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Hubble Diagram Test of 280 Supernovae Redshift Data

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ABSTRACT

We compare the Hubble diagram calculated from the observed redshift (RS)/magnitude (μ) data of 280 Supernovae in the RS range of z = 0.0104 to 8.1 with Hubble diagrams inferred on the basis of the exponential tired light and the Lambda Cold Dark Matter (ΛCDM) cosmological model. We show that the experimentally measured Hubble diagram follows clearly the exponential photon flight time (t_S)/RS relation, whilst the data calculated on the basis of the ΛCDM model exhibit poor agreement with the observed data.

KEYWORDS

Redshift/Magnitude Data Fitting; Linear Hubble Relation; Exponential Hubble Relation; ΛCDM Cosmological Model

1. Introduction

The basic assumption of the Lambda Cold Dark Matter (ΛCDM) cosmological model is that the universe is expanding, according to the Hubble's law [1], at a velocity of $v = zc = H_0D_C$, where z is the redshift (RS), c is the velocity of light, H_0 is the Hubble constant, and D_C is the co-moving radial distance that can be derived from the observable z/μ data by (1).

$$D_C = \frac{10^{\frac{\mu+5}{5}}}{(z+1)} \times 3.085 \times 10^{18} \quad (1)$$

An important test of confidence in modeling the universal expansion is to compare the observed z/μ data with those derived on the basis of the ΛCDM model. The results presented in the literature, however, are not undisputed and are still a matter of debate. LaViolette [2] and more recently, López-Corredoira [3], Crawford [4], and Marosi [5-7] have shown that the static or slowly expanding universe models fit the observational data better than the data calculated on the basis of the presently prevailing ΛCDM model.

Such results, however, are usually refuted with the argument that the static universe contradicts many other cosmological observations, for example, the time dilation test and the cosmic microwave background (CMB) temperature versus RS test [8].

It is not the aim of this paper to argue in favor of or against either the expanding or static cosmological models. We only want to examine which of the two relations: the linear Hubble's law or the exponential $e^{H_0\frac{D_c}{c}} = z+1$ fits the observational RS/μ data more accurately.

We mean that the result of a proper data fitting procedure of reliable observational data cannot be ignored out of respect to the predictions of a theory. If facts contradict the theoretical expectations, then the only scientifically adequate answer can be that the underlying theory is at best, incomplete.

In this paper, we analyze the observed Hubble diagram compiled from 280 supernovae z/μ data in the range of z = 0.0104 to 8.1. We expect that in the high RS range, it should be possible to check more precisely whether the Hubble diagram follows a linear $z = H_0D_C/c$ relation, or the exponential

$$e^{H_0\frac{d}{c}} = e^{H_0t_s} = z+1 \quad (2)$$

relation; an effect that is perceptible only slightly in the $z < 1$ region.

2. Data Collection and Processing

In our analysis, we have included 171 gold-set data [9], 59 calibrated high-RS gamma-ray burst (GRB) data (Hymnium data set) and 50 low-RS GRBs obtained by Wei [10] from the 557 Union 2-compilation.

As the z/μ data are plagued by considerable scatter, similar to the procedure described in [5], the potential $\mu = a \times z^b$ function was used to perform a global fitting over the RS range of $z = 0.0104$ to 8.1.

As differences between the different cosmological models become more pronounced only in the linear t_S/z data representation, using Equations (2)-(4), the potential best fit data were converted into a t_S/z data set.

The photon flight time t_S was calculated from

$$t_s = \frac{D_c}{c} = \frac{10^{\frac{\mu+5}{5}}}{(z+1)\times 3\times 10^{10}} \times 3.085\times 10^{18} \qquad (3)$$

In Equations (2) and (3), t_S means the flight time of the photons from the co-moving radial distance D_C to the observer, which should not be confused with the photon travel time (t) in an expanding universe. t_S means the flight time of photons between emission and reception, ($t_S = D_C/c$, c is the velocity of light), which is proportional to the D_C that in entered in the linear Hubble law.

The photon flight time t_S for the ΛCDM model was calculated with $H_0 = 72.6\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$, $\Omega_M = 0.266$, $\Omega_\Lambda = 0.732$ and $k = 0$ [11].

For the purpose of performing χ-squared tests in the high RS range of $t_S \times 10^{-14} = 6000$ to 11000 between the potential best fit and the t_S/z data calculated on the basis of the ΛCDM model we included 41 equidistant t_S/z data points in addition to the observed data.

The dimension of H_0 for the exponential function is expressed by the energy loss with time and it has the dimension $\text{Hz}\cdot\text{s}^{-1}\cdot\text{Hz}^{-1}$ instead of $\text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$ as in the ΛCDM model.

Excel, Excel Solver and WinSTAT [12] software were used for the data fitting, refinement, and analysis and data presentation.

3. Results

The potential best fit curve of the 280 observed z/μ data points is shown in **Figure 1**.

Four outliers with standard deviation > 3σ were identified in the z/μ data set and omitted from further regression analysis.

Results are shown in **Tables 1** and **2**.

It can be seen from **Table 2** that the omitted outliers have relatively little influence on the regression coefficients a and b and that all the results for a and b lie within the very small error limits of a ± 0.02 and b ± 0.0006, respectively.

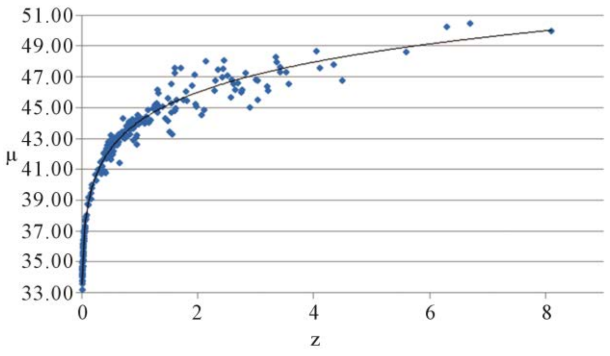

Figure 1. Solid line: potential $\mu = a \times z^b$ fit, diamonds: observed RS/μ data.

Table 1. Outliers in the regression with 280 data points.

Row	z-value	n*Sigma	P < 0.05
277	5.6	3.981	0.0152
278	6.29	4.573	0.0009
279	6.695	4.921	0.0001
280	8.1	6.127	6.218E-8

Table 2. Results of regression with $\mu = a \times z^b$ using 171, 276 and 280 z/μ data points.

Data points	a	b	R2	$\sum\chi_{\text{square}}$	$P_{\chi\text{test}}$, $\mu_{\text{obs}}/\mu_{\text{calc}}$
171, Ref.[5]	44.102	0.0593	0.9571	1.96634	1
276	44.109769	0.059883	0.9843	1.95407	1
280	44.1201	0.060005	0.9871	1.95407	1

For further data treatment the potential best fit function obtained from 276 data points

$$\mu = 44.109769 \times z^{0.059883} \qquad (4)$$

was used.

Tables 3-6 show the statistics of the fitting procedure with 276 data points.

4. The $t_S/(z + 1)$ Data Representation

Figure 2 shows the Hubble diagrams measured and calculated with $e^{2.024\times 10^{-18}\times t_s} = z+1$ in the range of $z + 1 = 1.0104$ to 5.35.

The goodness of fit indicators between the observed $t_S/(z + 1)$ data and the exponential $e^{2.024x}$ function for $z + 1 = 1.0104$ to 5.5, 6.5 and 9.1 are summarized in **Table 7**. The precise agreement between the measured and calculated data in the range of $z + 1 = 1.0104$ to 5.5 strongly supports the conclusion that the $t_S/(z + 1)$ function is exponential. It seems very likely that the small deviations at $z + 1 > 5.5$ are due to small systematic errors in distance measurements or to the calibration method at very high RSs.

Table 3. Descriptive statistics μ/z.

	Valid cases	Mean	Std. error of mean	Variance	Std. Deviation	
μ	276	41.76894928	0.242237842	16.19545144	4.02435727	
	Variation coefficient	Rel. V. coefficient (%)	Skew	Kurtosis	Minimum	Maximum	Range
μ	0.096348061	0.57994	–0.622585385	–0.735770108	33.21	48.68	15.47

Table 4. Descriptive statistics z/μ.

	Valid cases	Mean	Std. error of mean	Variance	Std. Deviation		
z	276	0.880278623	0.056577708	0.883486217	0.939939475		
	Variation coefficient	Rel. V. coefficient (%)	Skew	Kurtosis	Minimum	Maximum	Range
z	1.067774964	6.427249997	1.581919841	2.212059268	0.0104	4.5	4.4869

Table 5. Variable: μ; grouped by z; 95% confidence level.

μ	N	Mean	Conf. (±)	Std. Error	Std. Dev.
33 to 34	4	0.012725	0.004668869	0.01467069	0.002934138
34 to 35	21	0.016414286	0.001003628	0.000481134	0.002204832
35 to 36	18	0.027077778	0.001658866	0.000786261	0.0003335823
36 to 37	15	0.41213333	0.003964023	0.001848213	0.007158099
37 to 38	10	0.0625	0.006904831	0.003052322	0.009652288
38 to 39	3	0.104666667	0.046628617	0.010837179	0.018770544
39 to 40	5	0.1612	0.027294023	0.009830565	0.021981811
40 to 41	6	0.330166667	0.077409426	0.030113581	0.073762908
41 to 42	16	0.42775	0.050113435	0.023511433	0.094045734
42 to 43	46	0.521336957	0.33007283	0.016388078	0.111149352
43 to 44	43	0.813906977	0.061365095	0.030407637	0.199396209
44 to 45	37	1.167456757	0.103807992	0.0511849998	0.311346189
45 to 46	15	1.823953333	0.321476572	0.149887432	0.580511527
46 to 47	19	2.640421053	0.355072924	0.169008137	0.73668939
47 to 48	14	2.799142857	0.529540171	0.245115646	0.917138766
48 to 49	4	2.99875	1.37869082	0.4332173	0.8664346
Entire sample	276	0.880278623	0.111380452	0.056577708	0.939939475

Table 6. Variable: z; grouped by μ; 95% confidence level.

z	N	Mean	Conf. (±)	Std. Error	Std. Dev.
0.0 to 0.5	120	38.1235	0.578568683	0.292191652	3.200799178
0.5 to 1.0	76	3.29763158	0.148926165	0.074758293	0.65172769
1.0 to 1.5	28	44.6478571	0.233356837	0.113731045	0.601808122
1.5 to 2.0	18	45.6505555	0.62841576	0.297853401	1.263684958
2.0 to 2.5	9	46.6894444	1.000358877	0.433806188	1.301418564
2.5 to 3.0	10	46.331	0.485711017	0.214711434	0.678977172
3.0 to 3.5	9	46.975	0.693006582	0.300522693	0.901568078
3.5 to 4.0	2	46.93	4.828358221	0.38	0.537401154
4.0 to 4.5	3	48.0166666	1.45068823	0.3371611353	0.583980593
4.5 to 5.0	1	46.74	-	-	-
Entire sample	276	41.7689492	0.476876166	0.242237842	4.02435727

Table 7. **Goodness of fit indicators.**

Data points	$z + 1$ range	R^2	Std. error	Std. dev.	$\sum\chi^2$	P
276	1.0104 - 5.5	0.99996	0.006190	0.933469	0.007723956	1
278	1.0104 - 6.5	0.99985	0.019795	1.027633	0.010656491	1
280	1.0104 - 9.1	0.99838	0.046957	1.173129	0.088924843	1

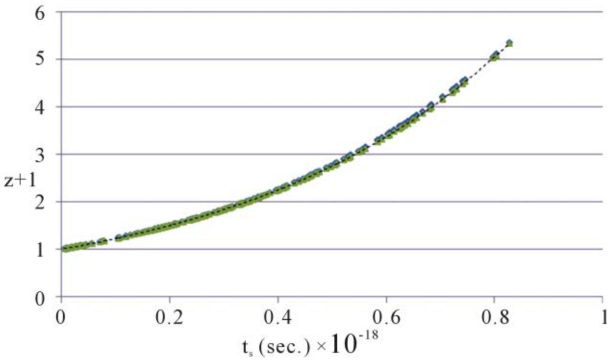

Figure 2. **Observed data (diamonds), data calculated with $e^{2.024\times10^{-18}\times t_s}$ (triangles), trendline with $e^{2.024x}$ (dashed line).**

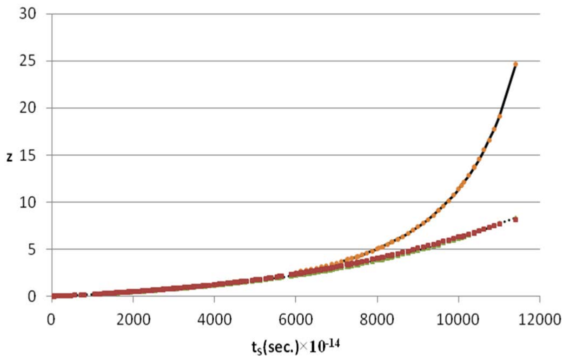

Figure 3. **Redshift of type Ia supernovae as a function of $t_S = D_C/c$. Squares: t_S/z data inferred from the potential best-fit curve of the observed z/μ diagram. Triangles: the exponential t_S/z relation with $H_0 = 2.024 \times 10^{-18}$. Circles: t_S/z relation derived from the ΛCDM model with H_0 = 72.6 km·s^{-1}·Mpc^{-1}.**

t_S/z Diagram in the Range of z = 0.0104 - 8.1, Comparison with the ΛCDM Model

Figure 3 shows the t_S/z diagram in the range of z = 0.0104 to 8.1 calculated using Equation (4) with the observed z/μ data set (squares), the exponential function $z = e^{2.024\times10^{-18}\times t_s} - 1$ (triangles), and the t_S/z relation derived from the ΛCDM model (circles) with H_0 = 72.6 km s^{-1} Mpc^{-1}, Ω_M = 0.266, Ω_Λ = 0.732 and k = 0.

One can see from **Figure 3** that, similar to the plot shown in **Figure 2**, the curves calculated from the best fit and the exponential function $z = e^{2.024\times10^{-18}\times t_s} - 1$ are nearly concurrent over the entire range of z, Pchi square = 1, whilst at $z > 2$ the t_S/z data calculated based on the ΛCDM model show clearly a different slope and depart considerably from both, the linear and the exponential functions. The χ-square test indicates statistical significance between the observed t_S/μ and the calculated ΛCDM data of P = 0.0173, indicating that from a statistical point of view, the two models are essentially different.

At RSs $z < 0.3$ (**Figure 4**), the t_S/z curves for the potential best fit, the exponential function, and the ΛCDM model can be fitted with the linear function $z = 0.000228725 \times t_S - 0.00332331$ ($R^2 = 0.9989$) with good approximation. The linear approximation, however, is deceiving. As can be seen in **Figure 3**, that at high RSs, the best-fit and the exponential curves follow strictly the exponential energy depletion relationship.

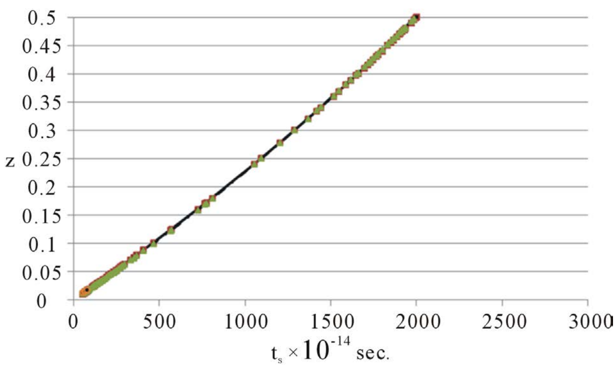

Figure 4. **The "linear" t_S/z relation in the low RS region for the potential best fit and the exponential function, and for the t_S/z data calculated based on the ΛCDM model.**

5. Conclusions

The most impressive result of the Hubble diagram test is that the t_S/z relation obtained from the potential best fit data can be expressed nearly exactly by the exponential formula $e^{2.024\times10^{-18} t_s} = z + 1$ over the entire range of z = 0.01 to 8.1.

In contrast, in the RS range $z > 2$ the t_S/z curve derived from the ΛCDM model with H_0 = 72.6 km·s^{-1}·Mpc^{-1}, Ω_M = 0.266, Ω_Λ = 0.732 and k = 0, shows poor agreement with the observed data. The χ-square test indicates statistical significance between the observational potential fit and the calculated ΛCDM data of P = 0.0173, indicating that from a statistical point of view the two models are essentially different.

Based on the results presented in this paper, a reconsideration of the ΛCDM model appears warranted.

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