-Wolfe effect. Low h EdeS models with DM and zero cosmological constant, however, are expected to show not only a better agreement with the expansion tests but, in addition, they perfectly fit the BAO power spectrum and as pointed out by Blanchard *et al.* [6] have no strong integrated Sachs-Wolfe effect and are in better agreement with the low quadrupole seen by WMAP.

3.2. The Redshift of Atomic Spectral Lines

Strong support in favor of a non-velocity interpretation of the RS of spectral lines comes from the exponential slope of the Hubble diagram. Harrison [12] has shown that that the relation $v = H_0 d$ in an expanding homogeneous and isotropic universe must be a linear velocity/distance function.

It has been shown [13] that the RS/d diagram of 280 supernovae and gamma ray burst RSs can be fitted exactly with the function

$$z = \mathrm{e}^{2.024\times10^{-18}\times t_S} - 1 \tag{6}$$

as shown in **Figure 1(a)**, or, equivalently, with the analytical function

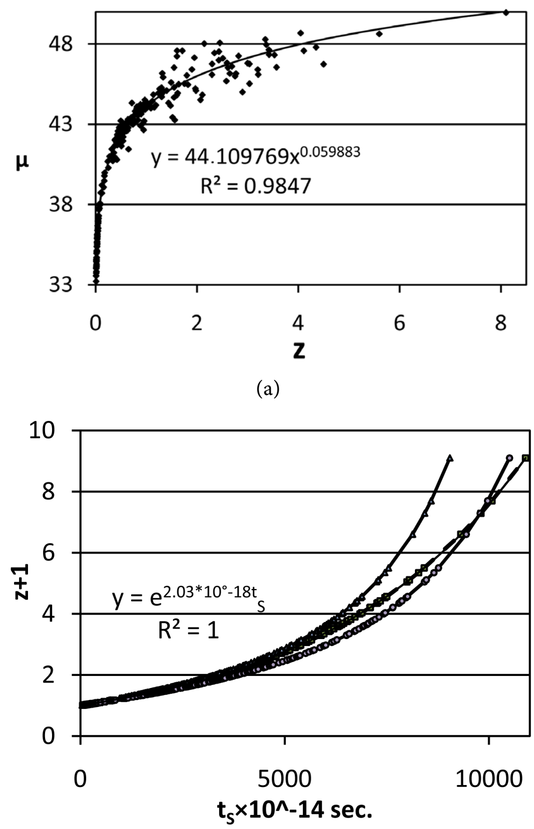
$$\mu = 25 + 5\log\left(c/H_0\right) + 5\log\left(\left(z+1\right)\ln\left(z+1\right)\right) \tag{7}$$

[14]. Here, t_S is the flight time of a photon from the co-moving radial distance to the observer and μ is the magnitude. These results have been confirmed [15] [16] [17].

As can be seen from **Figure 1(b)** (results are taken from [14]) ΛCDM models show a poor agreement with the observed data: the ΛCDM model with $H_0 = 62.5$ km·s^{-1}·Mpc^{-1} (bottom line) departs from the best-fit curve for $z + 1 < 6.5$ to the bottom, for $z + 1 > 6.5$ to the upper side of the trend-line (middle line). The deviations are of a systematic (non-statistical) nature and, therefore, the model cannot reflect the exponential slope.

In the range of $z > 3$ the ΛCDM model with $H_0 = 72.6$ km·s^{-1}·Mpc^{-1} (upper line) shows a sharp increase in slope and departs considerably from the observed exponential function. $\sum\chi^2$-test in the high RS range of $t_S \times 10^{-14} = 6000$ - 11,000 including 41 data points leads to a statistical significance between the observed t_S/z and the calculated ΛCDM data of $P = 0.053$, indicating that from the statistical point of view, the two data sets are essentially different.

The exponential slope of the Hubble diagram provides a clear indication for an energy decrease with a constant rate. However, it is not the aim of this paper to identify a specific energy decay mechanism I want only to point out that the disagreement between the two methods of determining H_0 is a real problem that needs explanation. With this, the Hubble diagram test could prove to be the most important cross check in identifying the true physical nature of H_0 (CMB) and H_0 (spectral lines). For further confirmation of the exponential slope of the



(a)

(b)

Figure 1. (a) Solid line: potential $\mu = a \times z^b$ best fit RS/μ data; (b) RS of type Ia supernovae and gammy ray bursts as a function of $t_S = D_C/c$.

Hubble diagram, more accurate data and more data points in the RS range of z > 3 are necessary to ensure a 4σ confidence level.

4. Conclusions

I have shown that the assumption of different physical origins for Hubble's constant of starlight and of the CMB represents a plausible explanation for the disagreement of the RSs obtained from the EdeS model without the cosmological constant. It also explains the results obtained by the determination of H_0 from atomic spectral lines. This conjecture is admittedly radical, but it is a logical conclusion if we refuse to believe that something is fundamentally wrong with the interpretation of the CMB anisotropies, or even with the concordance cosmological model itself.

There are only two possibilities to resolve the problem. Either we assume that the underlying ΛCDM cosmological model is in fact incomplete, or the distance measurements of H_0 are wrong. Alternatively, the presented interpretation, namely that the RS of starlight and RS of the CMB have different physical origins, is correct. At present, there is no third position. Currently, it might be too early to consider the ΛCDM model as definitely proved and confirmed by independent probes.

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