Exponential Energy Loss and Observational Deviation from the Hubble Law

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Abstract:

In this work we plot the observational measurements of 240 SNIA events in standard astronomical Hubble fashion. We demonstrate that there is a greater than 98% correlation to an exponential loss of energy with distance.

Introduction:

For the roughly three-quarters of a century between about 1920 and 1995, the apparently linear correlation of redshift to distance for extra-galactic objects was noted and became a cosmological paradigm. In these models, redshift is always interpreted as a measure of the speed of recession. A minority view throughout the period was that light lost energy with distance traveled. In general, such a theory is generally discounted in cosmology on the basis that there is no accepted theoretical mechanism for it.

Beginning in the 1990's, observations of supernovae deviated from the accepted Hubble relationship. In response, cosmologists changed the "cold dark matter" (CDM) model to include an ad hoc "dark energy." This became the current "lambda cold dark matter" (ΛCDM) model. By the 1990's, cosmologists were tweaking many different big bang models. They were focused on variations of theoretical parameters between the minor variations, and no longer questioning the underlying paradigm. This paper plots the raw supernovae data in the original non-cosmological Hubble layout. The resulting curve is found to be undeniably exponential – in full accord with an energy loss model.

Background History:

In the 1920's it was noticed that there as objects increased with distance, the spectrum of the absorption lines found in stellar emissions shifted more toward the red end of the spectrum (the red shift). This shift was originally interpreted as a Doppler shift due to motion away from the Earth[1]. The shift is now interpreted as a stretching of wavelengths due to expansion of space itself during the time light travels between emission and observations in our solar system. In both interpretations, distance between objects is increasing with time.

In these initial plots of redshift versus distance, the physical measure for the vertical axis is the change in wavelength ($\Delta\lambda$) divided by the original wavelength (λ). This ratio is often provided as **z**.[2] This is a general relationship of the apparent distance of a galaxy/object when plotted against its redshift.

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[1] Due to 10 years of mathematical/philosophical expectation that the universe would be expanding or contracting radially.
[2] Without multiplying by the speed of light: $\mathbf{z} = (\Delta\lambda/\lambda)$ [11]

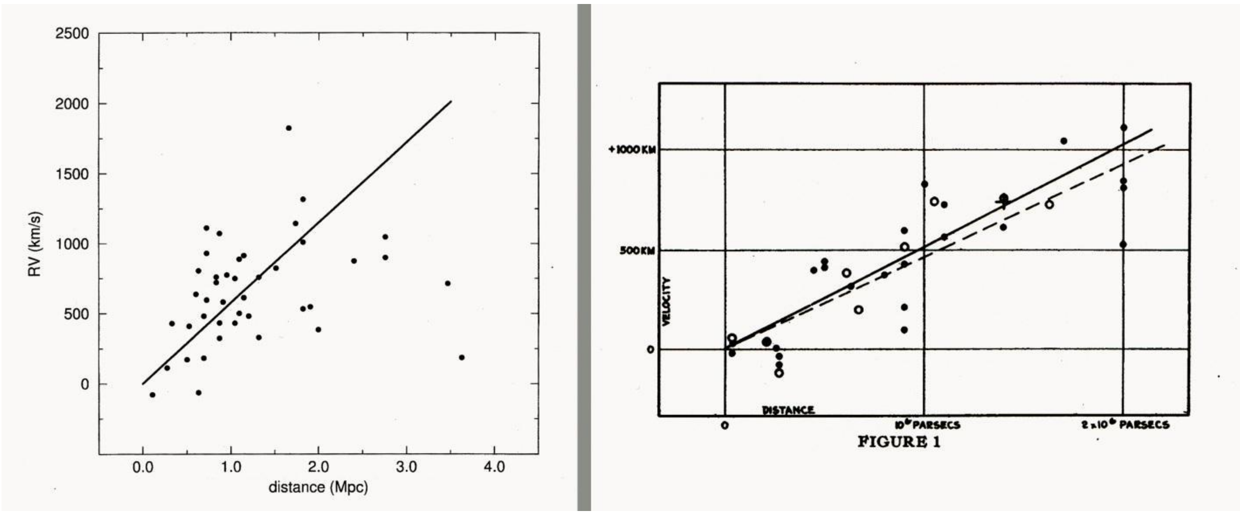

Figure 1- Redshift versus distance, Lemaitre 1927 & Hubble 1929

It is telling that from the very first graphs in 1927 (above)[3], the redshift-distance relations have always been presented with vertical axis converted to a theoretical Doppler speed by multiplying the redshift by the speed of light (**c**)[4]. *"(T)he predominant tradition in relativistic cosmology was heavily oriented towards mathematics and had little contact with either physics or observational astronomy*." [1], p 42. Although Hubble himself usually used the term "apparent velocity," the philosophical preference was ingrained from the start as a "recessional velocity" caused by the radial Doppler Effect. The impressed straight-line relation was later named "Hubble law" and is given by the simple equation; **v = Hr**, where **H** is the linear slope, and is called the Hubble constant[5], **v** is the recessional velocity of the galaxy, and **r** is the distance to the galaxy.

The assumption that the red shift was caused wholly or partially by motion was not universally accepted by many early astronomers. The most well-known of these was Fritz Zwicky, who proposed in 1929 [2] that light might lose energy as it traveled cosmic distances. According to Fred Hoyle, Zwicky's proposal was "*generally ignored, as is inevitably the case when the establishment has made up its mind, as it had by around 1930*." [3]. Correspondingly, Zwicky's proposal as such is not even referenced in many standard cosmological histories such as Peebles' "*Principals of Physical Cosmology*" [4] and Misner, Thorne, and Wheeler's "*Gravitation*." [5]

Currently we can safely state that there is no *accepted* physical cause for light to lose energy while traveling cosmological distances. Such loss of energy with distance is sometimes named "***Tired Light***." Misner, Thorne, and Wheeler summarize the establishment view that "*(n)o one has ever put forward a satisfactory explanation for the cosmological redshift other than the expansion of the universe.*" [5] (see p. 775).

As an aside, we can note that light scattering off of matter does not offer a physical basis for this exponential energy loss. This is a near-universal straw man for "proofs" that tired light cannot exist – beginning with a one-sentence dismissal from Zwicky. However, light scattering off of matter is already

[3] Similar relations were obtained by Carl Wirtz (1924), Lemaître (1927), and Slipher(1917)
[4] The Doppler speed for light waves is given by $\mathbf{v} = \mathbf{c}\ (\Delta\lambda/\ \lambda)$.
[5] Often called the Hubble parameter, that allows the value to change with time, based on matter density in the universe and (more recently) with the addition of dark energy.

subtracted out of local brightness measurements when allowing for extinction. There is none left for further energy degradation.

The Dimming of the Standard Candles (1998).

In 1998, measurements of 42 distant supernovae [6] were found to deviate from the straight-line prediction of the Hubble Law for the ΛCDM models. Perlmutter's team was trying to measure some upward curvature in figure 1 – due to gravitational slowing. Perlmutter's group found the opposite effect[6] – which is predicted by all tired light theories. Perlmutter's paper did not consider any non-CDM models.

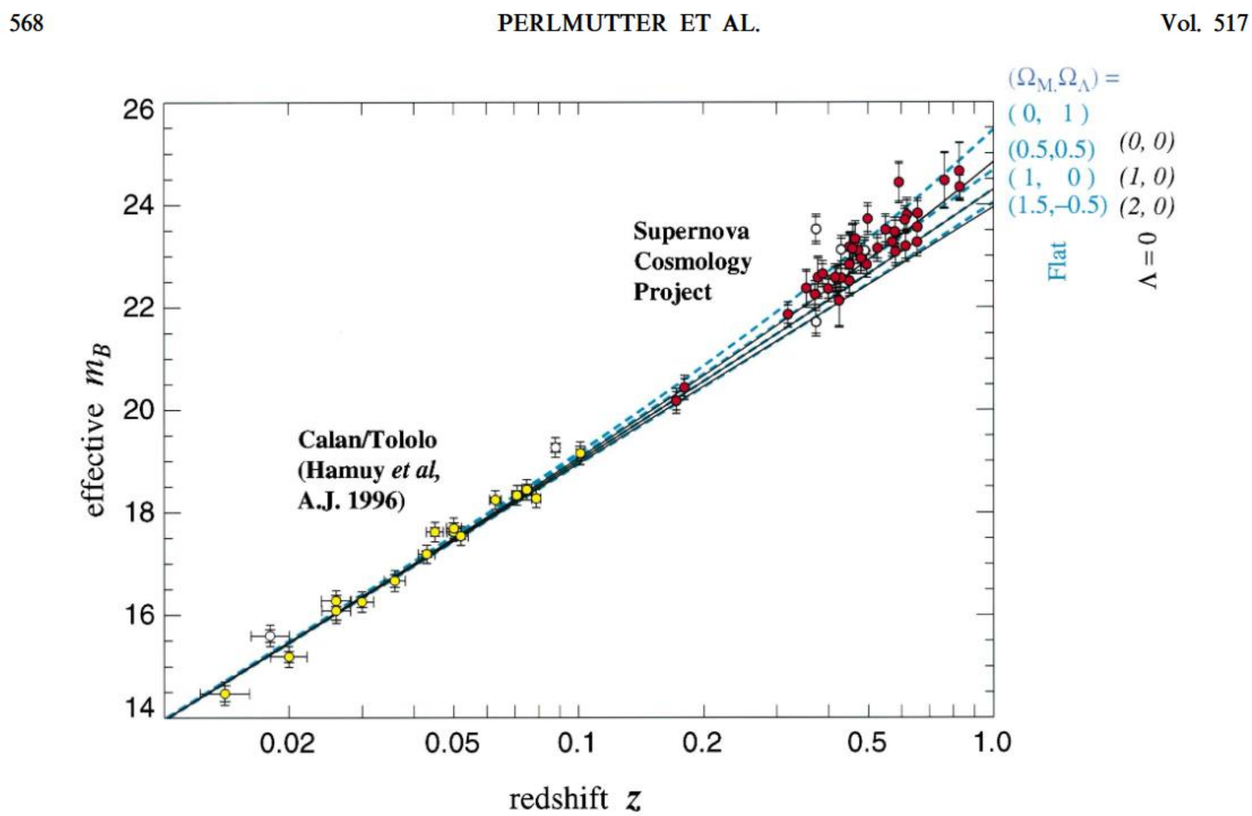

Figure 2

Perlmutter et al presented the above (*figure 2*[7]) as the "Hubble diagram." For their own purposes they have swapped the graph's axes. Redshift is presented along the bottom. "Effective magnitude" is brought in as a rough indicator of distance[8]. Deviations from the linear trend are interpreted as showing an accelerating expansion ("*dark energy*"[9]) from what is often called anomalous dimming. Cosmologists interpret this deviation as indicating that the universal expansion is accelerating via a sort of negative gravity that "may be" the cosmological constant (Λ)[10] . *No one has put forward a satisfactory explanation* for the source or creation of this energy from nothing.

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[6] And received the Nobel Prize for it.
[7] Presented as the "Hubble diagram" in Figure 1 in [6].
[8] Apparent brightness (m_B) drops off with distance. The astronomical scale for brightness gets dimmer as the magnitude number increases. (A 1st magnitude star is 2.5 times brighter than a 2nd magnitude star, and so on.)
[9] The term dark energy is derived as an extension from the earlier term dark matter.
[10] The "Λ" in the ΛCDM name.

Swapping the point-of-view:

One often learns unexpected lessons from changing one's point of view. Perlmutter's graph for ΛCDM dark energy can be converted back into a "standard" Hubble diagram by assuming that the visual absolute magnitude of Type Ia supernovae is Mv[11] = −19.3 [7]. See Appendix A-1 for the supporting table.[12] A reversion to non-cosmological point-of-view gives figure 3:

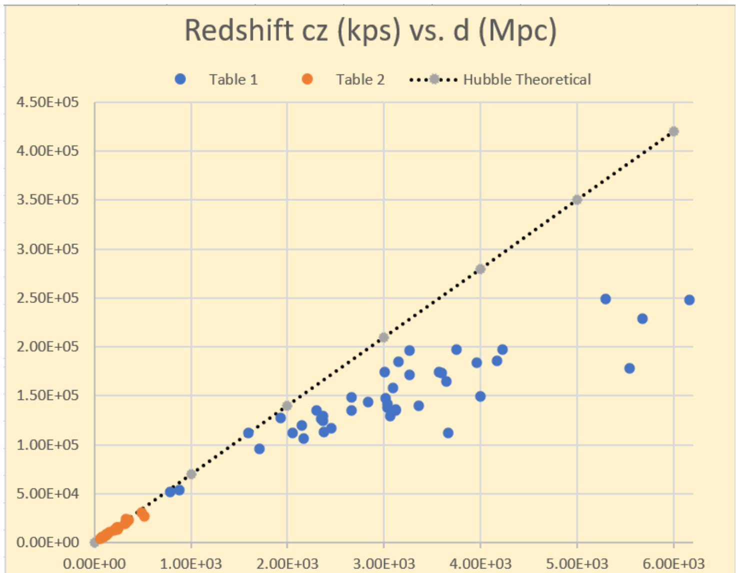

Figure 3

The dotted line is the theoretical standard value of H_0 = 70 kps/Mpc – upward deviations from which Perlmutter was trying to detect. This plot includes the 61 supernovae in Perlmutter (from two data tables).

The apparent reduction in universal expansion rate (H_0) is the evidence used for existence of "dark energy. In the past (at higher distances and z values), the universal expansion rate appears significantly lower than the current value of 70 kps/Mpc. This is interpreted as universal expansion increasing with time.

This historical point-of-view shows an increasing indicated ***distance*** beyond the expected linear Hubble prediction when normal astronomical standard candle calculations are used. The above plot shows a clear and accelerating deviation from the currently presumed linear Hubble slope value as distances exceed 600 Mpc. The departure from the straight line appears to profile an exponential process.

Although *Figure 3* has an undeniable exponential trend, we next added data from Tonry, et al (2003). Tonry's data has some apparent discrepancies.[13] These discrepancies drive a larger scatter than indicated

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[11] There are differences between the visual-filter magnitude (M_V) and the blue-filter magnitude (M_B). These are minor variances in the current analysis.

[12] Later presentations of more extensive data indicate hundreds of measured SN Ia supernovae. These papers do not present the data in an accessible, tabular form. They cover the same range and conform to the overall trend.

[13] Tonry presents distances as a function of the Hubble constant in Table 15. The only raw distance data provided is for six usable supernovae in table 13. Of these six, we could only duplicate the distance moduli for two, from the other data provided in Tonry. The other four supernovae in Table 13 vary, sometimes substantially. There is an apparent additional

by Perlmutter. Tonry includes data from 189 additional supernovae. [8] spanning distances from z = 0.002 to z = 0.830. This results in a total 240 observed SN1A with 167 having z greater than or equal to 0.02 putting them in the divergent from linearity region. We plotted both data sets, then used Excel's standard *Trendline* function to generate a 'best fit' curve of these values. The results are shown in *Figure 4* below:

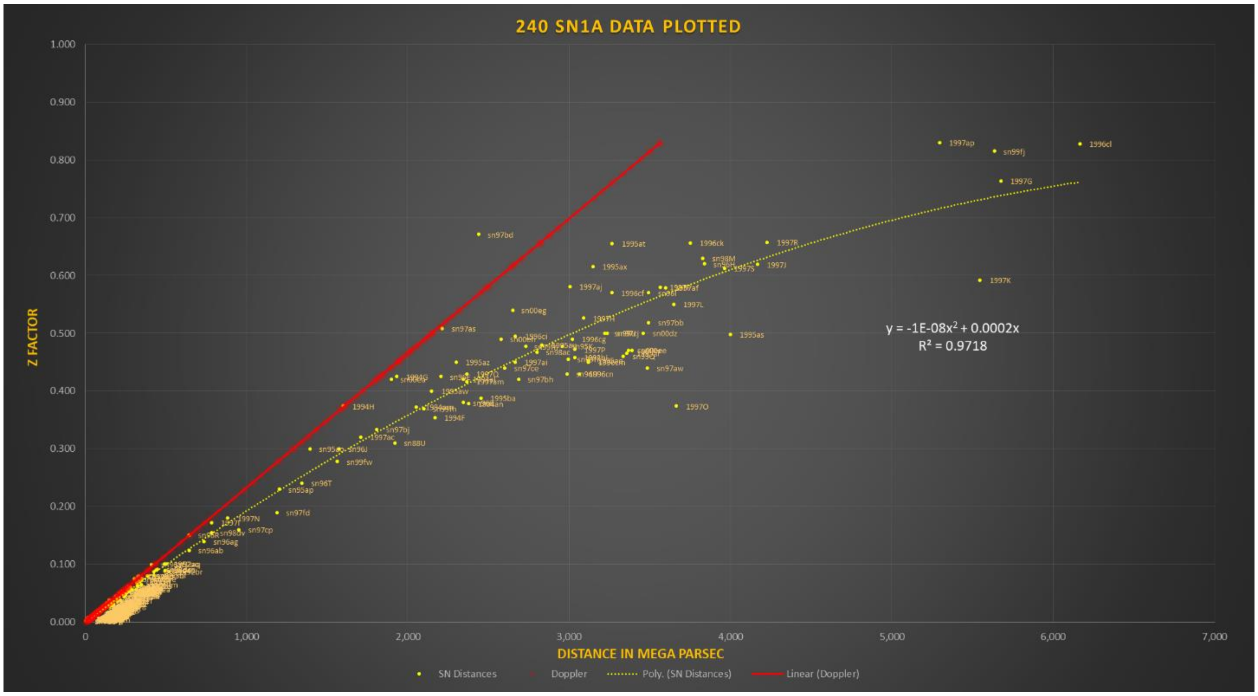

Figure 4

The trendline (yellow, dashed curve) enhances the visual impact of the exponential correlation in the measured distances. The red line is the ideal linear Hubble redshift-distance plot. The curve fit correlation (r) is 0.9859 showing that the data correlates extremely well to the resulting computed regression curve.

A standard exponential energy decay curve has the form:

$$\mathbf{E_x = E_o e^{-\mu x}} \quad \textit{Eq 1}$$

Where x is the distance traveled, μ is the linear attenuation coefficient and E is the energy of the photon. For light, E = h c / λ. z is defined as $\Delta\lambda/\lambda$. Since z is positive, $z = (\lambda-\lambda_0)/\lambda_0$. Substituting the equation for energy into the equation for z gives:

$$\mathbf{z = [(hc/E_x) - (hc/E_0)] / (hc/E_0) = (E_0/E_x) - 1} \qquad \textit{Eq 2}$$

Substituting equation 1 into the equation for z gives:

$$\mathbf{z = e^{+\mu x} - 1} \qquad \textit{Eq 3}$$

Equation 3 is "an" equation for exponential energy decay, but the constant μ has not yet been determined. Using the expansion series for exponential functions provides:

$$z = \left[\mathbf{1 + \mu x - \frac{(\mu x)^2}{2} + \frac{(\mu x)^3}{6} + \cdots}\right] \mathbf{- 1}$$

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undefined modification within Tonry that results in a higher scatter of data. Whether this is an oversight in Tonry or a misunderstanding on our part, the results are consistent – if more scattered.

$$z = \mu x - \frac{(\mu x)^2}{2} + \frac{(\mu x)^3}{6} + \cdots \quad Eq\ 4$$

Within the first term of equation 4, μ is the initial slope of the exponential function as x → 0. The measured slope is also the Hubble constant.

We then superimpose the calculated ideal exponential energy loss calculation using as an initial value the Hubble constant of 70 kps/Mpc (*equation 1 above*). This gives the green line shown in *Figure 5* below.

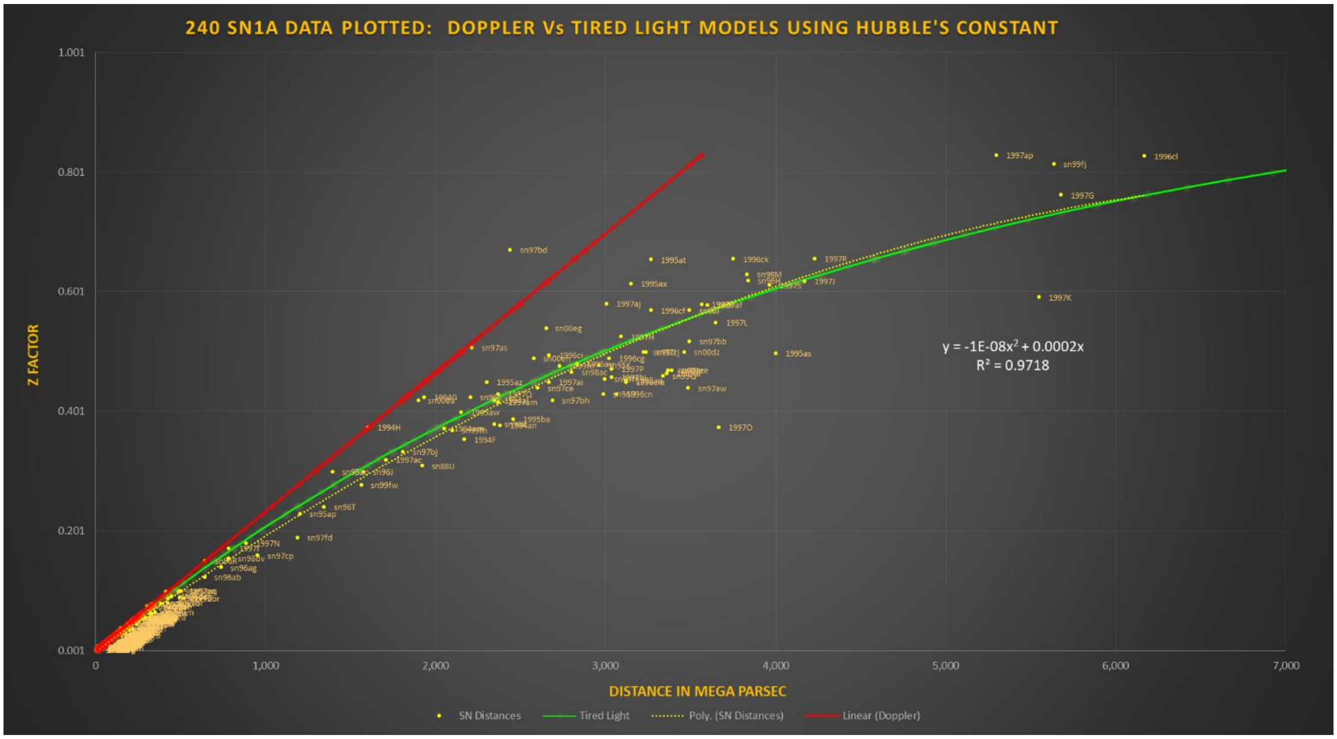

Figure 5

The fitted curve (yellow, dashed) almost perfectly matches the standard exponential energy loss profile (green, solid).

Energy Loss and the Redshift:

The data supports an exponential variant of the "tired light" hypothesis[14]. Tired light has been proposed several times over the past 90 years by theorists dissatisfied by various aspects of the ΛCDM model.[15] Tired Light is in general described as the concept that light ***naturally*** loses energy as it travels astronomical distances through space[16]. One can consider this postulate to be ad hoc (*hypothesis non fingo*). However, every other instance of wave propagation known to science has the observed physical property of the loss of energy with distance traveled. The lack of such loss for light (*electromagnetic waves*) would make it the only known exception to this otherwise universal rule.

[14] In general. Not necessarily Zwicky's specific theoretical causes.
[15] For a modern review, see [12]
[16] In other words, light need not interact with matter (i.e., electrons or dust) to lose energy.

While there is no currently-accepted model for light-wave energy loss, light is experimentally seen to lose energy exponentially with distance as it passes through matter. This is true for both high-energy light[17] and solar radiation passing through water.

The common units given for the initial slope of the Hubble diagram is 70 km/sec per Mpc. Converting to inverse meters, the value of μ becomes 7.5E-27 m^{-1}. The magnitude of this value far too small to exhibit any observable effects except at very great distances such as Hubble's measurements. The exponential decay profile is a unique property of a tired light effect. No other known cosmological model[18] ***naturally*** incorporates this profile.

Conclusions:

The deviation from the linear Hubble profile was not predicted by the Big Bang model –nor was the point at which this deviation would begin. The addition of "dark energy" – an ad hoc unphysical anti-gravity force of arbitrary strength – was added to account for these observations.

The observed curve fits a standard wave energy loss or "tired light" observation extremely well. There is no need for any additional ad hoc postulates. Using published observations from Nobel Prize winning research fit its predictive curve almost perfectly.

There is a common demand that a "tired light" model provide an alternate cosmology before it can even be considered. With exponential energy loss from the electromagnetic waves, there is simply no unique data that could define the origin and evolution of the universe – and all expanding universe models would lose their foundation.

This would certainly disappoint many who desire to be certain of the beginnings and endings of all things. It will disappoint cosmologists – who would lose the underpinnings of ΛCDM that generate most cosmological research papers. But there will be no lack of work for astronomers, astrophysicists, and cosmologists. The remoter rungs of the cosmological distance ladder which are currently tied to the linear Hubble law and the velocity/redshift assumptions would be re-evaluated. All distances to extragalactic objects would need to be reevaluated. Apparent anomalies such as quasar redshifts and distances could be examined anew.

And best of all, physicists could begin searching for the physical foundational process of this energy loss. One that would be acceptable to a large number of newly-disappointed theorists.

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[17] Gamma rays

[18] We considered variants of the expanding universe: BB, ΛCDM, plasma fireworks, Steady-State Cosmology, Quasi Steady-State Cosmology, and Variable Mass cosmology. Some variant of the Steady State might allow for same.

Appendix A-1

Conversion of Perlmutter et al, Tables 1 and 2 to standard Hubble law diagram format:

Sorted by redshift (z) within each table. Columns 1, 2, 3 from Perlmutter.

SN	redshift factor z	m_B^{eff}	Distance modulus*[19]	Distance (Mpc)[20]	Apparent velocity cz (kps)	Indicated H0 (kps/Mpc)
1997I	0.172	20.17	39.47	7.83E+02	5.16E+04	65.9
1997N	0.180	20.43	39.73	8.83E+02	5.40E+04	61.1
1997ac	0.320	21.86	41.16	1.71E+03	9.60E+04	56.3
1994F	0.354	22.38	41.68	2.17E+03	1.06E+05	49.0
1994am	0.372	22.26	41.56	2.05E+03	1.12E+05	54.4
1994H	0.374	21.72	41.02	1.60E+03	1.12E+05	70.1
1997O	0.374	23.52	42.82	3.66E+03	1.12E+05	30.6
1994an	0.378	22.58	41.88	2.38E+03	1.13E+05	47.7
1995ba	0.388	22.65	41.95	2.45E+03	1.16E+05	47.4
1995aw	0.400	22.36	41.66	2.15E+03	1.20E+05	55.9
1997am	0.416	22.57	41.87	2.37E+03	1.25E+05	52.7
1994al	0.420	22.55	41.85	2.34E+03	1.26E+05	53.7
1994G	0.425	22.13	41.43	1.93E+03	1.28E+05	66.0
1996cn	0.430	23.13	42.43	3.06E+03	1.29E+05	42.1
1997Q	0.430	22.57	41.87	2.37E+03	1.29E+05	54.5
1995az	0.450	22.51	41.81	2.30E+03	1.35E+05	58.7
1996cm	0.450	23.17	42.47	3.12E+03	1.35E+05	43.3
1997ai	0.450	22.83	42.13	2.67E+03	1.35E+05	50.6
1995aq	0.453	23.17	42.47	3.12E+03	1.36E+05	43.6
1992bi	0.458	23.11	42.41	3.03E+03	1.37E+05	45.3
1995ar	0.465	23.33	42.63	3.36E+03	1.40E+05	41.6
1997P	0.472	23.11	42.41	3.03E+03	1.42E+05	46.7
1995ay	0.480	22.96	42.26	2.83E+03	1.44E+05	50.9
1996cg	0.490	23.10	42.40	3.02E+03	1.47E+05	48.7
1996ci	0.495	22.83	42.13	2.67E+03	1.49E+05	55.7
1995as	0.498	23.71	43.01	4.00E+03	1.49E+05	37.4
1997H	0.526	23.15	42.45	3.09E+03	1.58E+05	51.1
1997L	0.550	23.51	42.81	3.65E+03	1.65E+05	45.2
1996cf	0.570	23.27	42.57	3.27E+03	1.71E+05	52.4
1997af	0.579	23.48	42.78	3.60E+03	1.74E+05	48.3
1997F	0.580	23.46	42.76	3.56E+03	1.74E+05	48.8
1997aj	0.581	23.09	42.39	3.01E+03	1.74E+05	58.0
1997K	0.592	24.42	43.72	5.55E+03	1.78E+05	32.0
1997S	0.612	23.69	42.99	3.96E+03	1.84E+05	46.3
1995ax	0.615	23.19	42.49	3.15E+03	1.85E+05	58.6

[19] Distance Modulus defined as: m - M = 5 log d – 5. Using Maximum Absolute Visual Magnitude for SN Ia of -19.3 [7]
[20] Standard-candle distance as determined from distance modulus.

1997J	0.619	23.80	43.10	4.17E+03	1.86E+05	44.5
1995at	0.655	23.27	42.57	3.27E+03	1.97E+05	60.2
1996ck	0.656	23.57	42.87	3.75E+03	1.97E+05	52.5
1997R	0.657	23.83	43.13	4.23E+03	1.97E+05	46.6
1997G	0.763	24.47	43.77	5.68E+03	2.29E+05	40.3
1996cl	0.828	24.65	43.95	6.17E+03	2.48E+05	40.3
1997ap	0.830	24.32	43.62	5.30E+03	2.49E+05	47.0
1990O	0.030	14.47	33.77	5.68E+01	4.20E+03	74.0
1990af	0.050	15.61	34.91	9.59E+01	5.40E+03	56.3
1992P	0.026	15.18	34.48	7.87E+01	6.00E+03	76.2
1992ae	0.075	16.08	35.38	1.19E+02	7.80E+03	65.5
1992ag	0.026	16.28	35.58	1.31E+02	7.80E+03	59.7
1992al	0.014	16.26	35.56	1.29E+02	9.00E+03	69.5
1992aq	0.101	16.66	35.96	1.56E+02	1.08E+04	69.4
1992bc	0.020	17.19	36.49	1.99E+02	1.29E+04	65.0
1992bg	0.036	17.61	36.91	2.41E+02	1.35E+04	56.0
1992bh	0.045	17.63	36.93	2.43E+02	1.50E+04	61.7
1992bl	0.043	17.69	36.99	2.50E+02	1.50E+04	60.0
1992bo	0.018	17.54	36.84	2.33E+02	1.56E+04	66.9
1992bp	0.079	18.24	37.54	3.22E+02	1.89E+04	58.7
1992br	0.088	18.33	37.63	3.36E+02	2.13E+04	63.4
1992bs	0.063	18.43	37.73	3.52E+02	2.25E+04	64.0
1993B	0.071	18.27	37.57	3.27E+02	2.37E+04	72.6
1993O	0.052	19.28	38.58	5.20E+02	2.64E+04	50.8
1993ag	0.050	19.16	38.46	4.92E+02	3.03E+04	61.6

Appendix A-2

Conversion of Tonry et al, Tables 15 and 13 to standard Hubble law diagram format:

Sorted by redshift (z) within each table. Columns 2, 4, 5 from Tonry.

SN	redshift factor z	log(dH0)[21]	Distance (Mpc)[22]	Apparent velocity cz (kps)	Indicated H0 (kps/Mpc)
sn72E	0.002	2.399	3.86E+00	6.90E+02	179.0
sn86G	0.003	2.440	4.24E+00	8.10E+02	191.2
sn94D	0.003	3.003	1.55E+01	8.10E+02	52.3
sn99by	0.003	3.067	1.80E+01	8.10E+02	45.1
sn89B	0.004	2.844	1.07E+01	1.08E+03	100.5
sn98aq	0.004	3.181	2.33E+01	1.11E+03	47.6
sn96ai	0.004	3.109	1.98E+01	1.23E+03	62.2
sn91bg	0.004	3.064	1.78E+01	1.26E+03	70.7
sn98bu	0.004	2.912	1.26E+01	1.29E+03	102.7
sn90N	0.004	3.204	2.46E+01	1.32E+03	53.6
sn94ae	0.005	3.295	3.03E+01	1.62E+03	53.4
sn98dm	0.005	3.498	4.84E+01	1.62E+03	33.5
sn81D	0.006	3.044	1.70E+01	1.68E+03	98.7
sn80N	0.006	3.140	2.12E+01	1.68E+03	79.1
sn94U	0.006	3.149	2.17E+01	1.68E+03	77.5
sn92A	0.006	3.124	2.05E+01	1.74E+03	85.0
sn95al	0.006	3.328	3.27E+01	1.80E+03	55.0
sn97dt	0.006	3.375	3.65E+01	1.83E+03	50.2
sn92G	0.006	3.286	2.97E+01	1.86E+03	62.6
sn91T	0.007	2.961	1.41E+01	2.10E+03	149.3
sn00cx	0.007	3.320	3.21E+01	2.10E+03	65.3
sn81B	0.007	3.077	1.84E+01	2.16E+03	117.6
sn96bk	0.007	3.298	3.06E+01	2.16E+03	70.7
sn91M	0.008	3.397	3.84E+01	2.28E+03	59.4
sn98dh	0.008	3.403	3.89E+01	2.28E+03	58.6
sn95D	0.008	3.373	3.63E+01	2.31E+03	63.6
sn96X	0.008	3.266	2.84E+01	2.34E+03	82.4
sn97br	0.008	3.282	2.95E+01	2.40E+03	81.5
sn99cl	0.008	3.009	1.57E+01	2.46E+03	156.6
sn96Z	0.009	3.387	3.75E+01	2.61E+03	69.6
sn99gh	0.009	3.356	3.49E+01	2.64E+03	75.6
sn97bp	0.010	3.416	4.01E+01	2.85E+03	71.1
sn98es	0.010	3.438	4.22E+01	2.85E+03	67.6
sn97bq	0.010	3.484	4.69E+01	2.88E+03	61.4
sn99ac	0.010	3.478	4.62E+01	2.97E+03	64.2

[21] Tonry's cosmological distance value
[22] Conversion of Tonry's dH0 to d, based on Tonry's value of H of 65 kpc/Mpc

sn98bp	0.010	3.475	4.59E+01	3.12E+03	67.9
sn99cp	0.010	3.525	5.15E+01	3.12E+03	60.5
sn97do	0.010	3.545	5.40E+01	3.12E+03	57.8
sn92K	0.011	3.432	4.16E+01	3.36E+03	80.8
sn99cw	0.011	3.469	4.53E+01	3.36E+03	74.2
sn95E	0.012	3.559	5.57E+01	3.48E+03	62.4
sn98dk	0.012	3.571	5.73E+01	3.60E+03	62.8
sn99da	0.012	3.623	6.46E+01	3.63E+03	56.2
sn99ej	0.013	3.684	7.43E+01	3.81E+03	51.3
sn98D	0.013	3.605	6.20E+01	3.96E+03	63.9
sn97E	0.013	3.624	6.47E+01	3.96E+03	61.2
sn99dq	0.014	3.548	5.43E+01	4.08E+03	75.1
sn91ag	0.014	3.626	6.50E+01	4.23E+03	65.1
sn92al	0.014	3.636	6.65E+01	4.23E+03	63.6
sn99dk	0.014	3.686	7.47E+01	4.23E+03	56.7
sn95bd	0.015	3.648	6.84E+01	4.56E+03	66.7
sn99aa	0.016	3.684	7.43E+01	4.71E+03	63.4
sn98de	0.016	3.727	8.21E+01	4.71E+03	57.4
sn94S	0.016	3.693	7.59E+01	4.83E+03	63.7
sn01V	0.016	3.662	7.06E+01	4.86E+03	68.8
sn97cw	0.016	3.674	7.26E+01	4.92E+03	67.7
sn00dk	0.016	3.677	7.31E+01	4.92E+03	67.3
sn96bo	0.017	3.653	6.92E+01	4.95E+03	71.5
sn00ce	0.017	3.705	7.80E+01	4.95E+03	63.5
sn97Y	0.017	3.730	8.26E+01	4.98E+03	60.3
sn96bv	0.017	3.663	7.08E+01	5.01E+03	70.8
sn98ef	0.017	3.650	6.87E+01	5.10E+03	74.2
sn98V	0.017	3.686	7.47E+01	5.10E+03	68.3
sn98co	0.017	3.729	8.24E+01	5.13E+03	62.2
sn97cn	0.018	3.730	8.26E+01	5.25E+03	63.5
sn99ek	0.018	3.687	7.48E+01	5.28E+03	70.6
sn92bo	0.018	3.745	8.55E+01	5.34E+03	62.4
sn93ae	0.018	3.684	7.43E+01	5.40E+03	72.7
sn92bc	0.019	3.777	9.21E+01	5.58E+03	60.6
sn99gd	0.019	3.779	9.25E+01	5.70E+03	61.6
sn00B	0.019	3.740	8.45E+01	5.79E+03	68.5
sn98ec	0.020	3.801	9.73E+01	6.00E+03	61.7
sn00fa	0.022	3.837	1.06E+02	6.54E+03	61.9
sn95ak	0.022	3.772	9.10E+01	6.57E+03	72.2
sn00cn	0.023	3.847	1.08E+02	6.99E+03	64.6
sn98eg	0.023	3.897	1.21E+02	7.02E+03	57.8
sn94M	0.024	3.835	1.05E+02	7.32E+03	69.6
sn96V	0.025	3.871	1.14E+02	7.50E+03	65.6
sn93H	0.025	3.845	1.08E+02	7.53E+03	69.9

sn99X	0.026	3.888	1.19E+02	7.71E+03	64.9
sn99gp	0.026	3.933	1.32E+02	7.80E+03	59.2
sn92ag	0.026	3.864	1.12E+02	7.86E+03	69.9
sn92P	0.027	3.939	1.34E+02	7.95E+03	59.5
sn00bk	0.027	3.911	1.25E+02	7.98E+03	63.7
sn96C	0.028	3.989	1.50E+02	8.28E+03	55.2
sn98ab	0.028	3.876	1.16E+02	8.34E+03	72.1
sn93ah	0.029	3.933	1.32E+02	8.58E+03	65.1
sn94Q	0.029	3.955	1.39E+02	8.70E+03	62.7
sn97dg	0.030	4.033	1.66E+02	8.91E+03	53.7
sn90O	0.031	3.977	1.46E+02	9.21E+03	63.1
sn97bz	0.031	4.060	1.77E+02	9.39E+03	53.2
sn99cc	0.032	3.983	1.48E+02	9.48E+03	64.1
sn98cs	0.033	3.956	1.39E+02	9.81E+03	70.6
sn91U	0.033	3.938	1.33E+02	9.93E+03	74.4
sn96bl	0.035	4.033	1.66E+02	1.04E+04	62.9
sn94T	0.036	4.014	1.59E+02	1.08E+04	68.0
sn92bg	0.036	4.036	1.67E+02	1.08E+04	64.6
sn00cf	0.036	4.112	1.99E+02	1.08E+04	54.2
sn99ef	0.038	4.147	2.16E+02	1.14E+04	52.8
sn90Y	0.039	3.985	1.49E+02	1.17E+04	78.7
sn90T	0.040	4.101	1.94E+02	1.20E+04	61.8
sn92bl	0.043	4.095	1.91E+02	1.29E+04	67.4
sn97by	0.045	4.084	1.87E+02	1.35E+04	72.3
sn92bh	0.045	4.191	2.39E+02	1.35E+04	56.5
sn92J	0.046	4.099	1.93E+02	1.38E+04	71.4
sn95ac	0.049	4.160	2.22E+02	1.47E+04	66.1
sn93ac	0.049	4.206	2.47E+02	1.47E+04	59.5
sn98dw	0.049	4.208	2.48E+02	1.47E+04	59.2
sn90af	0.050	4.149	2.17E+02	1.50E+04	69.2
sn93ag	0.050	4.209	2.49E+02	1.50E+04	60.3
sn94C	0.051	4.139	2.12E+02	1.53E+04	72.2
sn93O	0.052	4.231	2.62E+02	1.56E+04	59.6
sn95M	0.053	4.243	2.69E+02	1.59E+04	59.1
sn97fb	0.053	4.254	2.76E+02	1.59E+04	57.6
sn98dx	0.054	4.175	2.30E+02	1.61E+04	70.1
sn97fc	0.054	4.230	2.61E+02	1.62E+04	62.0
sn99ao	0.055	4.242	2.69E+02	1.65E+04	61.4
sn91S	0.056	4.283	2.95E+02	1.68E+04	56.9
sn98ea	0.057	4.314	3.17E+02	1.71E+04	53.9
sn92bk	0.058	4.222	2.56E+02	1.74E+04	67.8
sn96ao	0.058	4.240	2.67E+02	1.74E+04	65.1
sn96bx	0.058	4.256	2.77E+02	1.74E+04	62.7
sn98fb	0.060	4.262	2.81E+02	1.80E+04	64.0

sn92au	0.061	4.252	2.75E+02	1.83E+04	66.6
sn97cu	0.062	4.240	2.67E+02	1.86E+04	69.6
sn92bs	0.063	4.327	3.27E+02	1.89E+04	57.9
sn96am	0.065	4.356	3.49E+02	1.95E+04	55.8
sn95ae	0.068	4.315	3.18E+02	2.04E+04	64.2
sn93B	0.071	4.345	3.40E+02	2.13E+04	62.6
sn97dr	0.075	4.296	3.04E+02	2.25E+04	74.0
sn92ae	0.075	4.359	3.52E+02	2.25E+04	64.0
sn92bp	0.079	4.336	3.33E+02	2.37E+04	71.1
sn98cm	0.080	4.398	3.85E+02	2.40E+04	62.4
sn98br	0.081	4.442	4.26E+02	2.43E+04	57.1
sn92br	0.088	4.441	4.25E+02	2.64E+04	62.2
sn94B	0.090	4.507	4.94E+02	2.70E+04	54.6
sn98dz	0.091	4.458	4.42E+02	2.73E+04	61.8
sn98do	0.092	4.462	4.46E+02	2.76E+04	61.9
sn96af	0.100	4.428	4.12E+02	3.00E+04	72.8
sn92aq	0.101	4.513	5.01E+02	3.03E+04	60.4
sn96ab	0.124	4.621	6.43E+02	3.72E+04	57.9
sn96ag	0.140	4.680	7.36E+02	4.20E+04	57.0
sn96R	0.151	4.621	6.43E+02	4.53E+04	70.5
sn98dv	0.155	4.706	7.82E+02	4.65E+04	59.5
sn97cp	0.160	4.792	9.53E+02	4.80E+04	50.4
sn97I	0.172	4.713	7.94E+02	5.16E+04	64.9
sn97N	0.180	4.765	8.96E+02	5.40E+04	60.3
sn97fd	0.190	4.888	1.19E+03	5.70E+04	47.9
sn95ap	0.230	4.893	1.20E+03	6.90E+04	57.4
sn96T	0.241	4.941	1.34E+03	7.23E+04	53.8
sn99fw	0.278	5.007	1.56E+03	8.34E+04	53.3
sn95ao	0.300	4.957	1.39E+03	9.00E+04	64.6
sn96J	0.300	5.010	1.57E+03	9.00E+04	57.2
sn88U	0.310	5.096	1.92E+03	9.30E+04	48.5
sn97ac	0.320	5.051	1.73E+03	9.60E+04	55.5
sn97bj	0.334	5.070	1.81E+03	1.00E+05	55.4
sn94F	0.354	5.155	2.20E+03	1.06E+05	48.3
sn99fh	0.369	5.135	2.10E+03	1.11E+05	52.7
sn94am	0.372	5.131	2.08E+03	1.12E+05	53.7
sn94H	0.374	5.023	1.62E+03	1.12E+05	69.2
sn97O	0.374	5.383	3.72E+03	1.12E+05	30.2
sn94an	0.378	5.195	2.41E+03	1.13E+05	47.0
sn96K	0.380	5.183	2.34E+03	1.14E+05	48.6
sn95ba	0.388	5.209	2.49E+03	1.16E+05	46.8
sn95aw	0.400	5.151	2.18E+03	1.20E+05	55.1
sn97am	0.416	5.193	2.40E+03	1.25E+05	52.0
sn00ea	0.420	5.091	1.90E+03	1.26E+05	66.4

sn94al	0.420	5.189	2.38E+03	1.26E+05	53.0
sn97bh	0.420	5.242	2.69E+03	1.26E+05	46.9
sn94G	0.425	5.105	1.96E+03	1.28E+05	65.1
sn96E	0.425	5.156	2.20E+03	1.28E+05	57.9
sn97Q	0.430	5.193	2.40E+03	1.29E+05	53.8
sn96U	0.430	5.288	2.99E+03	1.29E+05	43.2
sn96cn	0.430	5.305	3.11E+03	1.29E+05	41.5
sn97ce	0.440	5.228	2.60E+03	1.32E+05	50.8
sn97aw	0.440	5.355	3.48E+03	1.32E+05	37.9
sn95az	0.450	5.181	2.33E+03	1.35E+05	57.8
sn97ai	0.450	5.245	2.70E+03	1.35E+05	49.9
sn96cm	0.450	5.313	3.16E+03	1.35E+05	42.7
sn95aq	0.453	5.313	3.16E+03	1.36E+05	43.0
sn99ff	0.455	5.289	2.99E+03	1.37E+05	45.6
sn92bi	0.458	5.301	3.08E+03	1.37E+05	44.7
sn99Q	0.460	5.336	3.33E+03	1.38E+05	41.4
sn95ar	0.465	5.345	3.40E+03	1.40E+05	41.0
sn98ac	0.467	5.260	2.80E+03	1.40E+05	50.0
sn00ec	0.470	5.340	3.37E+03	1.41E+05	41.9
sn00ee	0.470	5.343	3.39E+03	1.41E+05	41.6
sn97P	0.472	5.301	3.08E+03	1.42E+05	46.0
sn99fn	0.477	5.249	2.73E+03	1.43E+05	52.4
sn95K	0.478	5.284	2.96E+03	1.43E+05	48.5
sn95ay	0.480	5.271	2.87E+03	1.44E+05	50.2
sn00eh	0.490	5.224	2.58E+03	1.47E+05	57.0
sn96cg	0.490	5.299	3.06E+03	1.47E+05	48.0
sn96ci	0.495	5.245	2.70E+03	1.49E+05	54.9
sn95as	0.498	5.421	4.06E+03	1.49E+05	36.8
sn99U	0.500	5.321	3.22E+03	1.50E+05	46.6
sn97cj	0.500	5.323	3.24E+03	1.50E+05	46.3
sn00dz	0.500	5.352	3.46E+03	1.50E+05	43.4
sn97as	0.508	5.158	2.21E+03	1.52E+05	68.8
sn97bb	0.518	5.356	3.49E+03	1.55E+05	44.5
sn97H	0.526	5.309	3.13E+03	1.58E+05	50.4
sn00eg	0.540	5.236	2.65E+03	1.62E+05	61.2
sn97L	0.550	5.381	3.70E+03	1.65E+05	44.6
sn96cf	0.570	5.333	3.31E+03	1.71E+05	51.6
sn96I	0.570	5.356	3.49E+03	1.71E+05	49.0
sn97af	0.579	5.375	3.65E+03	1.74E+05	47.6
sn97F	0.580	5.371	3.61E+03	1.74E+05	48.1
sn97aj	0.581	5.297	3.05E+03	1.74E+05	57.2
sn97K	0.592	5.563	5.62E+03	1.78E+05	31.6
sn97S	0.612	5.417	4.02E+03	1.84E+05	45.7
sn95ax	0.615	5.317	3.19E+03	1.85E+05	57.8

sn97J	0.619	5.439	4.23E+03	1.86E+05	43.9
sn96H	0.620	5.397	3.84E+03	1.86E+05	48.5
sn98M	0.630	5.396	3.83E+03	1.89E+05	49.4
sn95at	0.655	5.333	3.31E+03	1.97E+05	59.3
sn96ck	0.656	5.393	3.80E+03	1.97E+05	51.8
sn97R	0.657	5.445	4.29E+03	1.97E+05	46.0
sn97bd	0.671	5.200	2.44E+03	2.01E+05	82.6
sn97G	0.762	5.573	5.76E+03	2.29E+05	39.7
sn99fj	0.815	5.564	5.64E+03	2.45E+05	43.4
sn96cl	0.827	5.609	6.25E+03	2.48E+05	39.7
sn97ap	0.829	5.543	5.37E+03	2.49E+05	46.3
sn98J	0.833	5.615	6.34E+03	2.50E+05	39.4
sn98aj	0.860	5.698	7.68E+03	2.58E+05	33.6
sn98I	0.887	5.575	5.78E+03	2.66E+05	46.0
sn99fm	0.949	5.580	5.85E+03	2.85E+05	48.7
sn97ck	0.970	5.638	6.68E+03	2.91E+05	43.5
sn99fk	1.056	5.659	7.02E+03	3.17E+05	45.2
sn99fv	1.199	5.651	6.89E+03	3.60E+05	52.2
sn97ff	1.755	5.905	1.24E+04	5.27E+05	42.6

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