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The Effect of He4 Fusion on Primordial Deuterium

Abstract

It is well known that approximately 23% to 25% of nucleons found throughout space are in the form of Helium 4 atoms. The distribution uniformity indicates that these atoms were formed in the very early universe. In addition, trace amounts of Deuterium, Lithium 3 and Beryllium 7 are also uniformly distributed. These elements are evidence of a process known as primordial nucleosynthesis based on historical work by G. Gamow, H. Bethe and A. Sakharov and more recently by N.D. Schramm [10].

The author explored a cosmology expansion curve called R1+R3 based on values found in a model of the proton [5][7][Appendix 1]. The expansion curve is similar to the concordance model [4][3]. Temperature histories that include He4 fusion energy appear to be missing from the literature. All temperature histories decrease from high values until He4 forms at 8e8K but if the He4 fusion energy is considered the temperature will spike and photo-disintegrate deuterium. Residual deuterium is a sensitive test for this period and the goal of the work below is to determine when residual primordial deuterium originated and re-evaluate limits on cosmological parameters.

Discussion

Fusion in stars is from hydrogen. The hydrogen contributes protons that must be converted to neutrons by energetic electrons. This is quite a different situation than exists for the first few minutes. In this environment there were still a large fraction of neutrons that had not decayed. It is widely accepted that He4 formed at a temperature of 8e8K. It is surprising however that literature [8][9] does not account for fusion energy of He4. WMAP results [12] are important to cosmology but the temperature response to He4 fusion appears to be absent from their analysis. WMAP results support the existence of dark energy and are widely quoted for the discovery that most of the expected matter in the universe is missing. WMAP results also claim that cosmologies that contain more than 0.046 baryon fraction [4][6] are ruled out by the residual deuterium criteria. The view that conventional mass is only 4% of the observed universe, with the remainder "missing" is reluctantly becoming accepted.

The baryon number fraction can be calculated with the following relationships. Baryon/photon ratio 4.4e-10 is a key value from WMAP. The measurement of residual deuterium in the universe (2.37e-5) is also a key value. The relationship is:

1.37E+17	R (Meters)
8.00E+08	T (K)
4.40E-10	Baryon/photon=(0.046*EXP(180)/(4/3*PI()*4.04e25^3))/(8*PI()/(4.31e-21*3e8)^3*(1.5*8.62e-11*2.73)^3
3.88E-05	D=0.00046*(4.4e-10*10000000000)^(-1.67)

The above calculation shows that the WMAP. At 8e8 K temperature, the measured Deuterium fraction agrees with the calculated value and they use this agreement as justification to calculate a 0.046 baryon fraction that indicates most of the mass of the universe is missing. Their methodology follows:

Photon number density=8*pi/(H*C)^3*(1.5*B*T)^3 number/m^3=5.8e8 at 2.73 K (Wiki).
B is the Boltzmann constant 8.62e-11 MeV/K, H is Heisenburg's constant and C is the speed of light

5.8e8 photon number*4.4e-10 baryons/photon=0.254 baryon number density

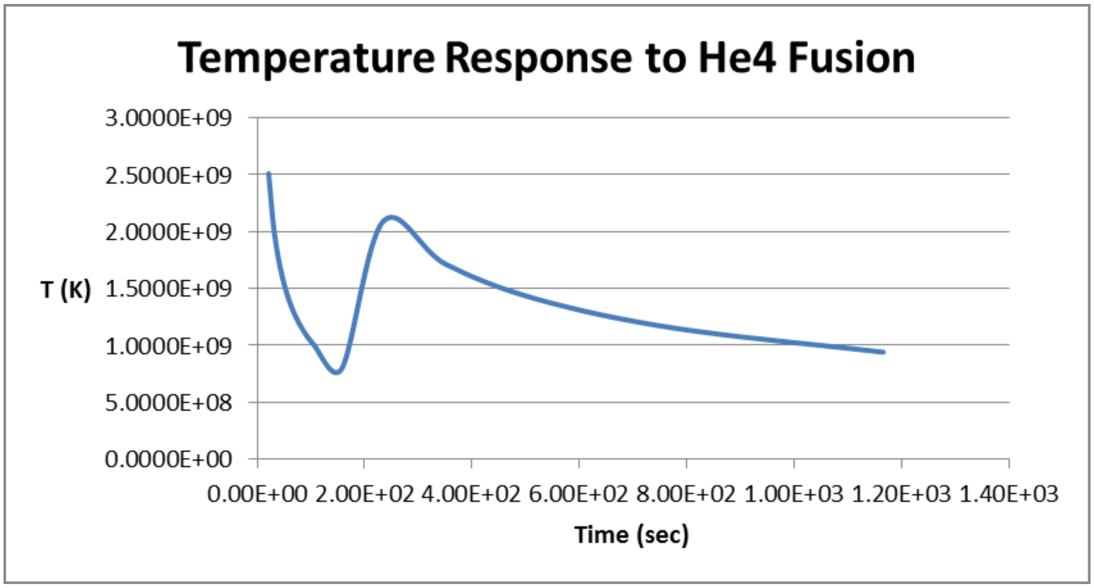
This leads directly to the Baryon fraction where 9.14e-27 kg/m^3 is critical density

0.254*1.67e-27/9.14e-27=0.046 baryon fraction

Baryon fraction (Omegab)=0.165 will be used for calculations below. Justification for using this value will be argued in the section below entitled "Late D Formation".

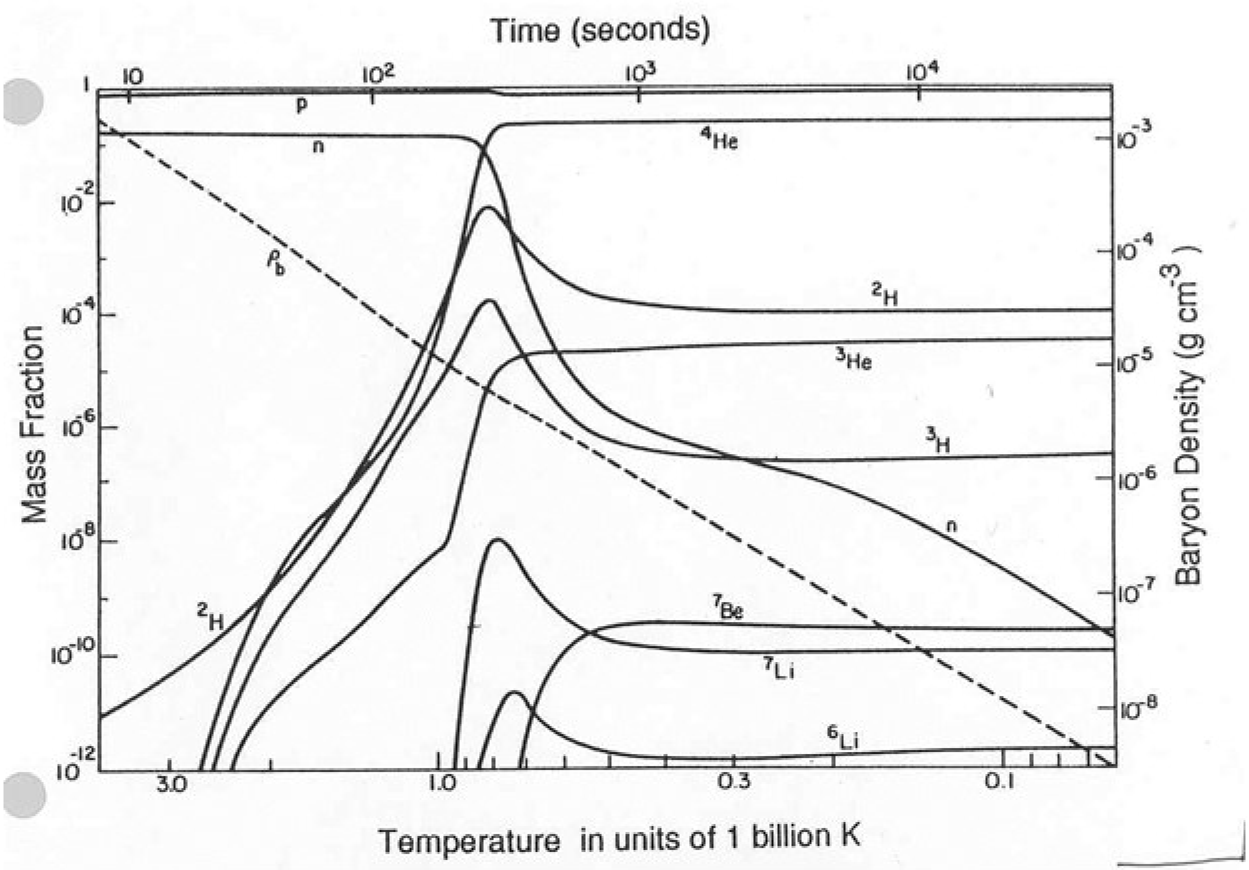
Temperature spike from He4 fusion

The R1+R3 expansion model starts at a kinetic energy of 10.11 MeV/particle [11]. The associated temperature history decreases initially but as He4 fusion occurs, the temperature increases before finally decreasing to the Cosmic Background Temperature (CBR) due to expansion. The temperature history during this period with release of 1.6 MeV/proton is shown below. This graph shows a dampened temperature response. Although protons release fusion energy, they are only 0.165 of the total mass.



Conventional Primordial Nucleosynthesis

The temperature in the graph below is about 3e9 K at 12 seconds. The kinetic energy associated with this temperature is 1.5*B*T=0.39 MeV, where B is Boltzmann's constant 8.62e-11 MeV/K. One can see from the smoothly decreasing temperature in the horizontal axis that as Helium 4 fuses, there is no increase in temperature. This amount of energy should increase the temperature to about 2e9 K as shown in the graph showing the temperature spike. Appendix 2 contains a similar graph from a different source [9]. Again, the temperature does not increase with He4 fusion.



http://burro.astr.cwru.edu/Academics/Astr222/Cosmo/Early/nucleosynth_fig.jpg

Photo-disintegration of Deuterium

Deuterium fraction is limited by photo-disintegration [4][6]. It is well known that deuterium readily fuses to He4 after the temperature falls to approximately 8e8 K.

The SAHA equation [4] is utilized to give the early deuterium fraction.

```
SAHA value=LN(4/3*((1*0.8)/((1.62E+66)/(0.165*EXP(180))))^(3/2))+LN((0.165*0.697^2)*(T/1e10)^(3/2))-(2.58/(T/1e10)
```

Example:

SAHA value=part1+part2-part3					
					Example
					T=8e8
	part1=LN(4/3*((1*0.8)/((1.62E+66)/(0.165*EXP(180))))^(3/2))				38.5706886
	part2=LN((0.165*0.697^2)*(T/1e10)^(3/2))				-6.31234251
	part3=(2.58/(T/1e10))				32.25
	SAHA value=part1+part2-part3				0.0083461
	SAHA fraction=1/exp(SAHA value)=D N/(n' p')				1

Where: Ln stands for natural logarithm, D=deuterium, N=total number of nucleons, p'=protons, n'=neutrons, Omega baryons=0.165 and T/1e10 is the temperature in degrees K divided by 1e10. The value exp(180) is the number of particles in the universe [] and the value 0.697 is h, the best value of the Hubble constant [3].
SAHA fraction=D N/(p' n') =1/exp(SAHA value). For example at equilibrium SAHA value=0 and fraction=1/exp(0)=1.

Freeze-out Mechanism

Initially the number of neutrons is controlled by a Boltzmann relationship: n'/N=exp(-1.293/Ke) where Ke is in MeV and p'=N-n'. As the kinetic energy falls with expansion, neutrons become less prevalent until a condition known as freeze-out occurs. At this condition, temperature reduction due to expansion is high compared to the reaction rates and the reaction favoring protons stops progressing. The relative forward and reverse reactions determine the balance of neutrons and protons as early expansion occurs. An excerpt from Pebbles [4] Table 6.2 pg. 185 is included below:

T(10^10 K)		lam t	lamb t		n'/(n'+p')
22.5		4700	5000		0.483
13.1		900	1010		0.471
7.6		170	208		0.451
4.45		31	43		0.418
2.59		5.4	9.7		0.363
1.51		0.85	2.3		0.292

When n'/(n'+p') takes on the approximate value 0.2, freeze-out has occurred because the forward reaction (lam t) cannot keep up with the reverse reaction rate (lamb t). This keeps more protons from forming from this mechanism fixing the ratio.

Decay mechanism

There is another mechanism that forms protons. The neutrons decay to protons with the relationship:

n'/N=(EXP(-0.693*t/866)) where t is time and 866 sec is the decay half time.

Determine D and He4

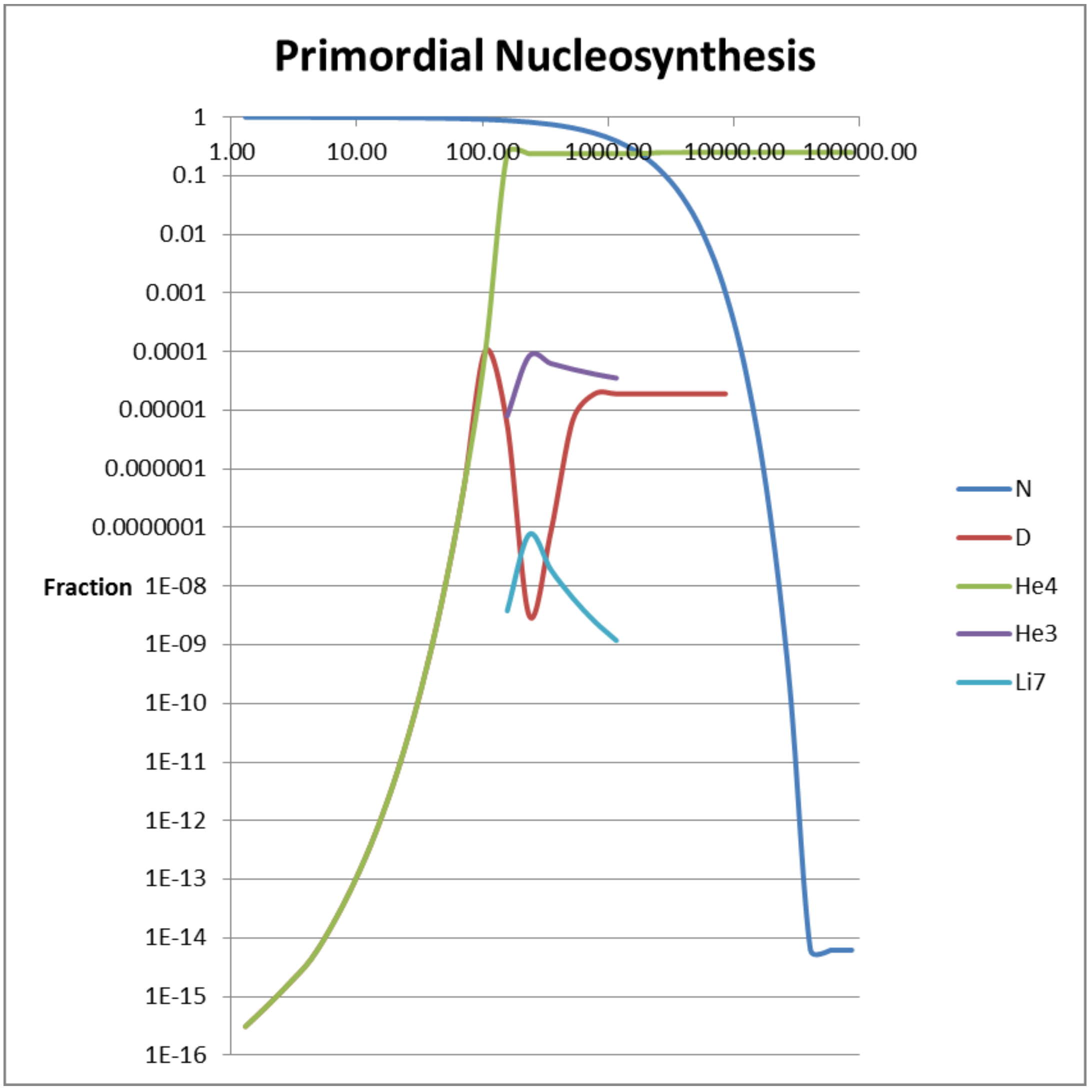
He4 formation can be calculated by applying the freeze-out mechanism to determine n'/N, then applying decay to n'/N. As temperature decreases D and He4 fraction is predicted by 1/exp(SAHA) but when T= 8e8K the SAHA fraction (DN)/(p' n') =1.0. At this condition, literature states that the deuterium D rapidly converts to He4.

The reaction equilibrium occurs at SAHA fraction=1, D N/(p' n')=1. Calculation of He4 fraction: At this point N=0.165*exp(180)=2.46e77 and N-n=2.35e77 and (N-n)/4N=0.24.

Late D formation

As the SAHA value decreased to 0, He4 fused and T9 (the temperature divided by 1e9 K) increased. With the addition of fusion energy, the SAHA criteria became negative again and caused photo-disintegration of deuterium. The temperature finally fell due to expansion and the SAHA value decreased to 0 where deuterium was again formed. The temperature spike took 600 seconds and delayed the point where 8e8 K occurs for the final time. The authors R1+R3 model shows that this occurred at 781 seconds and a radius of 1.45e17 meters.

The reaction equilibrium calculation is used with an expansion model the author calls R1+R3. Initially the kinetic energy is 10.11 MeV and temperature falls directly with expansion ratio z. The resulting graph of Helium and D fractions (the vertical axis) as a function of time in seconds (the horizontal axis) follows:



Helium4 abundance is shown in green and increases to 0.24. Neutrons decay and are shown in blue. Deuterium, shown in red, is photo-disintegrated and almost completely destroyed when the temperature spikes due to He4 fusion. However, when the temperature decreases following fusion, the D fraction recovers somewhat. After the SAHA value becomes positive (maximum = 1.0), the D fraction becomes fixed. Measured values are in column 1 below and calculated values for He3 and Lithium7 depend on the baryon/photon ratio. The proton mass fraction is used in the baryon/photon ratio since at this point neutrons are still decaying to protons and the baryon fraction 0.165 is only partially available. Results from reference 10 equations are detailed below. The deuterium residual agrees with measured values toward the end of the temperature spike. There are several factors considered in this calculation. The SAHA fraction (1/exp(SAHA value) decreases and destroys deuterium. The residual deuterium values are multiplied by the SAHA fraction until the fraction returns to 1 at the end of the spike. At this point, the equilibrium residual is calculated with the Boltzmann ratio=(exp(-1.115/MeV)=1.9e-5) where MeV is the energy associated with 8e8K and 1.115 MeV is the binding energy for deuterium. After that point the residual value is frozen at a value close to the measured value 2.3e-5.

Actual mass fraction =(p)/N*.165		1.58E-02	1.58E-03	2.78E-03	4.39E-03	6.41E-03
baryon/photon ratio		1.3936E-09	1.2844E-11	2.2695E-11	3.5796E-11	5.2267E-11
Temperature (K)	1.00E+09	7.99E+08	1.45E+09	1.18E+09	9.69E+08	7.94E+08
R (meters)		6.52E+16	7.97E+16	9.73E+16	1.19E+17	1.45E+17
Time (seconds)		158	235	351	523	781
1/EXP(SAHA)		1.00E+00	2.25E-07	1.58E-05	2.65E-03	1.00E+00
D=4.6e-4*(B/P*1e10)^(-1.67)	Measured	5.65E-06	1.42E-02	5.47E-03	2.56E-03	1.36E-03
D=4.6e-4*(B/P*1e10)^(-1.67)*1/exp(SAHA)	2.37E-05	5.65E-06	3.19E-09	8.63E-08	6.77E-06	1.91E-05
He3=3e-5*(B/P*1e10)^-0.5	3.3e-5 to 1e-4	8.04E-06	8.37E-05	6.30E-05	5.01E-05	4.15E-05
Li7=5.2e-10*(B/P*1e10)^-2.43+6.3e-12*(B/P*1e10)^2.43	6.00E-09	3.80E-09	7.62E-08	1.91E-08	6.31E-09	2.52E-09
http://cds.cern.ch/record/262880/files/9405010.pdf	SAHA value	0 (equilibrium)	1.53E+01	1.11E+01	5.93E+00	-2.58E-01

Recalculating parameters with 0.719 dark energy removed

Dark energy is largely a “place-holder” concept. The author studied the possibility that energy released by stars causes late stage expansion [11]. Surprisingly, the energy increased the later part of the curve appropriately but it depends on the star energy being added to the Cosmic Background Radiation temperature 2.73 K. WMAP measurements masks light from stars and radiometers used to measure temperature are for long wavelengths. The points of light from stars subtend very small angles and this energy is easier to calculate than measure.

Based on reference 11, we find that expansion is only partially density driven and we must separate the causes of expansion and treat them differently. Density related to mass can be calculated by removing the dark energy fraction from critical density.

Below we are not treating critical density (rhoC) as an incorrect value. Critical density is related to the accepted finding that the universe is “flat” and can be related to the Hubble constant with the equation rhoC=H^2/(8/3 pi G). However we need to separate matter density from the component of expansion called dark energy. Removing 0.719, we have only 0.235+0.0464=0.2814 for the mass fraction and we will scale this up so two mass components make up the critical density. There is a second expansion component but it requires very little energy (on the order of 2e-10 mev/proton). WMAP measured the ratio between light and dark matter. This ratio is unchanged by the scaling operation below.

old	multiplier	new		ratio l/d
0.235	3.55	0.835	dark matter	
0.046	3.56	0.165	light matter	0.197
0.281		1		

Note the useful ratio:
Old/new=1/3.56=0.281

Current cosmological parameters:

5.77E+08	Photon number density	
4.400E-10	baryons/photon	
0.254	baryon number density	
4.2377E-28	baryon mass densty	
9.14E-27	rhoC	
0.0464	Baryon fraction	
0.719	Dark Energy fract	

Revised cosmological parameters:

4.15	K	
2.04E+09	Photon number density	
4.43E-10	baryons/photon	
0.902	baryon number density	
1.507E-27	baryon mass	
9.14E-27	rhoC	
0.165	Baryon fraction	
0.835	dark matter fract	

At the present time the baryon/photon ratio is calculated as follows:

4.5000E-10	Baryon/photon=(0.165*EXP(180)/(4/3*PI()*4e25^3))/(8*PI()/(4.31e-21*3e8)^3*(1.5*8.62e-11*4.15)^3)	

This ratio is the ratio reported in reference 3 and would lead directly to the residual deuterium value 2.3e-5 with the value 0.165 and the temperature 4.15 K.

Conclusions

Primordial fusion of He4 releases a significant amount of energy and must be included when determining temperature curves associated with expansion. After formation of He4, the temperature rises and photo-disintegrates the deuterium. The photon/baryon ratio reported for WMAP is unchanged at 4.4e-10 at the end of expansion and is the value that allows the calculated and measured abundance of Deuterium to equal 3e-5. But this photon/baryon ratio is for star energy plus CBR temperature 4.15 K. This temperature takes into account the energy produced by stars starting approximately 200 to 500 million years after the beginning. These two affects produce cosmological parameters consistent with zero dark energy. Omega baryons=0.165*exp(180).

References:

1. Barbee, Gene. H., A top down approach to fundamental interactions, FQXi essay June 2012, revised Feb 2014, viXra:1307.0082. Reference Microsoft ® spreadsheet entitled Unifying concepts.xls, Barbee.

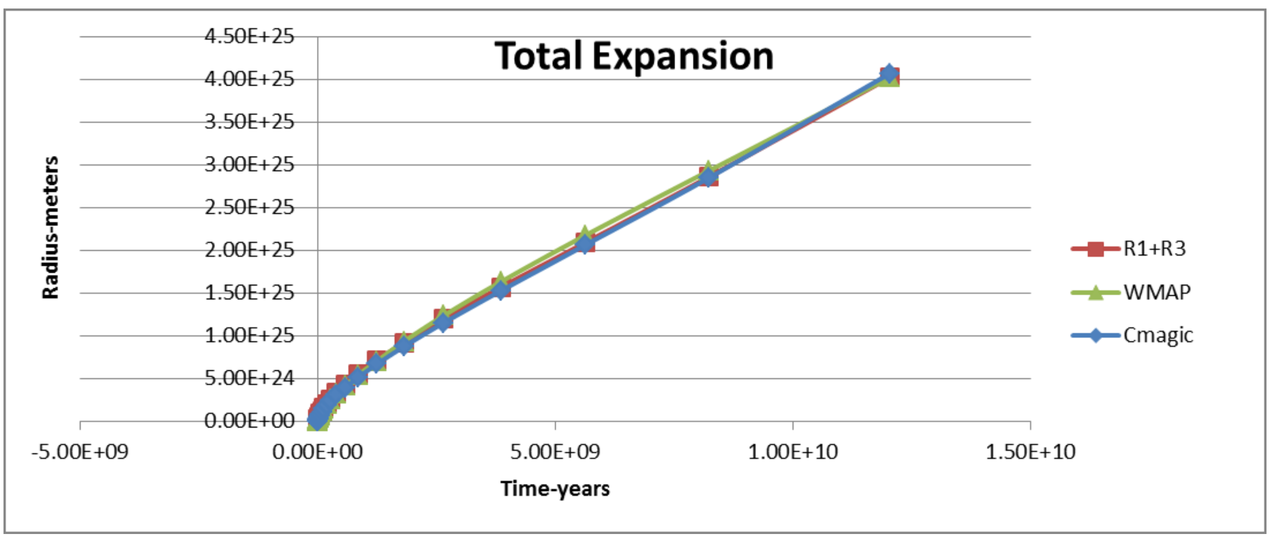
2. Barbee, Gene. H., Application of information in the proton mass model to cosmology, viXra:1307.0090 revised Nov 2013. Reference Microsoft ® spreadsheet entitled simple1c.xls, Barbee.
3. Bennett, C.L. et al. First Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Preliminary Maps and Basic Data, Astrophysical Journal, 2001
4. Peebles, P.J.E., Principles of Physical Cosmology, Princeton University Press, 1993.
5. Barbee, Gene H., On the Source of the Gravitational Constant, Prespacetime Journal, Volume 5 No 3, April, 2014. Originally viXra:1307.0085. Reference Microsoft ® excel spreadsheet entitled Why G Constant.xls.
6. Bergstom, L. and Goobar, A., Cosmology and Particle Astrophysics, 2nd Edition, Springer-Praxis Books in Astrophysics and Astronomy, 2004.
7. Barbee, Gene H., *On Expansion Energy, Dark Energy and Missing Mass*, Prespacetime Journal pending publication, Volume 5 No 5, May, 2014.
8. http://burro.astr.cwru.edu/Academics/Astr222/Cosmo/Early/nucleosynth_fig.jpg.
9. http://www.phys.utk.edu/witek/NP621/Greene.pdf

10. http://cds.cern.ch/record/262880/files/940501.pdf Review of work by N. D. Schramm.

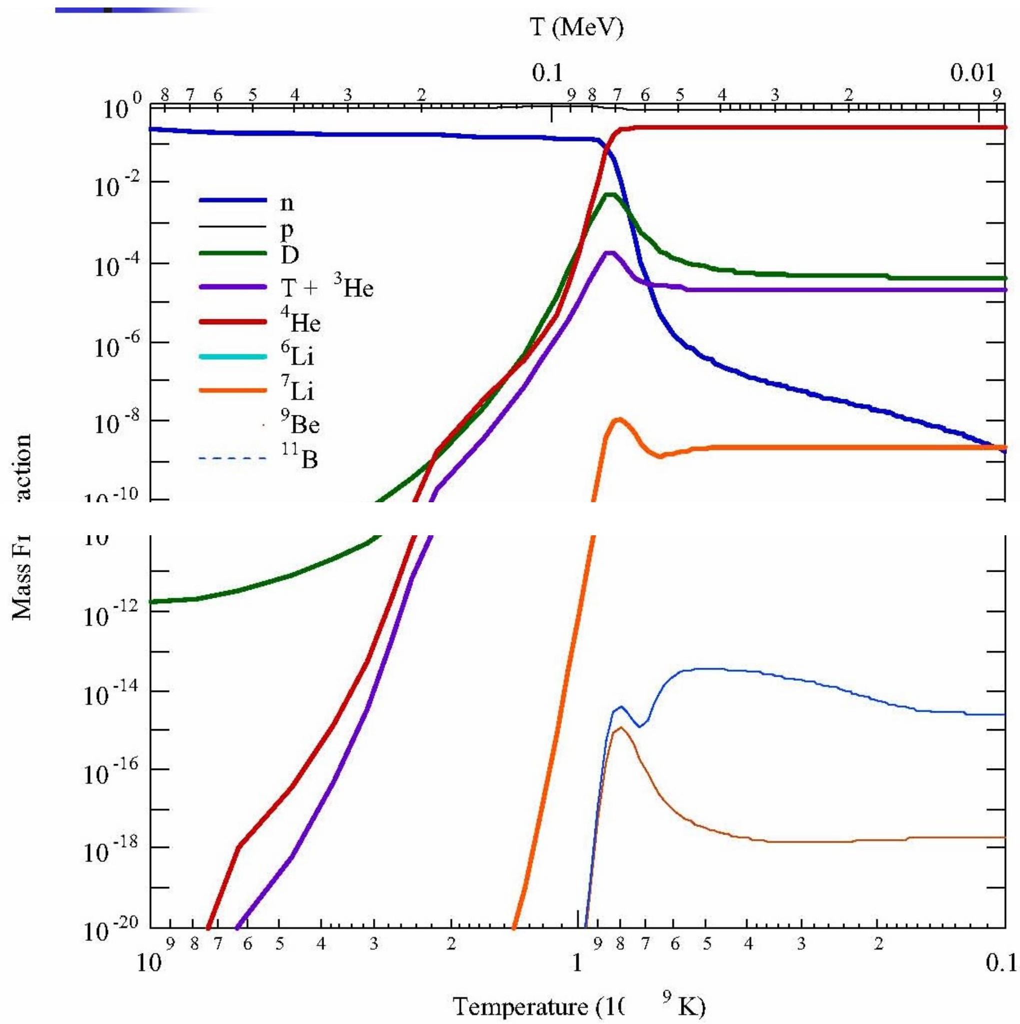
11. Barbee, Gene H., *Dark Energy*, viXra:1511.0185v1, December 2015.

Appendix 1 Expansion history

Interpretation of WMAP gives the following expansion history:



Appendix 2



http://www.phys.utk.edu/witek/NP621/Greene.pdf