# Using the Hubble Telescope to Determine the Split of a Cosmological Object's Redshift into its Gravitational and Distance Parts

Pharis E. Williams
Energetic Materials Research and Testing Center
801 Leroy Place, Socorro, NM 8780

The Hubble Telescope should make it possible to separate the redshift of light from any cosmological object into that redshift due to the gravitational potential difference between the emission and reception points and that portion due the distance between these points by comparing the redshifts measured on the Earth's surface to redshifts measured by the Hubble Telescope. This would allow a remapping of the cosmological objects and an increased understanding of gravitational conditions of these objects.

*Keywords*: gravitational redshift, cosmological redshift, Hubble telescope, Weyl gauge factor, gauge function, unit of action, variable unit of action

## Introduction

In 1911 Einstein used time dilation in the Special Theory of Relativity to predict that the atomic spectral lines should be shifted towards the red end of the color spectrum [1]. This prediction has since been verified by experiment using both solar and terrestrial gravitational potential differences [2-5]. Hubble measured the redshift of numerous stars and galaxies and noted that these displayed an almost direct relationship between the redshift and the cosmological distance of the radiating object from the Earth [6]. These experimental findings were later supported by solutions to Einstein's General Relativistic field equations, such as the Robertson-Walker solution [7]. However, these experimental and theoretical considerations provide no way to sort out how much of the cosmological object's redshift is due to the gravitational potential difference between the emitting object and the Earth and how much is due solely to the distance between them.

There exists a new theory, called the Dynamic Theory [8-14], which predicts significant differences between the redshifts that are measured on the Earth's surface and those that should be measured by the Hubble Telescope in its orbit. Further, the manner of the prediction is such that comparison of the redshifts measured at the Earth's surface and by the Hubble Telescope sets up two equations in the two unknowns; the cosmological distance to the object and its gravitational potential.

To display how the new predictions differ from the old let's first look at the old predictions. Einstein's gravitational potential difference redshift is given by

$$z = -\frac{G}{c^2}\left[\frac{M_r}{R_r} - \frac{M_e}{R_e}\right],$$

where the subscripts *e* and *r* denote the emitting and receiving gravitational potentials. The redshift due to the cosmological distance is the linear relation

$$z = \frac{H}{c}L,$$

where *H* is Hubble's constant and *L* is the cosmological distance between the emitting object and the Earth. By adding these two redshift predictions we find

$$z = -\frac{G}{c^2}\left[\frac{M_r}{R_r} - \frac{M_e}{R_e}\right] + \frac{H}{c}L, \tag{1}$$

which shows that the only difference this prediction would have between measurements at the Earth's surface and by the Hubble Telescope would come from the change in the difference in the gravitational potential of reception due to the orbital height of the telescope. However, because of the small size of the Earth in comparison to the cosmological objects this difference would be negligible. For example, for the Sun this effect is some $10^{-5}$ percent. For objects larger than the Sun the difference is even less.

The Dynamic Theory is based upon the laws of classical thermodynamics and it has been shown that these fundamental laws require Einstein's postulate of the constancy of the speed of light [13]. Given this result it is no surprise that Einstein's special theory of relativity quickly follows. What is less obvious, but also required, is that these basic laws provide a description of physical phenomena in five dimensions of space, time and mass [14]. We shall now provide a brief outline of the theoretical background leading to the redshifts prediction within this new theory starting be stating the adopted laws.

## First Law (Conservation of Energy)

The concept of conservation of energy is fundamental to all branches of physics and is the beginning of thermodynamics and mechanics [8,10,12,13]. In terms of generalized coordinates or independent variables, the notion of work, or mechanical energy, is considered linear forms of the type

$$đW = F_i(q^1,...,q^n,u^1,...,u^n)\,dq^i \quad (i = 1,2,...,n),$$

where the forces $F_i$ may be functions of the velocities ($dq^i/dt = u^i$) as well as the coordinates $q^i$ and the summation convention is used.

A system may acquire energy by other means in addition to the work terms; such energy acquisition is denoted $đE$. The system energy, which represents the energy possessed by the system, is considered to be

$$U(q^1,...,q^n,u^1,...,u^n).$$

With these concepts, then the First Law, which is the generalized Law of Conservation of Energy, has the form

$$đE = dU - đW = dU - F_i dq^i \quad (i = 1,...,n).$$

In the First Law the dimensionality is $n + 1$ and is determined by the system considered.

## Second Law

The statement of the Second Law is made using the axiomatic statement provided by the Greek mathematician Carathéodory [15] who presented an axiomatic development of the Second Law of thermodynamics that may be applied to a system of any number of variables. The Second Law may then be stated as follows:

*In the neighborhood (however close) of any equilibrium state of a system of any number of dynamic coordinates, there exist states that cannot be reached by reversible E—conservative ($đE = 0$) processes or motions.*

## Results of the Second Law

The Second Law requires that an integrating denominator must exist for the First Law and that this integrating factor must be a function of velocity only for mechanical systems. Using the integrating denominator the expression for the First Law may be written

$$\frac{đE}{f(u)} = f(s)\,ds\,.$$

Since $f(s)ds$ is an exact differential, the quantity $1/f(u)$ is an integrating denominator for $đE$.

The universal character of $f(u)$ makes it possible to define an absolute speed in the same manner as is done in thermodynamics when defining the absolute temperature. The definition of the absolute speed requires constant speed motions be considered. All Galilean frames of reference will display this process as one of constant speed. Further, if all reference frames are to be of equal status then observers in all Galilean reference frames must share the $đE = 0$ constant speed motion equivalently. Furthermore, each observer will have the same value for the absolute speed or else one of the frames will enjoy a privileged nature. Then the absolute speed is unique for all Galilean frames of reference. There is one such speed already known and that speed is the speed of light, *c*. Therefore, the absolute speed must be the speed of light and the same for all Galilean observers. This is Einstein's postulate. Thus, the first two laws require Einstein's postulate concerning the speed of light.

Since $s$ is an actual function of $u$ and $q$, the right-hand member is an exact differential, which may be denoted by $dS$; and where $S$ is the mechanical entropy of the system.

$$dS = \frac{\text{đ}E}{f(u)}$$

## Geometry

With the above laws and the definition of the entropy an expression for the generalized Clausius' inequality may be written and used to specify the stability condition

$$dU - F_i \Delta q^i - f\,dS > 0.$$

which leads to the quadratic form

$$(ds)^2 = h_{ij}\, dq^i\, dq^j;\; j,k = 0,1,2,\ldots,n,\; where\; q^0 = S / F_0$$

and

$$h_{jk} = \frac{\partial^2 U}{\partial q^j \partial q^k}\,.$$

The element of arc length may be parameterized using the local time as $ds = cdt$. However, Clausius' Inequality does not lead to a single variational principal on time rather it leads to two variational principals, one requiring the minimization of Free Energy and one requiring the maximization of the entropy for isolated systems for which $\text{đ}E = 0$. The differential of the entropy is on the right hand side of this quadratic form so that the form must be solved for the differential expression of entropy in order to use the entropy variational principal. When this is done we find that

$$\left(dq^o\right)^2 = f\left(c^2 dt^2 + 2h_{oa} c\,dq^a\, dt - h_{ab}\, dq^a\, dq^b\right) = f\left(ds\right)^2.$$

This shows the requirement for two metric spaces coupled by a gauge function, f. Since the Second Law requires that the entropy is a total derivative one may suspect that the entropy space will be an integrable space and this is indeed the case when the Second Law is applied to the metric coefficients. In addition, one finds that the second space, which we might call an energy space because of the tie to the First Law, must be a Weyl space. Therefore, we find that the gauge function acts as a geometrical integrating factor coupling the non-integrable Energy space to the integrable entropy space.

The appearance of Weyl character of the Energy space allows the use of London's work that shows that null trajectories in a Weyl space must be described by the equations of quantum mechanics [16]. In the Dynamic Theory, the necessity of considering null trajectories comes in a very natural way. For instance, in thermodynamics the desire to consider stable states would cause one to look for isentropic states. This is of course a null trajectory in the entropy space, however, for non-zero gauge functions this condition is also a null trajectory in the energy, Weyl, space. By the Second Law the differential change of entropy can never be negative for an isolated system so that $dq^0 \geq 0$. Therefore, the entropy metric is positive definite. For negative gauge functions the energy space will be negative definite and, therefore, complex. There are an infinite number of null trajectories for a complex space and these are given by the quantum states.

This may be more easily seen by considering the displacement of the element of arc length in the energy space that must take on the Weyl displacement form of

$$d(de) = f_k dq^k (de)$$

where the $f_k$ are the gauge potentials and are the logarithmic derivative of the square root of the gauge function. Then the isentropic condition that the integral of Equation (10) require that $(de) = (de)_0$ and, therefore, so that

$$e^{\int f_j dq^j} = 1$$

and

$$\int f_j dq^j = 2piN .$$

This is the quantum condition that London used to derive Schrödinger's equations of quantum mechanics. Here the quantum condition is required by the isentropic state specification.

When one first begins to study the thermodynamics of steam systems one writes the First Law as $dE = dU + Pdv - F_a dx_a$, $a = 1,2,3$. The right hand side of this statement of the First Law contains five unknown variables. The accepted method of reducing the number of unknowns is to, first, state that the mass density can always be written as a function of space and time thereby reducing the number of additional independent equations needed to four. These four equations are pointed out to be an equation of state and the three mechanical laws of motion from Newtonian physics.

The procedure outlined above for obtaining the equations of the metrics may also be used in five dimensions and then the dependence or independence of the mass density upon space and time may be determined as the predicted phenomena agree or disagree with experience. This leads one to a five dimensional entropy metric of space-time-mass. Here also one finds the appearance of the two spaces coupled by a gauge function for an isolated system. In this case the gauge function is a function of the same five variables.

The Dynamic Theory makes its prediction of redshifts starting from this five-dimensional geometry of space-time-mass in which the gauge function produces the fields. This gauge function is a function of space, time, and mass and it determines the unit of action in the atomic states as may be seen from the Quantum Poisson brackets when covariant differentiation is used, or

$$\left[x^j, P^k\right]\Psi = i\hbar g^{kl}\left[d_{jl} + \left\{ \begin{matrix} & j & \\ s & & l \end{matrix} \right\} x^s\right]\Psi$$

where the vector curvature would appear in the Christoffel symbols inside the brackets while the gauge function is a multiplicative factor in the $g^{kl}$. Then when the vector curvature is negligible the Quantum Poisson brackets become $\left[x^j, p^k\right]\Psi = i\hbar f\, d^{jk}\Psi$ where it may be seen that the unit of action is Dirac $d$ times the gauge function. It may be shown [12] by using the gauge field equations that the functional form of the gauge function must be

$$f = exp\left\{\left[\frac{k(a+bt)M}{R}\right]e^{-\frac{l}{R}}\right\}.$$

By requiring the photon energy to be conserved we have $hf_e\nu_e = hf_r\nu_r$ which produces the redshift expression

$$z = \frac{\Delta l}{l_e} = \exp\left\{k\left[\frac{M_r(a+bt_r)}{R_r}e^{-\frac{l_r}{R_r}} - \frac{M_e(a+bt_e)}{R_e}e^{-\frac{l_e}{R_e}}\right]\right\} - 1.$$

By expanding the right-hand side as a power series and comparing the first order approximation to the classical expression in Eqn. (1) the constants $k$, $a$, and $b$ may be evaluated. By setting $t_e = 0$ and $t_r = L/c$ we find our redshift expression becomes

$$z = \frac{\Delta l}{l_e} = \exp\left\{\left(\frac{-G}{c^2}\right)\left[\frac{M_r e^{-\frac{l_r}{R_r}}}{R_r} - \frac{M_e e^{-\frac{l_e}{R_e}}}{R_e}\right] + \left(\frac{HL}{c}\right)\frac{\left(\frac{M_r}{R_r}\right)}{\left(\frac{M}{R}\right)}\right\} - 1,$$

where $M/R$ is the gravitational potential at either the point of emission or the point of reception and the subscript $e$ stands for emission while the subscript $r$ stands for reception. The $R$ and $M$ without subscripts are the values of the radius and mass of the Earth respectively. Because of the distances involved the approximation $l << R$ may be used for both the emitter and the receiver. Then the approximation of Eqn (2) becomes

$$ln(z+1) \cong -\frac{G}{c^2}\left[\frac{M_r}{R_r}-\frac{M_e}{R_e}\right]+\left(\frac{HL}{c}\right)\frac{\left(\frac{M_r}{R_r}\right)}{\left(\frac{M}{R}\right)} \tag{3}$$

so that on the Earth's surface we would have the approximation

$$ln(z_{ES}+1) \cong -\frac{G}{c^2}\left[\frac{M}{R}-\frac{M_e}{R_e}\right]+\left(\frac{HL}{c}\right) \tag{4}$$

while, if we were to obtain experimental redshifts using the Hubble Telescope while in orbit at an orbital height of $h$ we would have

$$\ln(z_{HT}+1) \cong -\frac{G}{c^2}\left[\frac{M}{(R+h)}-\frac{M_e}{R_e}\right]+\left(\frac{HL}{c}\right)\frac{R}{(R+h)}. \tag{5}$$

Equation (4) and (5) represent two equations in the two unknowns, $L$ and $M_e/R_e$. The solution of these equations is given by the equations

$$\frac{M_e}{R_e} \cong \left(\frac{c^2}{hG}\right)\left[(R+h)\ln(z_{HT}+1)-R\ln(z_{ES}+1)\right] \tag{6}$$

and

$$L \cong \frac{c}{H}\left\{\ln(z_{ES}+1)-\ln(z_{HT}+1)\left(1+\frac{R}{h}\right)+\frac{GM}{c^2R}\right\}. \tag{7}$$

One may then see how comparing the redshifts obtained from the Earth's surface with those taken at a height above it will allow the determination of distance to, and the gravitational potential of, a cosmological object. The ability to obtain solutions from the two equations for redshifts at different receiving gravitational potentials does not exist in other predictions of redshifts. It is because of the appearance of the ratio of gravitational potentials in Eqn (2) that allows the Dynamic Theory to make the distance and potential predictions. For objects with a large gravitational potential compared to that of the Earth the major change in $\ln(z + 1)$ comes from the ratio of $h$ to $R + h$. For an orbit height of 380 miles this ratio is 0.0876. This means that the expected change in the measured redshift from the Earth's surface to the Hubble Telescope orbit is of the order of a few percent. A student survey of books reporting redshifts in the optical range puts the experimental error between a few percent and near 30 percent. Therefore, care needs to be taken or frequencies sought which have less experimental error.

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