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A Tired Light/Contracting Universe Model from the Union2.1 Supernovae Data

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Abstract

A tired light/contracting universe (TLCU) model is shown to be an excellent fit to the redshift/distance modulus data for the 580 supernovae 1a in the Union2.1 compilation. The data reveal that the Milky Way is in a static region with a radius of about 450 Mpc. Beyond the static region the universe is contracting with a space velocity which is linearly proportional to distance over the whole range of the data ($k = -7.6 \pm 2.3$ $\text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$). The other constant of the model is the Hubble constant for which a value of $H = 69.51 \pm 0.86$ $\text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$ is obtained. The fit of the TLCU model to the Union2.1 data is at least as good as the fit of the two constant ΛCDM model to the same data. A formula for photon travel distance is derived and an experiment for the possible detection of the tired light process is proposed.

Keywords

Cosmology, Observations, Theory

1. Introduction

Theory [1] predicts that the universe is either expanding or contracting with a space velocity which is linearly proportional to distance. An expansion may continue for ever or it may halt and then contract giving rise to the possibility of a "periodic world".

When it was observed that the redshift and distance for galaxies beyond the Local Group had a linear relationship [2] the expanding universe theory became established. Observations of supernovae 1a show that at higher redshifts [3], [4] the distances measured are greater than expected by the expanding universe theory and this is interpreted as an accelerating expansion for which a new force called "dark energy" is proposed.

The tired light theory [5] is an alternative explanation for the systematic

redshift. The viewpoint on the supernovae 1a observations from the tired light theory is that for a given distance the observed redshift is less than expected as a result of the blueshift of a contracting universe. Hence it is suggested that the new physics required by the supernovae 1a observations may possibly be the old idea of tired light instead of the new idea of dark energy.

A tired light/contracting universe (TLCU) model is developed here using the Union2.1 supernovae 1a data [6] and compared to the ΛCDM model. The TLCU model uses photon travel distance for which a formula is derived. A possible mechanism for the tired light effect is discussed and an experiment to test this mechanism is proposed.

2. The TLCU Model

The TLCU model is built on the idea [7] that the observed systematic redshift (z) has two components

$$z = z_{tl} + z_c \tag{1}$$

where z_{tl} is the result of an energy loss process and z_c is the result of space contraction. Assuming that photons lose energy by a first order rate process [8] the tired light component is given by

$$z_{tl} = \exp\left(\frac{H \times d}{c}\right) - 1 \tag{2}$$

where d is the photon travel distance, H is the Hubble constant[1] and c is the speed of light. The distance between the emitter and observer at the moment the photon is emitted (d_0) is here called the "initial distance" and $d \approx d_0$ for low values of d_0. The exact relationship between d_0 and d is considered later. Assuming a flat (*i.e.* Euclidean) universe the initial distance is related [9] to the luminosity distance (D) by

$$d_0 = \frac{D}{(1+z)} \tag{3}$$

The luminosity distance (D) is obtained from the distance modulus (dm) by the standard relationship.

$$\log_{10} D = \frac{dm + 5}{5} \tag{4}$$

The distance modulus (dm) is defined as $dm = m - M$, where m is the observed apparent magnitude of an object and M is it's absolute magnitude. For supernovae 1a "m" is the peak observed apparent magnitude (with appropriate corrections).

2.1. Preliminary Calculations

Initially z_c was calculated from the redshift and distance modulus data for

[1]The Hubble constant used in the TLCU model is a constant of nature and assumed to be independent of time and space. The usual units used for the Hubble constant are $\mathrm{km \cdot s^{-1} \cdot Mpc^{-1}}$ although the SI unit is $\mathrm{s^{-1}}$, which is characteristic of a first order rate process.
($70\ \mathrm{km \cdot s^{-1} \cdot Mpc^{-1}} \equiv 2.27 \times 10^{-18}\ \mathrm{s^{-1}}$).

each of the 580 SN 1a in the Union2.1 compilation using Equations (1) to (4) and with the assumptions that $d = d_0$ and $H = 70$. The results of the calculations are shown in Figure 1.

The 580 values of z_c consist of 158 positive values (redshifts) and 422 negative values (blueshifts). In a static universe z_c would consist of an equal number of redshifts/blueshifts and the 158/422 split rejects a static universe ($p < 10^{-10}$). Since z_c is essentially negative the initial assumption of a contracting universe is confirmed.

Although the overall picture is of a contracting universe the local situation is different. There are 176 supernovae with $0.015 < z < 0.101$ for which the z_c values show 78 redshifts and 98 blueshifts which is consistent ($p = 0.13$) with an even split. So the next conclusion is that the Milky Way is situated in a static region of about 450 Mpc radius.

2.2. The Final Model

In a gravitationally bound region of space the force of Newtonian gravity is greater than the cosmic force of expansion/contraction and although the region as a whole will take part in the universal cosmic expansion/contraction the effect of cosmic expansion/contraction cannot be measured within the region. It is now assumed that the static region extending to about 450 Mpc around the Milky Way is gravitationally bound. For the purpose of the model it is assumed that the Milky Way is located at the center of a static sphere with a radius of 450 Mpc. In order to be consistent with the observations it is also assumed that the cosmic contraction starts at the edge of the static sphere. For a cosmic contraction the velocity of contraction is proportional to distance, so that

$$z_c \times c = k \times (d_0 - 450) \tag{5}$$

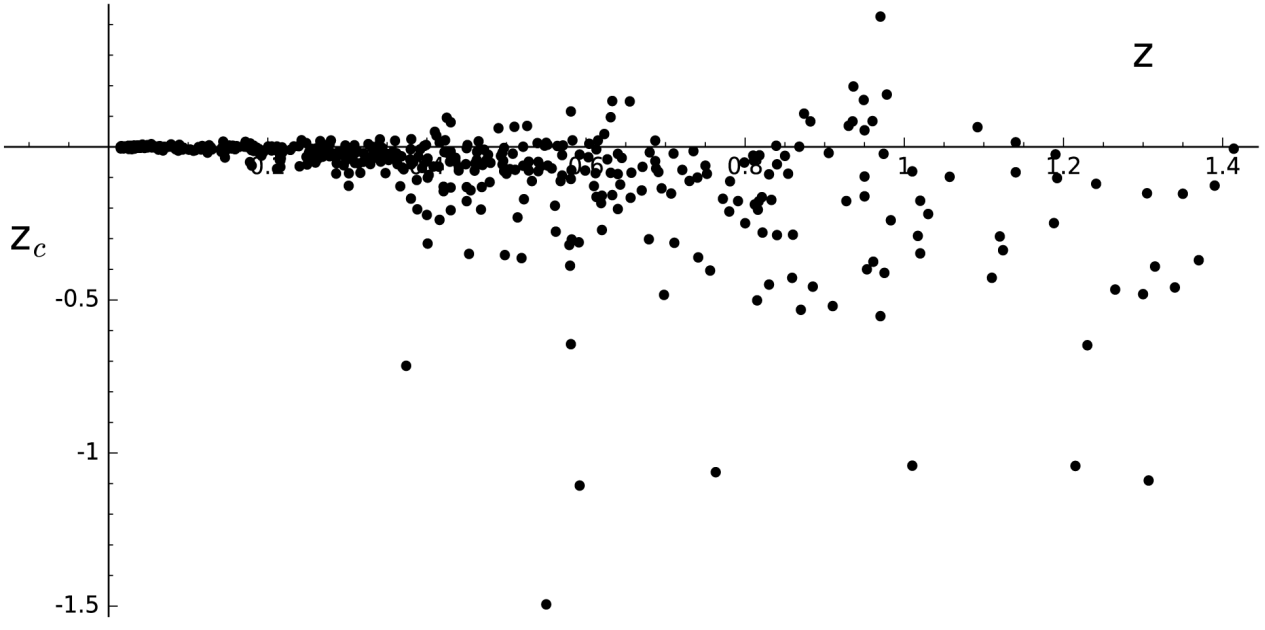

Figure 1. 580 values of z_c from the Union2.1 supernovae data with $H = 70$.

where k (km·s^{-1}·Mpc^{-1}) is the constant for cosmic contraction. Within the static region $d = d_0$, but, beyond the static region it is necessary to allow for the contraction that occurs during the photon travel time. The relationship between d_0, k and d is derived in Appendix 1, from which, Equation (11) re-arranged as

$$d = d_o \times \exp\left(\frac{k \times d}{c}\right) \tag{6}$$

is more convenient for finding d from d_o and k by repeated substitution. Equation (6) was used to calculate that part of the photon travel distance which is beyond the static region. The values of H and k for the TLCU model were found by fitting the model to the Union2.1 data. The sum of the weighted squares of the the dm residuals (S) is given by

$$S = \sum_1^n \left(dm_{\text{observed}} - dm_{\text{model}}\right)_i^2 \times w_i \tag{7}$$

where the weighting factor (w) is proportional to the inverse square of the estimated error in dm. For the Union2.1 data ($n = 580$), the values of the constants which minimize S are $H = 69.2 \pm 5.0$ km·s^{-1}·Mpc^{-1} and $k = -7.1 \pm 10.3$ km·s^{-1}·Mpc^{-1}. The rms weighted residual $dm = 0.170$ mag. while the rms un-weighted residual $dm = 0.226$ mag.

Figure 1 shows a large scatter in z_c so the data were binned in order to make the relationship between velocity of contraction and distance more precise. The 580 SN 1a were sorted into z order and divided into 29 bins each containing 20 SN 1a. The weighted average redshift and distance modulus were calculated for each bin (see Table 1). The procedure for finding H and k was repeated using the bin averages of redshift and distance modulus and gave $H = 69.51 \pm 0.86$ and $k = -7.6 \pm 2.3$ km·s^{-1}·Mpc^{-1} with the rms of the residual $dm = 0.030$ mag. The values of the contraction velocity calculated from the binned data using using $H = 69.5$ km·s^{-1}·Mpc^{-1} and $k = -7.6$ km·s^{-1}·Mpc^{-1} are shown in Figure 2. It is seen that the contraction velocity has an approximate linear relationship with distance beyond the static region over the whole range of the Union2.1 data. Hence the assumptions on which the model is based are consistent with the observed data. Figure 2 also shows a hint of periodicity in the velocity/distance relationship.

3. Comparison of TLCU and ΛCDM Models

In the two constant ΛCDM model the initial distance (from Equation (13) of ref. [10]) is

$$d_0 = c/H_0 \times \int_o^z \left[(1+z)^3 \times \Omega_M + 1 - \Omega_M\right]^{-0.5} \mathrm{d}z \tag{8}$$

In order to compare the models on the same basis the constants for the ΛCDM model were found by fitting Equation (8) to the Union2.1 data using the best fit criterium (Equation (6)). This gave $H_0 = 70.0 \pm 5.4$ km·s^{-1}·Mpc^{-1} and $\Omega_M = 0.278$ with a rms weighted residual $dm = 0.170$ while the rms un-

Table 1. The bin Hubble constants for the TLCU and ΛCDM models.

z	dm	d_o Mpc	d Mpc	z_c	z_{tl}	TLCU		ΛCDM	
						H	resid.	H_o	resid.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0.0157	34.158	67	67	0	0.0157	69.99	−0.79	70.31	−0.31
0.0192	34.589	81	81	0	0.0192	70.33	−1.13	70.71	−0.71
0.0231	35.033	99	99	0	0.0231	69.05	0.15	69.51	0.49
0.0260	35.294	112	112	0	0.0260	68.99	0.21	69.51	0.49
0.0304	35.659	131	131	0	0.0304	68.34	0.86	68.93	1.07
0.0338	35.862	144	144	0	0.0338	69.21	−0.01	69.88	0.12
0.0437	36.409	183	183	0	0.0437	69.90	−0.70	70.76	−0.76
0.0597	37.109	249	249	0	0.0597	69.72	−0.52	70.87	−0.87
0.0894	38.033	371	371	0	0.0894	69.15	0.05	70.82	−0.82
0.1287	38.894	532	532	−0.0020	0.1307	69.18	0.02	70.49	−0.49
0.1632	39.444	665	664	−0.0051	0.1683	70.20	−1.00	70.94	−0.94
0.1976	39.935	810	807	−0.0085	0.2061	69.58	−0.38	69.96	0.04
0.2352	40.378	964	957	−0.0122	0.2474	69.22	−0.02	69.44	0.56
0.2641	40.646	1065	1056	−0.0146	0.2786	69.76	−0.56	70.04	−0.04
0.2914	40.899	1171	1159	−0.0171	0.3085	69.52	−0.32	69.80	0.20
0.3243	41.135	1274	1258	−0.0195	0.3438	70.42	−1.22	70.88	−0.88
0.3554	41.416	1416	1395	−0.0229	0.3782	68.96	0.24	69.33	0.67
0.3897	41.671	1553	1526	−0.0261	0.4159	68.33	0.87	68.73	1.27
0.4221	41.862	1658	1625	−0.0286	0.4507	68.66	0.54	69.19	0.81
0.4538	42.076	1789	1749	−0.0317	0.4855	67.85	1.35	68.37	1.63
0.5017	42.279	1902	1855	−0.0344	0.5361	69.38	−0.18	70.24	−0.24
0.5427	42.440	1994	1941	−0.0366	0.5793	70.60	−1.40	71.73	−1.73
0.5895	42.712	2194	2126	−0.0413	0.6308	68.97	0.23	69.98	0.02
0.6302	42.860	2289	2214	−0.0436	0.6737	69.74	−0.54	70.94	−0.94
0.7080	43.180	2533	2437	−0.0493	0.7573	69.36	−0.16	70.62	−0.62
0.8011	43.624	2946	2810	−0.0591	0.8602	66.21	2.99	67.06	2.94
0.8799	43.722	2953	2817	−0.0593	0.9391	70.49	−1.29	72.01	−2.01
1.0060	44.130	3340	3160	−0.0684	1.0745	69.22	−0.02	70.49	−0.49
1.2559	44.763	3974	3712	−0.0835	1.3394	68.64	0.56	69.45	0.55

(1) weighted bin average redshift; (2) weighted bin average distance modulus; (3) initial proper distance-Equations (3) & (4); (4) photon travel distance Equation (6); (5) cosmic blueshift If $d_o < 450$ then $z_c = 0$ else $z_c = (-7.6/c) \times (d_o - 450)$; (6) tired light redshift $z_{tl} = z - z_o$; (7) $H = (c/d) \times \ln(1 + z_{tl})$; (8) resid = 69.2 − H; (9) Equation (8) $\Omega_M = 0.278$; (10) resid = 70.0 − H_o.

weighted dm residual = 0.266. These residuals are identical to the residuals from the TLCU model. There is also a close correlation between the un-weightd dm residuals for the ΛCDM model and those for the TLCU model as seen in Figure 3. Thus the fit of the TLCU model to the Union2.1 data is nearly identical to the fit of the ΛCDM model to the same data.

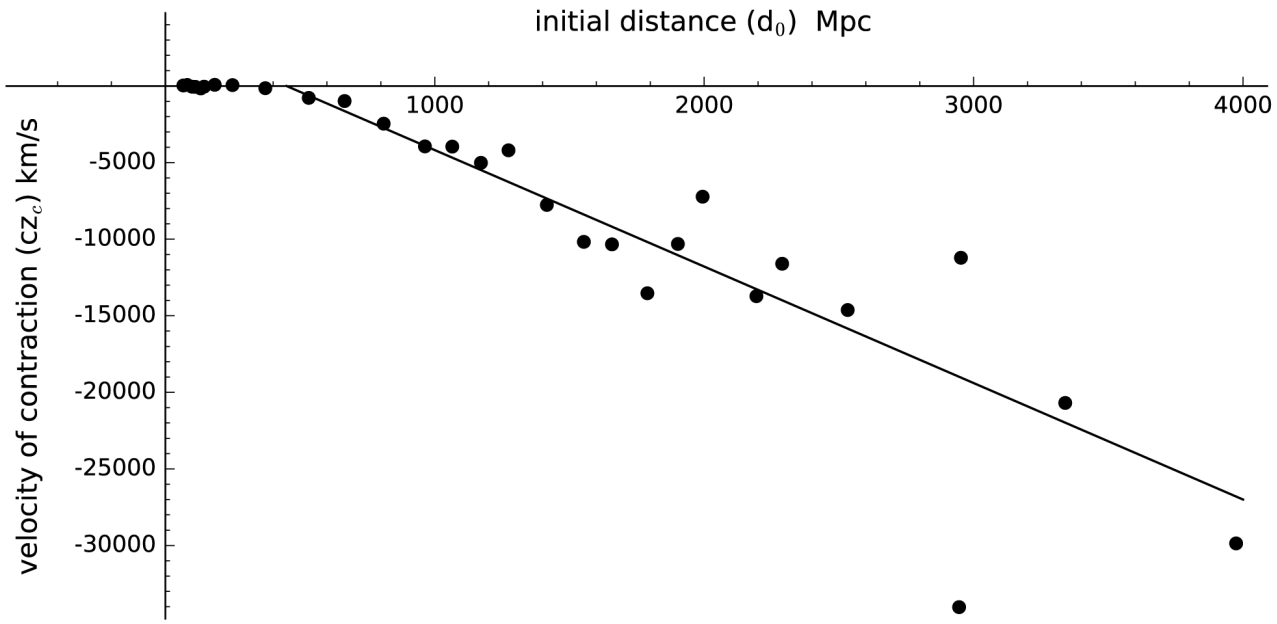

Figure 2. z_c from the binned Union2.1 data (see text) for the TLCU model with $H = 69.5\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$ and $k = -7.6\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$.

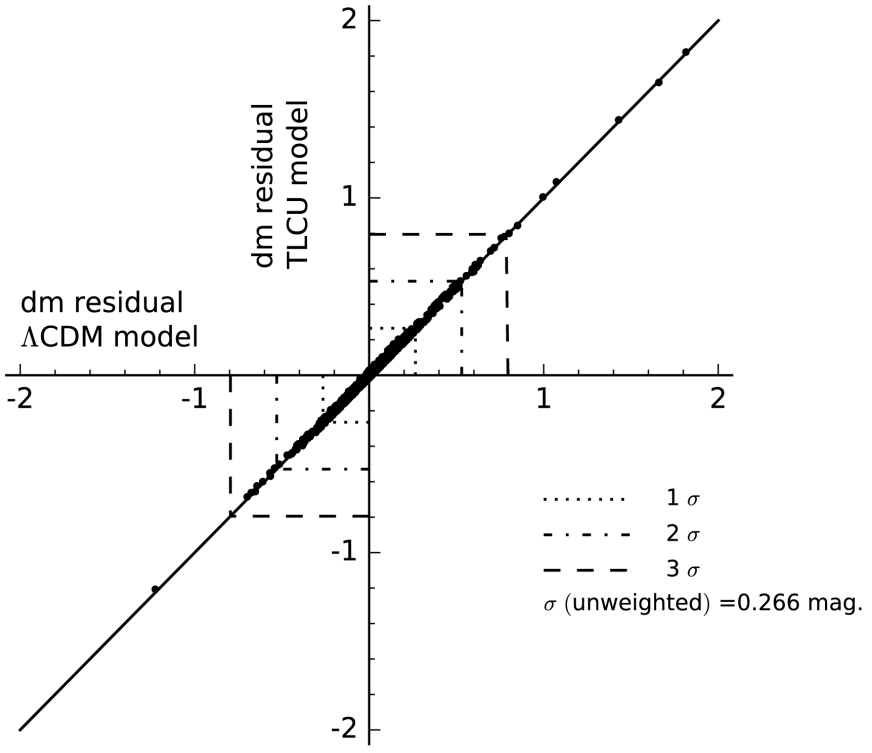

Figure 3. *dm* residuals for ΛCDM and TLCU models using Union2.1 supernovae data.

Fitting the ΛCDM model to the binned data ($n = 29$) gives $H_0 = 70.09 \pm 1.01\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$, $\Omega_M = 0.274$ with a rms residual dm of 0.031 mag. The uncertainties in the Hubble constant and for the calculated dm are slightly greater than those for the TLCU model. The dm residuals for the binned

data for both models are shown in Figure 4.

The hint of periodicity shown in Figure 2 is repeated in Figure 4 and not only for the TLCU model but also for the ΛCDM model.

Another method of comparing the models is to fix the minor constants and then to calculate the value of the Hubble constant for each bin of the binned data. This calculation (with $k = -7.6\ \mathrm{km \cdot s^{-1} \cdot Mpc^{-1}}$ for the TLCU model and $\Omega_M = 0.274$ for the ΛCDM model) gives $H = 69.51 \pm 0.86\ \mathrm{km \cdot s^{-1} \cdot Mpc^{-1}}$ for the TLCU model and $H_0 = 70.10 \pm 1.01\ \mathrm{km \cdot s^{-1} \cdot Mpc^{-1}}$ for the ΛCDM model. The results of these calculations are presented in Table 1. The values of the uncertainty in the Hubble constant show that the TLCU model is a better fit to the binned data than is the ΛCDM model.

4. Discussion

Although the TLCU model only shows a contracting universe it is reasonable to assume that there was a prior expansion which would be consistent with the "periodic world" predicted by Friedman [1]. In this case the linear contraction revealed by the model can be expected to reverse at higher redshifts and eventually show the expanding phase. The periodicity hinted at in Figure 2 and Figure 4 may possibly be harmonics of the fundamental period. More accurate observations at higher redshifts are needed to reveal the truth.

The reality of the contracting universe depends, of course, on the reality of the tired light effect and although the TLCU model is an excellent fit to the observed data such a fit is no guarantee of the reality of the assumptions on which the model is based. It is also claimed [11] that time dilation falsifies the tired light theory although the assumption that the thirteen high redshift supernovae used are not subject to a Malmquist type bias may not possibly be the case. Nevertheless independent evidence for the tired light effect is essential. A possible

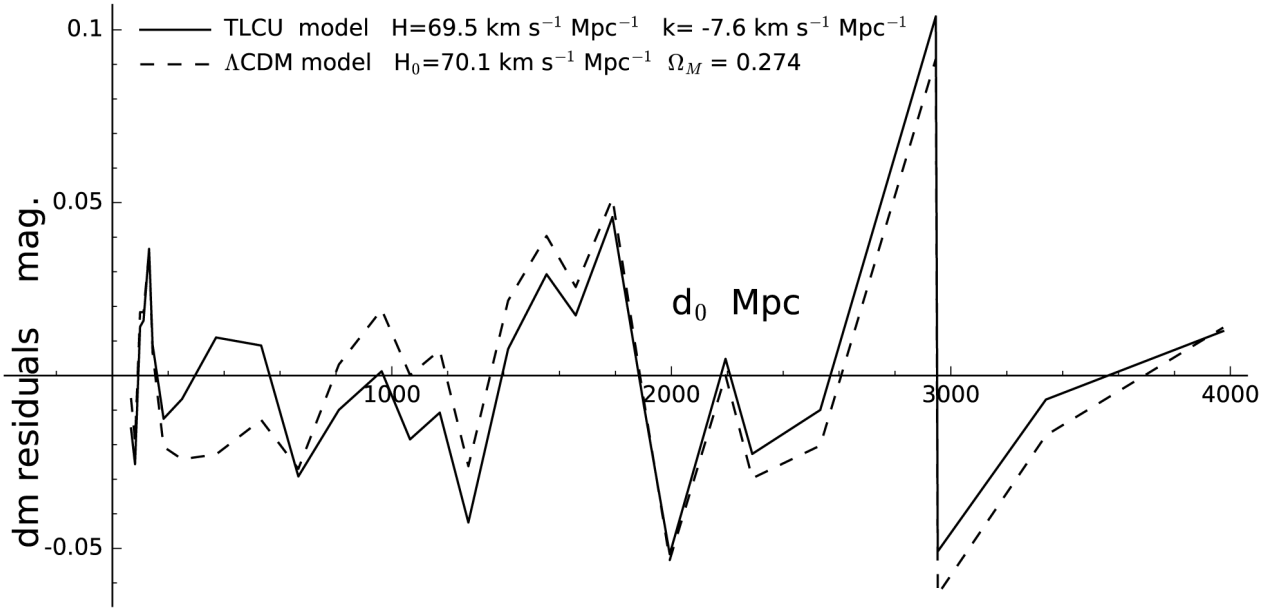

Figure 4. *dm* residuals for ΛCDM and TLCU models using binned data (see text).

mechanism for the tired light process and a terrestrial experiment to test this mechanism are discussed in Appendix 2.

5. Conclusion

It is concluded that further experimental work on a possible photon energy loss process would be justified.

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Appendix 1: Photon Travel Distance (d)

The initial distance (d_0) is the distance between emitter and observer at the moment a photon is emitted. In an expanding or contracting universe the path traversed by the photon will have expanded or contracted when it reaches the observer so that $d_0 \neq d$ although $d_0 \approx d$ for low values of d_0 . The relationship between d and d_0 derived below is based on three assumptions: 1) the universe is flat [*i.e.* Euclidean], 2) the space velocity is much les than the speed of light, and 3) the space velocity is linearly proportional to distance

$$\frac{\mathrm{d}x}{\mathrm{d}t} = k \times x \tag{9}$$

where x is distance and k is a constant. Integrating Equation (9) between $x = d_0$, $t = 0$ and $x = d$, $t = t_p$ (where the photon travel time, $t_p = d/c$)

$$k \times \int_o^{t_p} \mathrm{d}t = \int_{d_o}^{d} \left(\frac{1}{x}\right) \mathrm{d}x \tag{10}$$

gives

$$\frac{k \times d}{c} = \ln\left(\frac{d}{d_o}\right) \tag{11}$$

Equation (11) is re-arranged as Equation (6) for use in Section 2.2.

Appendix 2: Tired Light Experiment

Mechanisms for the tired-light effect which involve photon/photon interactions or photon/baryon interactions would involve deflection and blurring of images which is not observed. However a possible mechanism which avoids the blurring problem is spontaneous photon decay [8] in which it is assumed that a primary photon decays producing secondary photons [12] all continuing to travel in the same direction. It is necessary that the frequency of these secondary photons would be considerably less than the frequency of the primary photon in order to avoid significant linebroadening .

Spontaneous decay of the primary radiation from the sun would produce secondary photons amounting to about 1.5×10^{-12} Wm^{-2} $(H = 70)$ at the earth. These tired light photons from the sun would need to be in the GHz/MHz range or lower in order to avoid the line broadening effect and so would make a significant contribution to the observed quiet sun radio emission. Thus it may be that tired light secondary photons have already been observed and this raises the possibility of detecting the tired-light effect experimentally.

It is suggested here that the tired light radio emission which would be produced from a pulsed femtosecond optical laser could be detected in a terrestrial experiment. It would be necessary to conduct the laser beam through an evacuated tube in order to prevent the radio emission which would otherwise result [13] from ionization of the gas through which the laser beam travelled.