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ACCELERATING HUBBLE REDSHIFT

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ABSTRACT

Understanding the "acceleration" of modern Hubble redshift measurements begins with Schrödinger. In 1939 he proved that all quantum wave functions coevolve with the curved spacetime of a closed Friedmann universe. While both photon wavelengths and atomic radii are proportional to the Friedmann radius, the wavelengths of photons that an atom emits are proportional to the square of the radius. This larger shift in atomic emissions changes the current paradigm that redshift implies expansion. Instead, redshift implies the contraction of a closed Friedmann universe. Hubble redshifts are observed only when old blueshifted photons are compared to current atomic emissions that have blueshifted even more. This theoretical prediction is confirmed by modern Hubble redshift measurements. The Pantheon redshift data set of 1048 supernovas was analyzed assuming that atoms change like Schrödinger predicted. The Hubble constant and deceleration parameter are the only variables. The fit, $H_o = -72.03 \pm 0.25\, km\, s^{-1} Mpc^{-1}$ and $1/2 < q_o < 0.501$, has a standard deviation 0.1516 compared to the average data error 0.1418. No modifications to general relativity or to Friedmann's 1922 solution are necessary to explain accelerating Hubble redshifts. A nearly flat Friedmann universe accelerating in collapse is enough.

Keywords: cosmology: accelerating hubble redshift — cosmology: dark energy — cosmology: collapsing Friedmann universe —

1. INTRODUCTION

The traditional assumption that Hubble redshifts result from photon wavelengths increasing with the radius of an expanding universe fails to explain modern redshift observations. This failure came from not realizing that atoms change in the same way that photons do when the curvature of the universe changes.

Modified redshift equations which include the atomic changes discovered by Schrödinger (1939) are derived from the original Friedmann solution. These equations are used to find the best match between Hubble redshift observations and the geometry of a closed Friedmann universe.

These calculations which include atomic as well as photon changes are confirmed by modern Hubble redshift observations.

2. FRIEDMANN SOLUTION

Friedmann (1922) published a closed universe solution to Einstein's theory of general relativity without a cosmological constant. The Friedmann solution rapidly expands from a singularity, slowing until it reaches a maximum size before accelerating back to a singularity.

Friedmann assumed the metric,

$$ds^2 = c^2 dt^2 - a^2(t) \left[\frac{dr^2}{(1-r^2)} + r^2 \left(d\theta^2 + sin^2\theta\, d\phi^2 \right) \right], \tag{1}$$

and homogeneous, incoherent matter, conserved in amount and exerting negligible pressure. His solution is the cycloid shown in Figure 1.

$$a = \frac{\alpha}{2}(1 - \cos\psi), \qquad c\,t = \frac{\alpha}{2}(\psi - \sin\psi), \tag{2}$$

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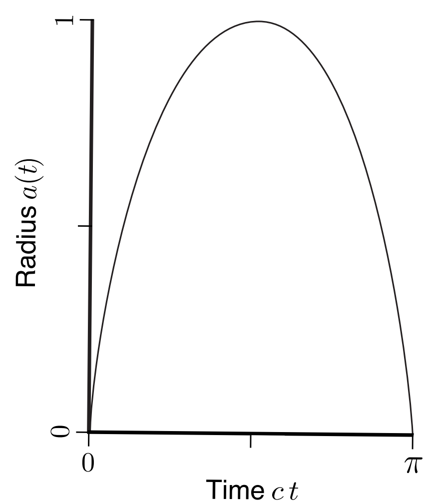

Figure 1. Friedmann's solution for a closed universe with $\alpha = 1$ in equations (2).

where α is a constant and $0 \leq \psi \leq 2\pi$ (Tolman 1934).

3. ATOMS CHANGE WITH FRIEDMANN GEOMETRY

Schrödinger (1939) proved that every quantum wavelength expands in proportion to the Friedmann radius $a(t)$. Schrödinger argued that if spacetime is curved as general relativity requires, then its effects on quantum processes must not be dismissed without careful investigation. Using the equations of relativistic quantum mechanics, Schrödinger found that the plane-wave eigenfunctions characteristic of flat spacetimes are replaced in the curved spacetime of the closed Friedmann universe by wave functions with wavelengths that are proportional to the Friedmann radius. Every eigenfunction changes wavelength as the radius of the universe changes.

The quantum systems they describe change as well. In an expanding universe, quantum systems expand. In a contracting universe, they contract. The assumption is often made that small quantum systems are isolated and that their properties remain constant as the Friedmann universe evolves. Schrödinger concluded this assumption is incompatible with relativistic quantum mechanics and with the curved spacetime of general relativity (Sumner & Sumner 2000).

These changes in quantum systems may equivalently be viewed as a logical consequence of the fact that the energy and momentum of "isolated systems" are not conserved. Energy and momentum change when the spacetime curvature of the universe changes. There are no "isolated systems". While photon energies are proportional to their momentum, electron energies are proportional to the square of their momentum. Schrödinger (1956, p 58) wrote:

> In an expanding space *all momenta decrease* ... for bodies acted on by no other forces than gravitation ... This simple law has an even simpler interpretation in wave mechanics: all wavelengths, being inversely proportional to the momenta, simply expand with space.[1]

In a contracting space, the opposite is true. *All momenta increase* and all wavelengths, being inversely proportional to the momenta, simply contract with space.

Schrödinger had a deep understanding of both wave mechanics and general relativity. Like most physicists, Schrödinger assumed that Hubble redshift meant that the universe is expanding. This was a hangover from the pre-relativistic interpretations of redshifts originally made by Slipher (1917) and Hubble (1929) who tentatively assumed that all galactic redshifts are solely Doppler effects. It is interesting to speculate how long it would have taken Schrödinger to correctly interpret Hubble redshift if he had asked himself the question: "Would the changes in atoms and photons that I found change my interpretation of Hubble redshift?"

4. HUBBLE REDSHIFT

In the following equations t is the mathematical time coordinate in Friedmann geometry. The wavelength of a photon λ emitted at t_1 and observed at t_1 will be written $\lambda(t_1, t_1)$. The wavelength of a photon λ emitted at t_1 and observed at t_2 will be written $\lambda(t_1, t_2)$.

The traditional formula for redshift z assumes that atomic emissions do not evolve, $\lambda(t_2, t_2) = \lambda(t_1, t_1)$, but assumes that photons do evolve, $\lambda(t_1, t_2) = [a(t_2)/a(t_1)]\lambda(t_1, t_1)$,

$$z = \frac{\lambda(t_1, t_2) - \lambda(t_1, t_1)}{\lambda(t_1, t_1)} = \frac{a(t_2)}{a(t_1)} - 1. \tag{3}$$

t_2 is the time of observation and t_1 is the time of emission.

But atomic emissions do evolve with spacetime geometry, $\lambda(t_2, t_2) = [a^2(t_2)/a^2(t_1)]\lambda(t_1, t_1)$ (Sumner 1994). A new redshift variable ζ (the Greek letter zeta) is defined to match what is done experimentally,

$$\zeta = \frac{\lambda(t_1, t_2) - \lambda(t_2, t_2)}{\lambda(t_2, t_2)}, \tag{4}$$

[1] Pauli (1958, p 220) made the same observation.

$$\zeta = \frac{a(t_1)}{a(t_2)} - 1. \tag{5}$$

t_2 is the time of observation and t_1 is the time of emission.

Hubble redshift ($\zeta > 0$) implies $a(t_1) > a(t_2)$. The universe was larger in the past, $a(t_1)$, than it is now, $a(t_2)$. This puts us somewhere on the collapsing half of the curve in Figure 1. The logic is simple. Since Hubble shifts are red ($\zeta > 0$), the Friedmann universe is collapsing. If Hubble shifts were blue ($\zeta < 0$), the Friedmann universe would be expanding.

5. ANALYZING HUBBLE REDSHIFTS

The following mathematical analysis of redshift observations includes the change in atomic emissions in addition to the change in photons (Sumner & Vityaev 2000). Astronomers measure the redshift defined by ζ, equation (5). The following derivation is similar to one made when atomic evolution is ignored and the universe is assumed to be expanding. It is modified because ζ not z describes the observed redshift and some choices in signs are made differently because the universe is contracting.

The mathematical coordinate distance r to a source can be shown to be a function of the observed redshift ζ of the source and the deceleration parameter q_o in the following way.

Setting $ds = 0$ in the Friedmann metric, equation (1), gives

$$c\,dt = \frac{-a(t)\,dr}{(1 - r^2)^{1/2}}. \tag{6}$$

The source is located at the spatial coordinates $(r_1, 0, 0)$ with emission at time t_1 and the observer is at $(0, 0, 0)$ with reception at time t_2. Integrating equation (6) gives

$$c \int_{t_1}^{t_2} \frac{dt}{a(t)} = \int_0^{r_1} \frac{dr}{(1 - r^2)^{1/2}} = \sin^{-1} r_1. \tag{7}$$

Substituting $a(t)$ and dt calculated from equations (2), gives

$$r_1 = \sin(\psi_2 - \psi_1). \tag{8}$$

The Hubble constant H and the deceleration parameter q are defined

$$H(t) = \frac{\dot{a}(t)}{a(t)}, \quad \frac{\ddot{a}(t)}{a(t)} = -q(t)H^2(t). \tag{9}$$

Dots indicate time derivatives. H is negative and q is greater than 1/2 for a closed, collapsing universe. Present day values are denoted by H_o and q_o.

Solving for ψ_2 and ψ_1 in terms of ζ and q_o and substituting into equation (8) gives

$$r_1 = \frac{(2q_o - 1)^{1/2}}{q_o}\left[\zeta - \frac{(1 + \zeta)(1 - q_o)}{q_o}\right] + \frac{(1 - q_o)}{q_o}\left\{1 - \left[\zeta - \frac{(1 + \zeta)(1 - q_o)}{q_o}\right]^2\right\}^{1/2}. \tag{10}$$

The luminosity distance D_L to the source is (Weinberg 1972, p 441)

$$D_L = r_1\, a(t_2)\,(1 + \zeta), \tag{11}$$

where $a(t_2)$ is (Narlikar 1983, p 114)

$$a(t_2) \;=\; \frac{-c}{H_o}\,\frac{1}{(2q_o\,-\,1)^{1/2}}. \tag{12}$$

Substituting equations (10) and (12) into (11) gives

$$\begin{aligned} D_L \;=\; &\frac{-c}{H_o}\frac{(1+\zeta)}{q_o}\left\{\left[\zeta-\frac{(1+\zeta)(1-q_o)}{q_o}\right]+\right.\\ &\left.\frac{(1-q_o)}{(2q_o-1)^{1/2}}\left(1-\left[\zeta-\frac{(1+\zeta)(1-q_o)}{q_o}\right]^2\right)^{1/2}\right\}. \end{aligned} \tag{13}$$

The relationship between distance modulus (the difference between the apparent magnitude m and absolute magnitude M of a celestial object) and luminosity distance, D_L, is (Narlikar 1983, p 292)

$$m - M = 5\log_{10}\left(\frac{D_L}{10\,\mathrm{parsecs}}\right). \tag{14}$$

The Hubble constant H_o (negative for the contracting half of the curve) and the deceleration parameter q_o (which must be $> 1/2$) characterizing a closed Friedmann universe are varied to find a best least-squared fits to Hubble redshift observations of ζ and $m - M$.

6. SUPERNOVAE REDSHIFTS

The Pantheon redshift data set of 1048 supernovas (Scolnic 2018) was fit using equations (13) and (14). The fit for $H_o = -72.03 \pm 0.25\,km\,s^{-1}Mpc^{-1}$ and $1/2 < q_o < 0.501$ is shown in Figure 2. The average data error is 0.1418. For these fit parameters the standard deviation is 0.1516.

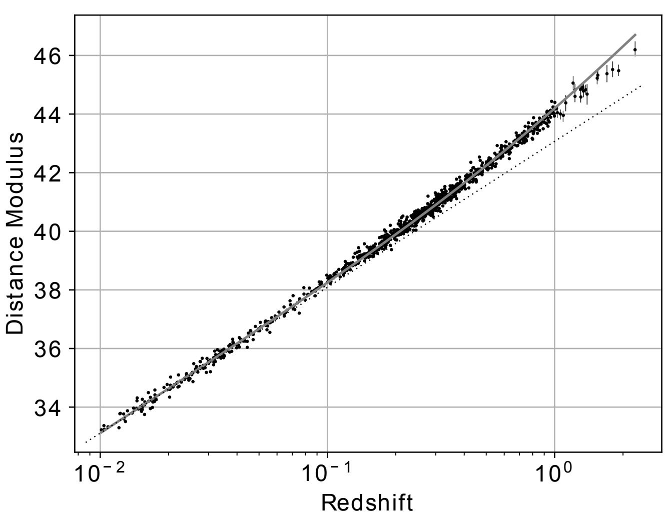

Figure 2. The solid line is the fit to the Pantheon redshift data with the parameters $H_o = -72.03 \pm 0.25\,km\,s^{-1}Mpc^{-1}$ and $1/2 < q_o < 0.501$. The dotted straight line is included to visually clarify the upward curve (or "acceleration") of the data and fit. The average data error is 0.1418. The standard deviation for this fit is 0.1516.

Since this Friedmann universe is closed, $q_o > 1/2$. Every search conducted found a lower standard deviation when q_o was closer to 1/2. No lower limit for $\delta = q_o - 1/2$ was found. The upper limit 0.501 in $1/2 < q_o < 0.501$, was chosen because there is little further change in the quality of fit with smaller q_o. Our universe is nearly flat. This is illustrated in Figure 3.

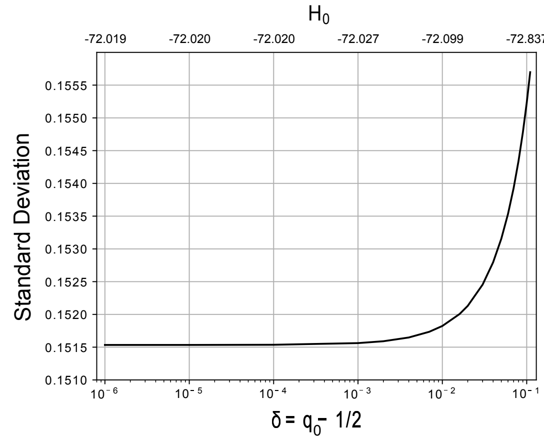

Figure 3. Standard deviation for fits at smaller values of $\delta = q_o - 1/2$. The values of H_o on the top axis are the best fits for the δ values on the bottom axis. No minimum for δ was found.

The absolute magnitude $M = -19.308$ was used. This value was determined by varying M to find the best fit to the Pantheon data. The points in Figure 4 illustrate the fit sensitivity to M.

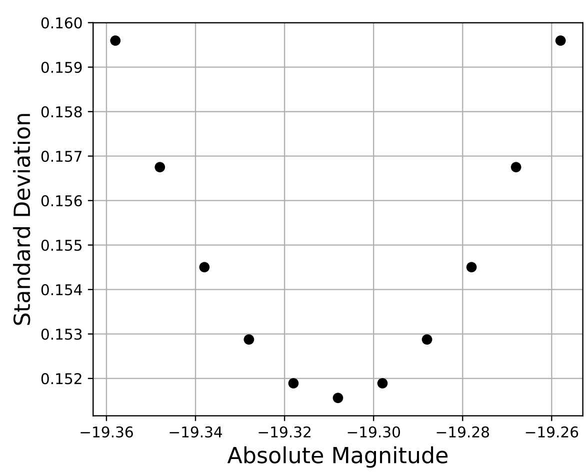

Figure 4. The Absolute Magnitude $M = -19.308$ used in this analysis gave the best fit to the Pantheon data.

7. CONCLUSIONS

Schrödinger proved that the wavelength of every quantum wave function is proportional to the radius of a closed Friedmann universe. In an expanding universe, photon and atomic wavelengths expand. In a contracting universe, they contract. The wavelengths of atomic emissions shift more than atomic and photon wavelengths do. This reverses the interpretation of Hubble redshift. Instead of expansion, Hubble redshift implies the contraction of a closed Friedmann universe. Traditional analyses do not match modern Hubble redshift measurements because these crucial changes in atomic emissions were not recognized. When the atomic emission changes are included, theory matches accelerating Hubble redshifts observations. Our universe is collapsing and nearly flat. No modifications to general relativity or to Friedmann's 1922 closed solution are necessary. The Pantheon data set provides compelling experimental confirmation of old physics and old physicists.

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The Python program curve_fit from scipy.optimize was used with equations (13) and (14) to analyze the Pantheon data (Scolnic 2018).

Data: https://dx.doi.org/10.17909/T95Q4X

REFERENCES

Friedmann, A. 1922, Z. Phys., 10, 377
Hubble, E. 1929, Proceedings of the National Academy of Science, 15, 168
Narlikar, J. 1983, Introduction to Cosmology (Cambridge: Cambridge University Press)
Pauli, W. 1958, Theory of Relativity (Oxford: Pergamon)
Schrödinger, E. 1939, Physica, 6, 899
—. 1956, Expanding Universes (Cambridge: Cambridge University Press)
Scolnic, D. 2018, ApJ, 859, 101
Slipher, V. 1917, Proc. Amer. Phil. Soc., 56, 403
Sumner, W. 1994, ApJ, 429, 491
Sumner, W., & Sumner, D. 2000, arXiv:0704.2791v1 [physics.gen-ph]
Sumner, W., & Vityaev, E. 2000, arXiv:astro-ph/0008386v1
Tolman, R. 1934, Relativity, Thermodynamics, and Cosmology (Oxford: Clarendon)
Weinberg, S. 1972, Gravitation and Cosmology (New York: John Wiley and Sons)