Default Output Explanation

Cosmology Model Input Parameters:
Observer located at Age = 13.720645822 Gyr using z=0.00 and CMB_z viewed as redshift = 1091.000
H_o = 69.600, $\Omega Omega_m$ = 0.28600, Ω_{vac} = 0.71400000, Ω_K = -0.00008598, Ω_R = 0.00008598 [General]

<-- Section 1 - Input Data

First using: z_{cmb} = 1091.000 - Edge of visible universe (aka Last Scattering)[1].

- It is now 13.720645822 Gyr since the Big Bang (Observer located at "now" or z = 0.0).
- Age at Last Scattering (LS) was 0.000374666 Gyr or 374,666 yrs.
- Light travel time from Last Scattering to now was 13.720271156 Gyr.
- Comoving radial distance that goes into Hubble's law is 13,952.961 Mpc or 45.508473670 Gly.
- Comoving volume (within redshift 1091.000) is 11,376.520 Gpc^3 or 394,718.111 Gly^3.
- Angular size distance D_A (for redshift 1091.000) was 12.775516 Mpc or 41,668,160 ly.
- This gives a D_A scale of 0.061937 kpc/"
- Luminosity distance D_L (redshift 1091.000) is 15,234,342.914 Mpc or 49,687.781 Gly.
- LS-Photon (CMB_z) Proper Distance (at LS) was 0.041674426 Gly or 41,674,426 ly.
- LS-Photon (CMB_z) Proper Distance (at LS) minus Angular size distance was or 6,266 ly.
- Scale factor (for redshift 1091.00000) (1/(1+z)) = 0.000915751.

<-- Section 2 - Items 1-11

- CMB temperature now is 2.72528 °K.
- CMB temperature at Last Scattering was 2976.00576 °K.
- Hubble Time is 14.048738816 Gyr (Age vs. Hubble Time Ratio = 97.665%).
- Average CMB_z recession since the LS is 3.3138 ly/yr
- Current CMB_z recession usng input H_o is 3.2393 ly/yr
- Universe expansion accelerates at z=0.7092 (+/- 0.0001) at age 7.293427507 Gyr.
- ==> Hubble Parameter =101.87635 with CMB_z viewed as z = 637.89539.
- Maximum LS-Photon proper distance is 5.795930144 Gly at z = 1.622403 (+/- 0.0001).
- Points for integrals = 1,000 Note: "Displaced Viewer"=OFF

<-- Section 3 - Items 1-9

Now using: z_{input} = 3.00000000 [More on redshift]

- Age since Big Bang (at redshift 3.000) was 2.171463679 Gyr.
- Light travel time (from redshift 3.000) to now was 11.549182143 Gyr.
- Comoving radial distance that goes into Hubble's law is 6,481.275 Mpc or 21.139092261 Gly.
- Comoving volume (within redshift 3.000) is 1,140.389 Gpc^3 or 39,566.780 Gly^3.
- Angular size distance D_A (for redshift 3.000) was 1,620.266 Mpc or 5.284601604 Gly.
- This gives a D_A scale of 7.855272 kpc/"
- Luminosity distance D_L is 25924.259 Mpc or 84.554 Gly.
- LS-Photon Proper Distance (at/from redshift 3.000) was 1,620.319 Mpc or 5.284773065 Gly.
- Scale factor (for redshift 3.00000) (1/(1+z)) = 0.250000000.

<-- Section 4 - Items 1-9

- CMB temperature at redshift 3.000 age was 10.90112 °K.
- CMB redshift (at redshift 3.000) was 272.000000.
- At z - H_z Calcs = $\Omega Omega_{mz}$ = 18.3040000, Ω_{vacz} = 0.7140000, Ω_{Kz} = -0.0013757, Ω_{Rz} = 0.0220108
- Ω Fractions at z= $\Omega Omega_{mz}$ = 0.9614135, Ω_{vacz} = 0.0375027, Ω_{Kz} = -0.0000723, Ω_{Rz} = 0.0011561
- Hubble Parameter (Omega Calc)(at redshift 3.000) was 303.68766 k/s/Mpc.(E(z)=4.363328).
- Actual Time Expansion ratio (from redshift 3.000) is (11.549182143) / (5.284773065) = 2.185.
- Light from z=3.000000 first reached Observer at age 1.460567537 Gyr (age z = 4.220899832).
- Visible universe then was CMBz= 208.159347 at a proper radial distance of 4.051164537 Gly.

<-- Section 5 - Items 1-8

- CMB_z proper distance (from redshift 3.000) (Then) was 6.095171675 Gly.
- Expansion part of CMB_z proper distance (from redshift 3.000) (Then) was 6.072845039 Gly.
- % of LS-Proper Distance (CMB_z) used (by redshift 3.000) was 53.574% or 0.022326636 Gly.
- PDtoCMB_z (at redshift 3.000) was 3,489.107 Mpc or 11.379944741 Gly.
- Expansion part of the PDtoCMB_z (at redshift 3.000) was 11.360596950 Gly.
- % of LS-Proper Distance (CMB_z) remaining was 46.426% or 0.019347790 Gly.

<-- Section 6 - Items 1-8

- CMB_z Recession Speed (PDtoCMB_z from Observer's location) (Then) using H_z was 3.5344 ly/y.
- Actual CMB_z Recession Speed (from redshift point 3.000) (Then) was 1.8931 ly/y.
- Actual z Recession Speed for redshift point 3.000 from Observer was 1.6414 ly/y.**
  ** Recession speed crosses below 1.000 ly/y at maximum LS-Photon distance.
- Current CMB Recession Speed (from redshift point 3.000) (now) is 1.7346 ly/y.
- Current Observer Recession Speed to redshift point 3.000 (now) is 1.5047 ly/y.
- Average CMB_z recession for (PDtoCMB_z) since LS (at redshift 3.000) was 5.2327 ly/y.
- Average CMB_z recession (for/at redshift point 3.000) since LS was 2.7971 ly/y.

<-- Section 7 - Items 1-7

Documention PDFs | Tutorial: | FAQ | Age | Distances | Relativity | Glossary

Cite: Wright (2006, PASP, 118, 1711) - Calculator - Ned Wright home page

<<-- Dr. Edward "Ned" Wright (UCLA - retired)
<<-- Links to his tutorials, Calculator, and 2006

The best manner in which to read this document is to open two windows (or tabs) in your browser – both with the preloaded default input data – but click "Show z Table" on the second window. There are many references to the z Tables in this document.

Default Output – Section 1

Cosmology Model Input Parameters:
Observer located at Age = 13.720645822 Gyr using z=0.00 and CMB_z viewed as redshift = 1091.000
H_o = 69.600, ΩOmega$_m$ = 0.28600, Ω_{vac} = 0.71400000, Ω_K = -0.00008598, Ω_R = 0.00008598 [General]

Output Section 1 is simply the data entered into the Input Data Form and printed for reference. The first line is used to orient the Observer position/age and the CMB redshift (z). **The term "Gyr" designates billions of years.**

See: http://davidcook.com/Input_documentation.pdf for additional information regarding the **Input Data Form** and the setting of **Ωr** and **Ωk**.

Shown in yellow highlight is the Display Option (geometry) selected by the user for the output calculations ("**General**" or "**Flat**" or "**Open**" or "**Manual**")

Users have asked **why the model shows so many decimal places**, particularly for large values such as the age of the universe. The answer is that **the ability to check the accuracy of the numbers overrides the decimal brevity issue** as will be seen later in some areas such as points in integrals, cross-checking answers, and when moving the Observer location to the past or to the future.

Default Output – Section 2

First using: z_{cmb} = 1091.000 - Edge of visible universe (aka Last Scattering)[1].

- It is now 13.720645822 Gyr since the Big Bang (Observer located at "now" or z = 0.0).
- Age at Last Scattering (LS) was 0.000374666 Gyr or 374,666 yrs.
- Light travel time from Last Scattering to now was 13.720271156 Gyr.
- Comoving radial distance that goes into Hubble's law is 13,952.961 Mpc or 45.508473670 Gly.
- Comoving volume (within redshift 1091.000) is 11,376.520 Gpc^3 or 394,718.111 Gly^3.
- Angular size distance D_A (for redshift 1091.000) was 12.775516 Mpc or 41,668,160 ly.
- This gives a D_A scale of 0.061937 kpc/"
- Luminosity distance D_L (redshift 1091.000) is 15,234,342.914 Mpc or 49,687.781 Gly.
- LS-Photon (CMB_z) Proper Distance (at LS) was 0.041674426 Gly or 41,674,426 ly.
- LS-Photon (CMB_z) Proper Distance (at LS) minus Angular size distance was or 6,266 ly.
- Scale factor (for redshift 1091.00000) (1/(1+z)) = 0.000915751.

Section 2 and Section 3 ignore the **z** value from the Input Data Form and instead **focus on the entire visible universe** as can described by the entered data. The farthest detectable signal is from the **Cosmic Microwave Background** (**CMB**).

First, the **Age Now** of the universe (**13.720645822 Gyr**) since the Big bang is shown (calculated using z=0.000).

The "**Age at Last Scattering (LS)**" is calculated by using the input **CMB z** value of **1091** and other Omega values entered (or imputed). This age, **374,666 years**, represents the age when all the matter in the universe had sufficiently **separated and cooled due to the rapid expansion of space** thus allowing photons to stream in all directions across the universe. This calculated value is generally between 370,000 and 390,000 years if all of the entered input data falls within expected ranges.

The model does impute a certain initial radiation value in order to determine the LS age (among other uses). Failure to have this imputed value or if the user decides to use the **Manual Ωr** option, which allows the user to zero out the **Ωr** value, will result in an error of approximately +100,000 years in the LS age.

The "**Light travel time" (13.720271156 Gyr) + "Age at Last Scattering**" **(0.000374666 Gyr)** will equal the A**ge now (13.720645822 Gyr)**.

<u>Default Output – Section 2 (continued-1)</u>

The next few output items are best described by the original CosmoCalc author, **Dr. Ned Wright at UCLA (recently retired)**. His 2006 paper can be found at:

https://iopscience.iop.org/article/10.1086/510102/pdf

If you read Dr. Wright's often-cited paper and find yourself at a loss (as I did when I first read it), hopefully things will begin to clear up a little as this document attempts to translate the answers to a more understandable layman's form. **There are a number of links throughout the Default Output and at the bottom of the page to many of Dr. Wright's web pages and tutorials at UCLA (including his original calculator) as well as to some additional pages at Wikipedia.**

"**Comoving radial distance**" is the distance today from the Observer location (Earth) to the CMB. That is, if the universe could be instantly frozen in place today and if it could be possible to measure the distance to the CMB, the distance would be **45.508473670 billion light years**. The term **Mpc** is also used and designates a measurement of millions of parsecs. A **parsec is approximately 3.26156377697121 light years**. Cosmologists often use **Mpc** as opposed to the **Gyr** (billions of light years) term that might be more understandable to non-cosmologists. Both measurements are shown when possible.

"**Comoving volume**" is literally the volume area of the visible universe as of today. It is **394,718.111** <u>**cubic**</u> **Gyr**.

"**Angular size distance**" is a distance measurement for a given point that is slightly different than a straight-forward Flat geometry measurement (known as **Proper Distance**) and takes into account the implied curvature (if any) of the universe. The answer shown, **41,668,160 light years**, is <u>calculated as of the time of the LS</u> (age of 374,669 years) and would have been the apparent distance between the CMB viewed today and <u>Earth's future location</u> at the LS age.

Default Output – Section 2 (continued-2)

"**Luminosity distance DL**" is defined in terms of the relationship between the absolute magnitude and **apparent magnitude** of an astronomical object. The answer, which takes into account flux and other issues, is **49,687.781 billion light years (which is actually 49.7 trillion light years).** The calculation can be confirmed by multiplying the **Angular Size Distance** (**41,668,160 light years)) by $(1+z)^2$ (or** 41,668,160 * 1092 * 1092 = 49,687,780,746 light years). Many of these values are explained in much greater specificity on Dr. Wright's website at UCLA to which many links are provided throughout the Default Output.

The "**LS-Photon (CMB) Proper Distance**" is calculated based on Flat geometry and the difference between this calculation, **41,674,426 light years**, and the "Angular size distance" of **41,668,160 light years** is also shown as a demonstration of the impact of the **Ωk** value. If the **Flat option (no curvature) rather than the default General option** is chosen, these two values will match. This **difference** value (**6,266 light years**) was calculated in order to show the evolution of curvature over time versus a Flat universe and is fully-displayed in **Column 7 in Table 5 of the z Tables** output option.

Here is an example of how some of the values are related:

If you divide the **Comoving radial distance (45.508473670 Gly)** by the [**CMB z plus 1] or (1+z) which is 1092, the** answer would be **41,674,426 ly** and that equals the **LS-Photon (CMB) Proper Distance.**

More can found at:

https://en.wikipedia.org/wiki/Distance_measures_(cosmology)

Default Output – Section 3

- CMB temperature now is 2.72528 °K.
- CMB temperature at Last Scattering was 2976.00576 °K.
- Hubble Time is 14.048738816 Gyr (Age vs. Hubble Time Ratio = 97.665%).
- Average CMB_z recession since the LS is 3.3138 ly/yr
- Current CMB_z recession usng input H_o is 3.2393 ly/yr
- Universe expansion accelerates at z=0.7092 (+/- 0.0001) at age 7.293427507 Gyr.
- ==> Hubble Parameter =101.87635 with CMB_z viewed as z = 637.89539.
- Maximum LS-Photon proper distance is 5.795930144 Gly at z = 1.622403 (+/- 0.0001).
- Points for integrals = 1,000 Note: "Displaced Viewer"=OFF

Continuing on the **visible universe**, Section 3 starts by comparing the **current** Cosmic Microwave Background (CMB) temperature with the CMB temperature at the age of the Last Scattering (LS). **The current CMB temperature is 2.72528 °K compared to the calculated CMB temperature at the time of the LS of 2976.00576 °K**. This answer comes pretty close to the predicted 3000 °K at the Last Scattering.

Hubble Time is shown only for reference. It is an estimate of the age of the universe **based only upon the current Hubble Constant** (Input Data Form). The current "**Age now versus Hubble Time Ratio"** at **97.665%** is close to 100.000% today simply because of where we are in the expansion of the universe. That is, the **Average CMB recession rate** since the Last Scattering, **3.3138 ly/yr** just happens to be pretty close to the **Current CMB recession rate of 3.2393 ly/yr**. Later, when moving the Observer to the past or, particularly, to the future, wide divergences appear for this ratio as shown in **Column 7 in Table 7 of the z Tables** output option.

Highlighted in brown above is the **z value (z=0.7092) and age (7.293 Gyr) at which the expansion of the universe began to accelerate (See Column 5 of z Table 3 – Ωm =~0.666 and Column 6 of z Table 5 – Recess=1.000)**. Also shown is the then-**concurrent Hubble Parameter (101.87635 k/s/Mpc)** and the then-observed **CMB redshift z (z=637.89539)**.The **k/s/Mpc** term represents kilometers per second per million parsecs (megaparsec).

The "acceleration" **z** value can be calculated directly for relatively Flat geometry cases by taking the **third root of [(2* Ωvac) / Ωm] minus 1.000** but is not used in this model.

Default Output – Section 3 (continued-1)

Highlighted in yellow is the maximum recession distance (**5.795930144 Gly at z=1.622403 and an age of approximately 4.030 Gyr**) that the current CMB (1091) **photons** reached from Earth's future location before the speed of light exceeded the rate of space expansion between the photon and Earth's future location which then allowed the photon to eventually reach Earth today (**see columns 2 and 8 in Table 4 at z=1.622403 of the z Tables option**). Note that when the photon started toward Earth's future location, the original distance to Earth's future location was **41.674** **million** light years (at LS) before the expansion ballooned the photon's distance to **5.796** **billion** light years at **z** value 1.622403 (when the **age of the universe was 4.030 billion years**) which was **over 9.5 billion years ago**.

Calculation Integrals (for Model V1) currently have 1,000 steps as a default. Many crosscheck values tighten up at higher step counts but this also slows down the model. **Model V2 has 10,000 steps and seems to be a good balance between speed and accuracy.** Users are welcome to copy the source code and change the value.

For example, model V1 JavaScript has:

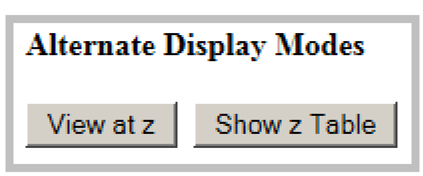
var n = 1000; // number of points in integrals

Model V2 JavaScript has:

var n = 10000; // number of points in integrals

Simply change this to a higher number (but it could take much longer to generate z tables – particularly above 10,000 steps). **If you have a problem after making a change, perhaps you will learn to dislike JavaScript as much as I do**.

Section 3 ends with "**Displaced Viewer**" status. Normal status is "**OFF**" but will change to "**ON**" when the "**View at z**" output button is clicked.



Default Output – Section 4

Now using: z_{input} = 3.00000000 [More on redshift]

- Age since Big Bang (at redshift 3.000) was 2.171463679 Gyr.
- Light travel time (from redshift 3.000) to now was 11.549182143 Gyr.
- Comoving radial distance that goes into Hubble's law is 6,481.275 Mpc or 21.139092261 Gly.
- Comoving volume (within redshift 3.000) is 1,140.389 Gpc^3 or 39,566.780 Gly^3.
- Angular size distance D_A (for redshift 3.000) was 1,620.266 Mpc or 5.284601604 Gly.
- This gives a D_A scale of 7.855272 kpc/"
- Luminosity distance D_L is 25924.259 Mpc or 84.554 Gly.
- LS-Photon Proper Distance (at/from redshift 3.000) was 1,620.319 Mpc or 5.284773065 Gly.
- Scale factor (for redshift 3.00000) (1/(1+z)) = 0.250000000.

Section 4 changes the focus from the visible universe as a whole to answers associated with the z value from the Input Data Form. The **default z value is z=3.000.**

A given z point denotes when the photons that we observe today as the CMB passed a certain point in space and, further, how much expansion of the space between that point and Earth's future location has occurred from that moment until now (when we see now **both** the CMB photon and any light that emanated concurrently from that z point, such as light from a galaxy). **This is a difficult concept but this is how the z scale works.**

The **Age at z=3.000** was **2.171463679 Gyr** after the Big Bang.

The rest of the answers shown are as in Section 2 except that all of the answers pertain to z=3.000 surface instead of the Last Scattering surface (CMB).

Again, as in the example given in Section 2, the Comoving radial distance for **z=3.000** (**21.139092261 Gly**) can be divided by **1+z** (1+3 = 4) to calculate the **Proper Distance** at that time from Earth's future location (**5.284773065 Gly**). Cosmologists tend to use the scale factor 1/(1+z) to accomplish the same answer.

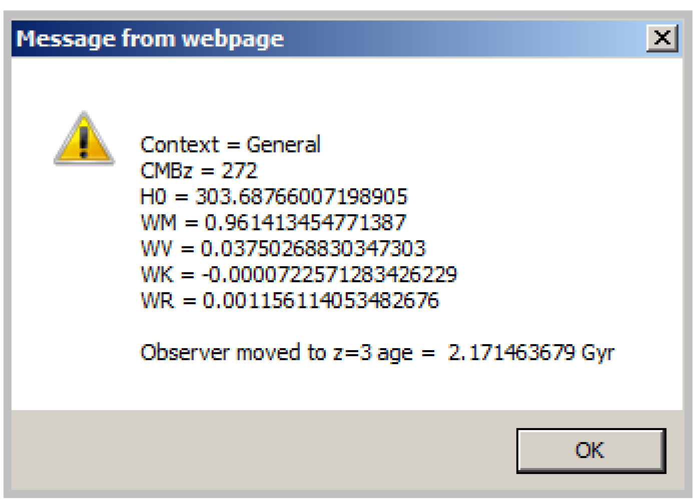
Default Output – Section 5

- CMB temperature at redshift 3.000 age was 10.90112 °K.
- CMB redshift (at redshift 3.000) was 272.000000.
- At z - H_z Calcs = ΩOmega$_{mz}$ = 18.3040000, Ω_{vacz} = 0.7140000, Ω_{Kz} = -0.0013757, Ω_{Rz} = 0.0220108
- Ω Fractions at z= ΩOmega$_{mz}$ = 0.9614135, Ω_{vacz} = 0.0375027, Ω_{Kz} = -0.0000723, Ω_{Rz} = 0.0011561
- Hubble Parameter (Omega Calc)(at redshift 3.000) was 303.68766 k/s/Mpc.(E(z)=4.363328).
- Actual Time Expansion ratio (from redshift 3.000) is (11.549182143) / (5.284773065) = 2.185.
- Light from z=3.000000 first reached Observer at age 1.458403380 Gyr (age z = 4.226085793).
- Visible universe then was CMBz= 207.951794 at a proper radial distance of 4.044981575 Gly.

As discussed in Section 3, the CMB temperature at the LS was **2976.00576 °K** and has come down to **2.72528 °K** today. By z=3.000 (**2.171463679 Gyr**), the CMB temperature had already fallen to **10.90112 °K.**

The **CMB redshift observed at that time** would have been **272.000** as opposed to the 1091.000 today.

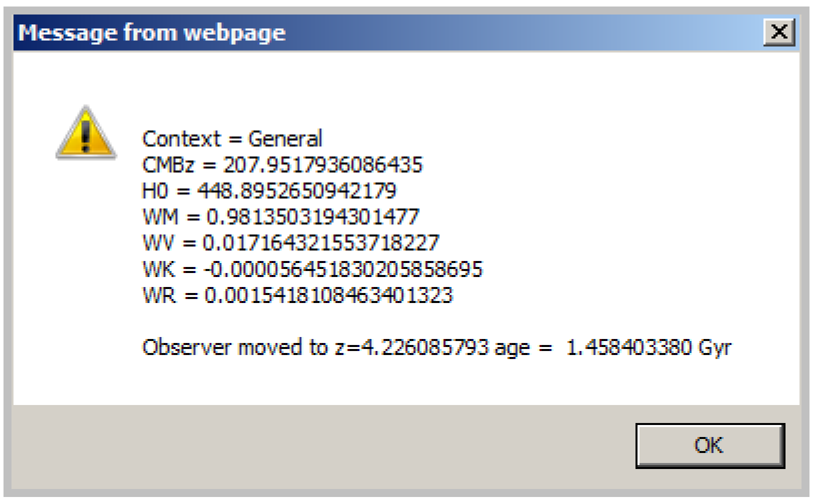
The next 3 lines of output provide the component calculations for the Hubble Parameter at z=3.000. These values allow the model to **repopulate** the Input Data Form – if the user chooses the **View at z** option:



Default Output – Section 5 (continued-1)

The "**Time Expansion ratio**" (**2.185**) is shown to contrast the difference between time expansion versus space expansion (denoted by (1+z) or **4.000** for z=3.000). See **Columns 4 and 5 in Table 6 of the z Tables option** for a more complete understanding.

The final 2 lines of Section 5 (highlighted in yellow) show the age when photons that originated from the z=3.000 surface **first reached Earth**'s future location. That age was **1.458403380 Gyr, a proper distance of 4.044981575 Gly, and an at-the-time CMBz=207.952**. **<u>This is the age and distance at which the z=3.000 surface/point would have been viewed from Earth's future location as the CMB surface at that time.</u>** This is an interesting item and can be fully-explored by using the given **z=4.226085793** and choosing the **View at z** option.



You will be shown the universe as it would have looked from Earth's future location when the **current z=3.000 surface** would viewed as the **CMB surface**. Again, in plain English, the "visible universe" at that time would have ended at the location of the now z=3.000. It would have appeared at that time to be CMBz=208.15934707 and not CMBz=1091 or z=3.000.

See **Column 8 in Table 6 as well as the <u>entire Table 8</u> (which is devoted entirely to these calculations) of the z Tables option** for a more complete understanding.

Default Output – Section 6

- **CMB_z proper distance (from redshift 3.000) (Then) was 6.095171675 Gly.**
- **Expansion part of CMB_z proper distance (from redshift 3.000) (Then) was 6.072845039 Gly.**
- **% of LS-Proper Distance (CMB_z) used (by redshift 3.000) was 53.574% or 0.022326636 Gly.**
- **PDtoCMB$_z$ (at redshift 3.000) was 3,489.107 Mpc or 11.379944741 Gly.**
- **Expansion part of the PDtoCMB$_z$ (at redshift 3.000) was 11.360596950 Gly.**
- **% of LS-Proper Distance (CMB_z) remaining was 46.426% or 0.019347790 Gly.**

Section 6 is important to the understanding of spatial positioning of luminous objects in space. Determining the proper place for z=3.000 relative to Earth and the CMB on a linear basis allows the user to understand how far the original CMB (1091) photon has travelled through the starting LS Proper Distance of 41,674,426 light years.

The percentage for z=3.000 of the distance (**53.574%**) between the CMBz and Earth's future location (as viewed from the CMBz) has remained constant since the Last Scattering but the distances between each location have greatly changed due to the expansion of space.

The first 3 lines show the Proper Distance (**6.095171675 Gly**) from z=3.000 to the CMB at the time the CMB photon we see today first reached z=3.000 (**2.171463679 Gyr**). Of this distance travelled, the portion attributable to the original 41,674,426 light years was (**0.022326636 Gyr**) or 22,326,636 light years.

This also shows the amount of expansion that occurred (**6.072845039 Gyr**) between the CMB and z=3.000 by that age.

The next 3 lines show the Proper Distance from Earth's future location to the CMB at z=3.000 age (**11.379944741 Gly**), the expansion portion of that distance at z=3.000 age (**11.360596950 Gly**), and the remaining distance of the original 41,674,426 light years yet to be crossed (**46.426% and 0.019347790 Gly** or 19,347,790 light years).

The accuracy of this calculation is limited by the Model V1 1,000 points per integral but is fairly close. **It tightens up to 53.562%/46.438% using Model V2's 10,000 points per integral and will very closely match today's visible universe Proper Distances rather than miss by a few million light years.**

<u>Default Output – Section 6 (continued-1)</u>

Note: there are other ways to find the spatial orientation of certain z values. For example, by dividing the Comoving radial distance at z=3.000 (**21.139092261 Gyr**) by today's z=1091 Comoving radial distance (**45.508473670 Gly**), you get 46.451% remaining rather 46.426% shown in this output. While this can be cleared up by more points in the integrals, it does not solve the problem of computing the Proper Distance between z=3.000 and the CMB at age=2.171480953 Gyr and then having that distance match the Comoving radial distance when the "View at z" option moves the Observer to that age and uses different integrals than the Observer today. The intervals are different and these are some of the minor crosscheck value issues mentioned earlier that crop up due to points in integrals and segmenting (for those of you care about such things).

<u>Special Note regarding terms:</u>

PDtoCMB is Observer distance to input CMBz

PDtoCMBz is Observer distance to CMBz at input z

Default Output – Section 7

- CMB$_z$ Recession Speed (PDtoCMB$_z$ from Observer's location) (Then) using H$_z$ was 3.5344 ly/y.
- Actual CMB$_z$ Recession Speed (from redshift point 3.000) (Then) was 1.8931 ly/y.
- Actual z Recession Speed for redshift point 3.000 from Observer was 1.6414 ly/y.**
  ** Recession speed crosses below 1.000 ly/y at maximum LS-Photon distance.
- Current CMB Recession Speed (from redshift point 3.000) (now) is 1.7346 ly/y.
- Current Observer Recession Speed to redshift point 3.000 (now) is 1.5047 ly/y.
- Average CMB$_z$ recession for (PDtoCMB$_z$) since LS (at redshift 3.000) was 5.2327 ly/y.
- Average CMB$_z$ recession (for/at redshift point 3.000) since LS was 2.7971 ly/y.

Section 7 also relates to spatial positioning but more so as it affects expansion and recession speeds than distances.

The yellow highlighted line shows the CMB recession speed (**3.5344 ly/y**) from Earths future location at z=3.000 age. Lines 2 and 3 break out the portion attributable to the space between the CMB and z=3.000 (**1.8931 ly/y**) and the portion attributable to the space between z=3.000 and Earth's future position (**1.6414 ly/y**).

Items 4 and 5 update those values to today (**1.7346 ly/y and 1.5047 ly/y**) which add to 3.2393 ly/y (see **item 5 of Section 3** above – Current CMB recession using input **H$_0$** is 3.2393 ly/y).

Item 6 shows Earth's future location Average CMB recession speed (**5.2327 ly/y**) for the time between the Last Scattering age of **374,666 years** (0.000374666 Gyr) and z=3.000 age (**2.171563679 Gyr**)

Item 7 shows Average CMB recession (**2.7971 ly/y**) that an observer at z=3.000 age would have measured. This can be confirmed by using the **View at z** option.

Back to Documentation Main Table of Contents:

http://davidcook.com/Main_documentation.pdf