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Estimation of Redshifts from Early Galaxies

Michael L. Smith[a], Ahmet Mecit Öztaş[b], Jan Paul[c]

a. Anabolic Laboratories, Inc., Tempe, Arizona 85281, USA,
email: `mlsmith10@cox.net`
b. Department of Engineering Physics, Hacettepe University of Engineering,
TR-06532 Ankara, Turkey, email: `oztas@hacettepe.edu.tr`
c. Division of Physics, Luleå University of Technology, S-971 87 Luleå
Sweden, email: `janpaul55@hotmail.com`

ABSTRACT. Dating early galaxies is a current technical, empirical and theoretical problem. Progress has been made recently calculating these dates using the observed redshift, z, alone. While this relaxes the need for simultaneous determination of luminosity distances with redshifts; accurate redshift determination beyond $z \geq 3$ is difficult. We have shown that light emissions tend toward blue with increasing emission age and this is supported by recent data. Here we combine calculations of cosmological times from redshifts alone with the emission frequency model for lookback times. This allows a better gauge between recombination and the first galaxies and may provide additional 50-200 M years between these events.

KEYWORDS: cosmic time, redshift, light frequency, SFR

1 Introduction

Universe age, commencement of galaxy formation (GF) and the related problem of star formation rates (SFR) are of current interest [1, 2, 3]. Estimates of GF place this evolution immediately after recombination, which now stands at 380,000 absolute years [4]. We have little data for anything between recombination and appearance of complete galaxies, which occurred between redshifts of $z \approx 3$ beginning from z of 6.5 to 7.

Several difficult, technical problems hinder more exact determination of GF ages. Luminosity distances, D_L, from supernovae type Ia (SNe Ia) emissions is a good method of determining galaxy age. This technique demands many dedicated hours of very large telescope time but decreasing S/N ratio with increasing lookback time means data beyond $z \approx 2$ are still unreliable [5]. As astronomers search even further back in time the density of interfering, hot gas between the earth and old emissions increases. So detection of reliable redshift data is quite difficult beyond $z \approx 3$ and a horrific problem for co-determination of z with $D_L$distances. It is now more useful to estimate GF using a simple formula for calculation, depending upon a few parameters; z and the Hubble constant, H_0. A useful formula dependent only upon z and the Universe age has recently been published [6]. This is reminiscent but not identical with an earlier presentation again dependent upon only $z$and H_0 [7].

We have recently published a model suggesting emissions gradually become blue-shifted with increasing lookback time [8]. The general form of this model which is useful over the range from the present to $z \approx 7$ is

$$\frac{d\nu}{dt} = U_{(t)}(\frac{\nu}{t}) \tag{1}$$

where $d\nu/dt$ is the frequency decline with increasing absolute time (of the emission) and $U_{(t)}$ is a new universal constant of unknown value. When a derivation of Eq. 1 is added in linear fashion to the usual solution of spacetime expansion in the Friedman-Robertson-Walker (FRW) geometry, we can easily fit the best, recent D_L and z data without necessitating input of *vacuum energy* [8]. The Hubble constant and matter density estimated from this solution using the astrophysical data are both well within the ranges currently thought reasonable. This model is necessary because we also recently uncovered inconsistencies within the mathematics of the FRW model, but only when a term for the *vacuum energy* is included [9]. These inconsistencies will leave the FRW model without a solution when in a state of low matter and energy densities expected in our future. Computerized solutions presented in ref. [9] also predict the so-called "jump" in the distant past of the Universe as an artifact of the FRW solutions that include a term for *vacuum energy.*

2 Emission age from the redshift

The formula derived based both spacetime geometry and velocity for estimating emission age time, depends only upon the current Hubble constant and redshift as presented in reference [6]

$$t = \frac{2H_0^{-1}}{1 + (1 + z)^2} \tag{2}$$

where t represents the time at emission. For a Hubble constant of 70 km/s-Mpc, consistent with a Universe age of about 14 Gyears [10] this becomes a useful formula for quickly estimating distant emission age

$$t \approx \frac{28}{1+(1+z)^2} \tag{3}$$

with time in Gyears [6]. The formula using a previously published estimate from ref. [7] is

$$t \approx \frac{14}{(1+z)^{\frac{3}{2}}}. \tag{4}$$

The results differ only slightly from approximation (3) for nearby galaxies but approach significance in the distant past. The largest source of error in both formulae might be H_0 itself, with the error currently estimated to be about 10%.

Since emission frequencies, as well as the redshift suffered by traveling photons, are both time dependent we must correct approximations (3) and (4) with a term to account for this. This effect can be represented as

$$t' = t_0((1-z)^{\frac{-1}{U}} - 1) \tag{5}$$

where t' is the correction to the lookback time at distant emission, t_0 the current absolute time and U is the unitless, proportionality constant relating frequency incline to lookback time [8]. The value of U is unknown and may be quite large. Equation (5) functions locally, because at $z = 0, t' = 0$ no matter the values of U or t_0. This decrease of light traveling time to the observer is usually extremely slight because the observed emission frequency increase from SNe Ia only becomes noticeable from older emissions, from $z \geq 0.3$ or so. Unfortunately this also means estimation of U is difficult using the data from local emissions and equation (5) is of little help estimating t_0. We will incorporate this correction, t_0, for emission blueing approaching singularity which allows distant galaxies to be slightly closer to the observer than estimated by redshift alone. We also make the reasonable assumption that $t' \ll t$.

Another difficulty of tracking the emission blue shift applying Eq. (5) is the unavoidable mathematical difficulty about $z = 1$. To avoid problems of evaluation when applying data from the region about $z = 1$ we must expand Eq. (5) as a series by presuming $U \neq 0$ and $z \ll 1$ in a similar manner as previously presented, ref. [8] and allow t_0 to be 14

Gyears

$$t' \approx (\frac{14z}{U}) + 7(\frac{z}{U})^2(1+U) + \frac{7}{3}(\frac{z}{U})^3(1+2U)(1+U) \\ + \frac{7}{12}(\frac{z}{U})^4(1+3U)(1+2U)(1+U) + ... \tag{6}$$

There exists another method for expanding Eq. (5) which yields a similar, though not identical, dependence upon z and the powers of U. We find it instructive to use this expansion as a term for correcting the lookback times by adding this to approximation (3) giving us

$$t'' \approx \frac{28}{1+(1+z)^2} + (\frac{14z}{U}) + 7(\frac{z}{U})^2(1+U) + \frac{7}{3}(\frac{z}{U})^3(1+2U)(1+U) \\ + \frac{7}{12}(\frac{z}{U})^4(1+3U)(1+2U)(1+U) + ... \tag{7}$$

where t'' is the corrected lookback time to very distant galaxies. We have added these two approximations in a linear manner because the effects are orthogonal; frequency increases with great lookback times and is only dependent upon the absolute time. Inspection of formula (7) reveals this correction for frequency increase to be of little importance at small z and large U, where $t'' \approx$ equalities (3 or 4) becoming significant at distant lookback times.

In Figure 1 we present lookback times for formulas (3) and (7), as a function of z with a value for U of 50,000. The solutions yield smaller lookback times at a given redshift with U increasing to 250,000. We calculate at $z = 6.7$, as far removed as current GF data allows, the absolute time for the first GF increasing from 465 Myears to 640 Myears for a U of 50,000 and to 500 M years for a U of 250,000. The first term of formula (7) may be substituted with a similar term, approximation (4) to yield similar results. Better estimates of U and t are difficult; best fits to recent $D_L$and z data, only reaching back to $z < 2$, can only estimate a wide range of values for U of the magnitude tested here.

3 Conclusions

A difficult and puzzling surprise for those modeling the early Universe are the results from investigations of galaxies in deepest space. Current data allow only a short time between recombination and signals from

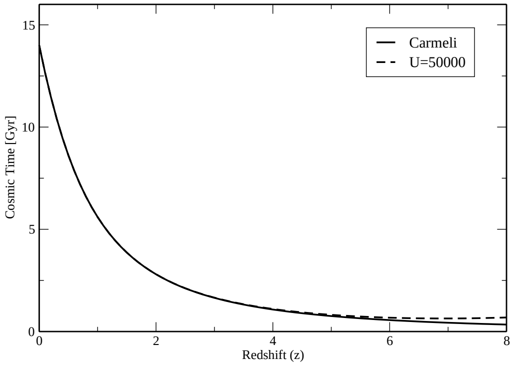

Figure 1: Distances in Gyears as a function of redshift, solid line from Carmeli *et al.*, dashed line this presentation.

the very first galaxies, significantly less than 1 Gyear and perhaps only 100 Myears. One might think star formation a slow process, even in a Universe densely packed with dust. While gravitational attraction slowly draws dust together, the unavoidable thermal heating arising during matter compression strongly retards this process. So development of the critical mass density and pressure necessary to give birth to young stars, by the millions, should demand significant time.

We have shown that a slight perturbation to two useful formulae estimating galaxy ages may allow significantly more time for SFR than currently credited. If the Universe age is actually closer to the value credited by recent estimates from nuclear decay, 14.5 Gyears [11], we may again find that well over 1 Gyear was necessary for star formation. Better estimates for the time between recombination and GF will have to wait for better astronomical SNe Ia data (or experiments of similar design) to overcome the insensitive nature of estimating lookback times from large redshifts alone. For instance, $D_L$data from the first galaxies or the very first, massive SN (these are much more massive than SN Ia) might be better suited to the inquiry. These measurements require great care in estimations of source mass and thousands of hours of very large telescope time. Additional corrections for the effects of massive amounts of intervening dust are both difficult and critical for these type of data collection.

These results also have implications upon the many questions surrounding gamma ray bursts [12]. These objects emit at high frequencies from enormous distances, seem uniformly distributed throughout space-time, but also seem to violate the Einstein mass-energy equivalency. Corrections for emission frequency at large redshifts may reduce emission energies to understandable levels, conserve the Einstein mass-energy relationship and help us better grasp the physics of this interesting problem.

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