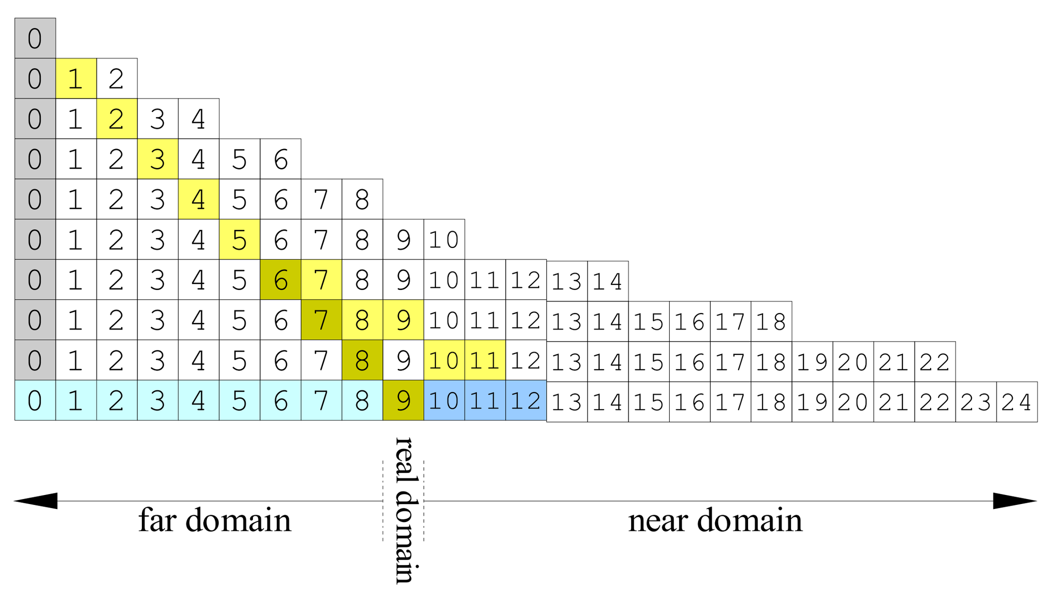
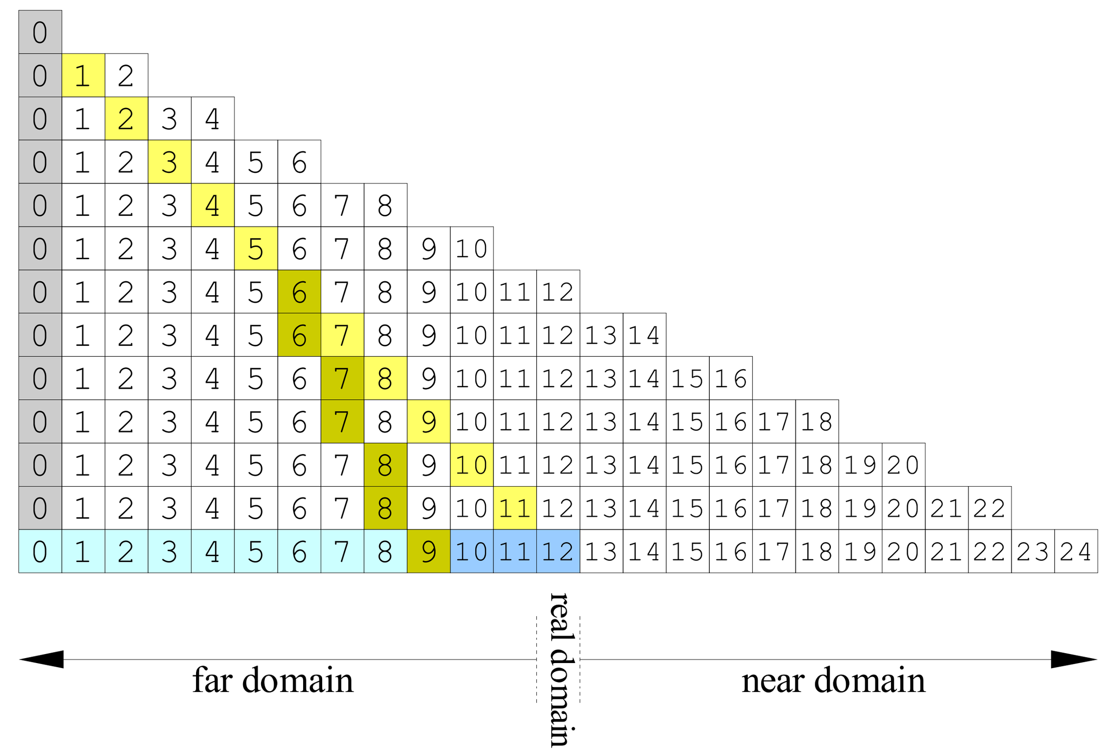
Fig 7, 8 & 9 • **Causal Behavior and Time Dilation** • Fig 1 is redrawn to emphasize the causal behavior of the model. The real domain (diagonal yellow) now appears to travel by one cell per step. This rate of causality is show to change (dark yellow), first (Fig 8, left) from the point of view of a moving observer and second (Fig 9, right) from the point of view of a stationary observer.





Special Relativity

Relative to a stationary observer, a second observer has the choice to move through either space **or** time; for every temporal step, the second observer travels either one cell spatially, or one cell causally. For the stationary observer, the causal distance $\boldsymbol{t}_C$ is the same as the temporal distance $\boldsymbol{t}_T$. A spatial distance $\boldsymbol{t}_S$, traveled at an equivalent velocity of $\boldsymbol{v}=\boldsymbol{t}_S/\boldsymbol{t}_T$ by the second observer, shortens the causal distance and thus results in a causal *time dilation*. The size of the dilation is calculated using simple Pythagorus, and if the causal distance is related to the temporal distance with a scale factor $1<\Gamma<\infty$, then the result is identical to Einstein's Special Theory of Relativity. The subtle difference here is that the dilation is a shortening of causality; the temporal distance traveled by both observers is equal – they both remain in the same present.

$$\boldsymbol{t}_C^2 = \boldsymbol{t}_T^2 - \boldsymbol{t}_S^2$$

$$\boldsymbol{t}_C = \frac{\boldsymbol{t}_T}{\Gamma}$$

$$\Gamma^2 = \frac{1}{1-\boldsymbol{v}^2}$$

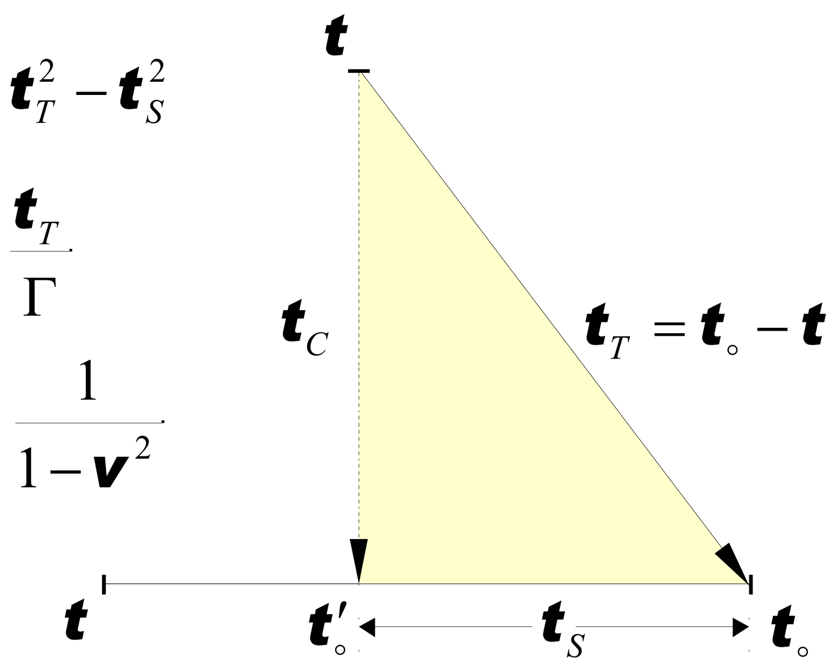


Fig 10 • **Special Relativity** • Effect on causal distance after spatial displacement: Starting at time $\boldsymbol{t}$, a stationary observer arrives at time $\boldsymbol{t}_\circ$. An observer, spatially displaced by $\boldsymbol{t}_S$, arrives at time $\boldsymbol{t}'_\circ$.

Planck Natural Units

In 1899, Max Planck proposed a system of Natural Units, where the units of time $t_\bullet$ and distance $x_\bullet$ can be defined in the following way:

$$t_\bullet = \sqrt{\frac{Gh}{c^5}}$$

$$t_\bullet = 4.28234(33)\times10^{-60}\,Gyr$$

$$x_\bullet = ct_\bullet$$

$$c = 306.595\ psc/kyr$$

*Note: As in Planck's original proposal, we use the Planck constant h, instead of the Dirac constant ħ. We use standard cosmological units for time (Billions of Years) and distance (Megaparsecs = parsecs per kiloyear * gigayear)*

These two units are treated as the absolute minimum possible divisions of both space and time. Dividing a distance in space or duration of time by their respective units, results in a dimensionless *natural number,* represented in **bold** type below:

$$\boldsymbol{x} = \frac{\Delta x}{x_\bullet} \qquad \boldsymbol{t} = \frac{\Delta t}{t_\bullet}$$

When defining distances from an observer, we will use a causal radius, using twice the distance unit $x_\bullet$:

$$\boldsymbol{r} = \frac{r}{r_\bullet} \qquad r_\bullet = 2x_\bullet$$

Another type of Planck Natural unit represents the absolute maximum; an example of which are the units of velocity and acceleration. Dividing a velocity or acceleration by their respective units results in a dimensionless *unit fraction*, also represented similarly in **bold** type below:

$$\boldsymbol{v} = \frac{v}{v_\bullet} \qquad v_\bullet = c$$

$$\boldsymbol{a} = \frac{a}{a_\bullet} \qquad a_\bullet = \frac{v_\bullet}{t_\bullet}$$

Cosmological Models

We will consider the Friedmann cosmological model – homogeneous, isotropic universe, filled with a single perfect fluid as defined by an equation of state as follows:

$$p = w\rho c^2$$

The parameter w is a constant and will be used in determining the cosmological time t relative to redshift z, and the radius of the Hubble sphere r_c.

$$t = t_\circ(1+z)^{-\frac{3}{2}(1+w)}$$

$$r_c = \tfrac{3}{2}(1+w)ct$$

We will also state the equations for the deceleration parameter $q_\circ$ and radius of the particle horizon r_H.

$$q_\circ = \tfrac{1}{2}(1+3w)$$

$$r_H \approx r_c/q_\circ$$

The universe is matter-dominated when w=0, and has the cosmological time to redshift relation:

$$t = t_\circ(1+z)^{-3/2}$$

However, due to an assumption in the Friedmann model, the above relation represents a composite time function, which we will refer to as ***normal time***. The typical assumption of a constant, unchanging time function, is referred to as ***unity time***. We will demonstrate this function by simply integrating *unity* over an interval of ***natural time*** $\boldsymbol{t}$.

$$\breve{t} = t_\bullet\int_0^{\boldsymbol{t}} d\boldsymbol{t} = t_\bullet\boldsymbol{t}$$

The flat U above the t indicates unity time. Here the Planck natural unit of time is treated as a constant at all natural times. Note the unity-time age of the universe is simply:

$$\breve{t}_\circ = t_\bullet\boldsymbol{t}_\circ$$

Causal Variable Planck Scale

We will introduce the following causal variation in the Planck natural unit of time, relative to the natural time $\boldsymbol{t}$.

$$t_{\bullet(\boldsymbol{t})} = t_\bullet\left(\frac{\boldsymbol{t}_\circ}{\boldsymbol{t}}\right)^{1/4}$$

Separating the causal constant $t_{\bullet\bullet}$, we integrate from the origin 0 to the natural time and calculate the normal time t.

$$t_{\bullet\bullet} = t_\bullet\boldsymbol{t}_\circ^{1/4}$$

$$t = t_{\bullet\bullet}\int_0^{\boldsymbol{t}}\boldsymbol{t}^{-1/4}d\boldsymbol{t}$$

$$t = \tfrac{4}{3}t_{\bullet\bullet}\boldsymbol{t}^{3/4}$$

Deriving the normal age $t_\circ$, we substitute the causal-variable normal time into the solution for w=0. Solving for unity time now gives us the Friedmann model cosmological time to redshift where w=⅓.

$$t_\circ = \tfrac{4}{3}t_\bullet\boldsymbol{t}_\circ$$

$$\breve{t} = \breve{t}_\circ(1+z)^{-2}$$

We also introduce the following causal variation in the Planck natural unit of length, which is also relative to the natural time $\boldsymbol{t}$.

$$r_{\bullet(\boldsymbol{t})} = r_\bullet\left(\frac{\boldsymbol{t}}{\boldsymbol{t}_\circ}\right)^{1/2}$$

Following the same procedure as before, we arrive at the normal radius r for a cosmological horizon.

$$r_{\bullet\bullet} = r_\bullet\boldsymbol{t}_\circ^{-1/2}$$

$$r = r_{\bullet\bullet}\int_0^{\boldsymbol{t}}\boldsymbol{t}^{1/2}d\boldsymbol{t}$$

$$r = \tfrac{2}{3}r_{\bullet\bullet}\boldsymbol{t}^{3/2}$$

Expansion of Space

We will consider the propagation of an electromagnetic wave against a varying Planck scale. The change in the natural scale factor is related to the emitted and received wavelengths as follows:

$$\lambda_{em} = r_{\bullet\bullet}\boldsymbol{t}^{1/2}\boldsymbol{R}_{then}$$

$$\lambda_{rec} = r_\bullet\boldsymbol{R}_{now}$$

Determining the redshift relation of above leads to the realization that there is no causal change in the natural scale factor.

$$z = (\lambda_{rec} - \lambda_{em})/\lambda_{em}$$

$$1+z = \left(\frac{\boldsymbol{t}_\circ}{\boldsymbol{t}}\right)^{1/2}\frac{\boldsymbol{R}_{now}}{\boldsymbol{R}_{then}}$$

$$\boldsymbol{R}_{then} = \boldsymbol{R}_{now}$$

Recession of Horizons

The cosmological horizon is equivalent to the Hubble sphere measured using unity space. The unity radius for the following two Friedmann solutions are:

$$w = \tfrac{1}{3} \qquad \breve{r}_\circ = 2c\breve{t}_\circ$$

$$w = 0 \qquad \breve{r}_\circ = \tfrac{3}{2}ct_\circ$$

Using the normal time solution for w=0, we convert to normal space and determine the normal cosmological horizon as follows:

$$r_\circ = \tfrac{2}{3}r_\bullet\boldsymbol{t}_\circ = \tfrac{2}{3}\breve{r}_\circ$$

$$r_\circ = ct_\circ$$

This final normal radius relates to the Friedmann solution for w=−⅓. This gives a constant recession velocity of c, and an infinite particle horizon r_H:

$$q_\circ = 0$$

$$r_H = \infty$$

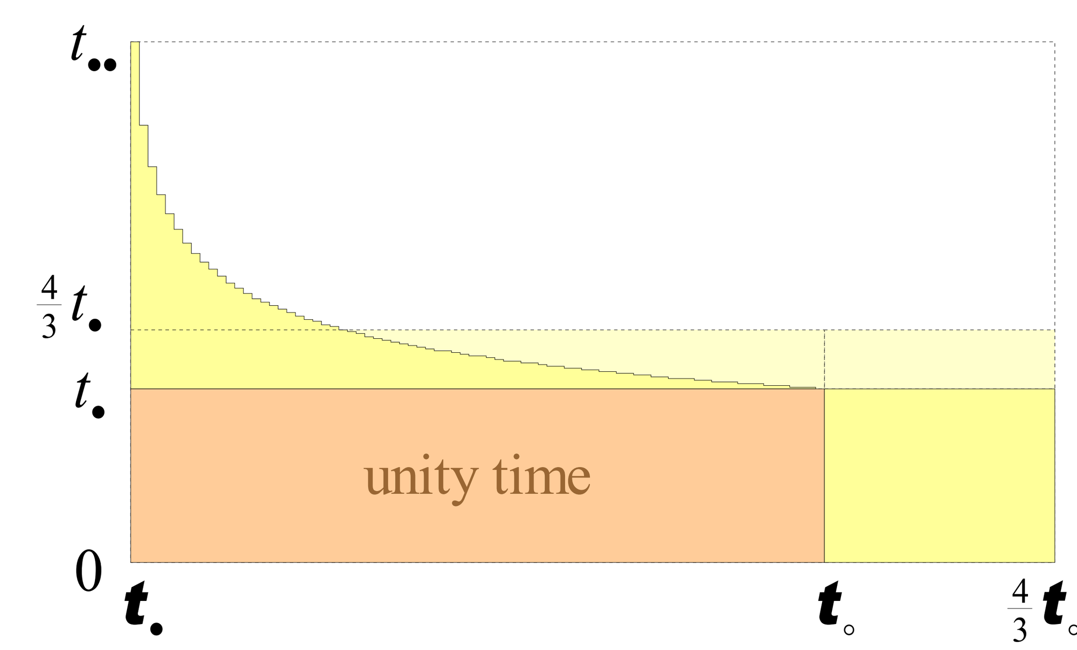


Fig 11 • **Variable Planck Time** • Example of the relative change in the value of the Planck Time against the natural time (the minimum natural time $\boldsymbol{t}_\bullet$=1). Keeping the computational throughput constant results in the unity time; the normal time is a third more.

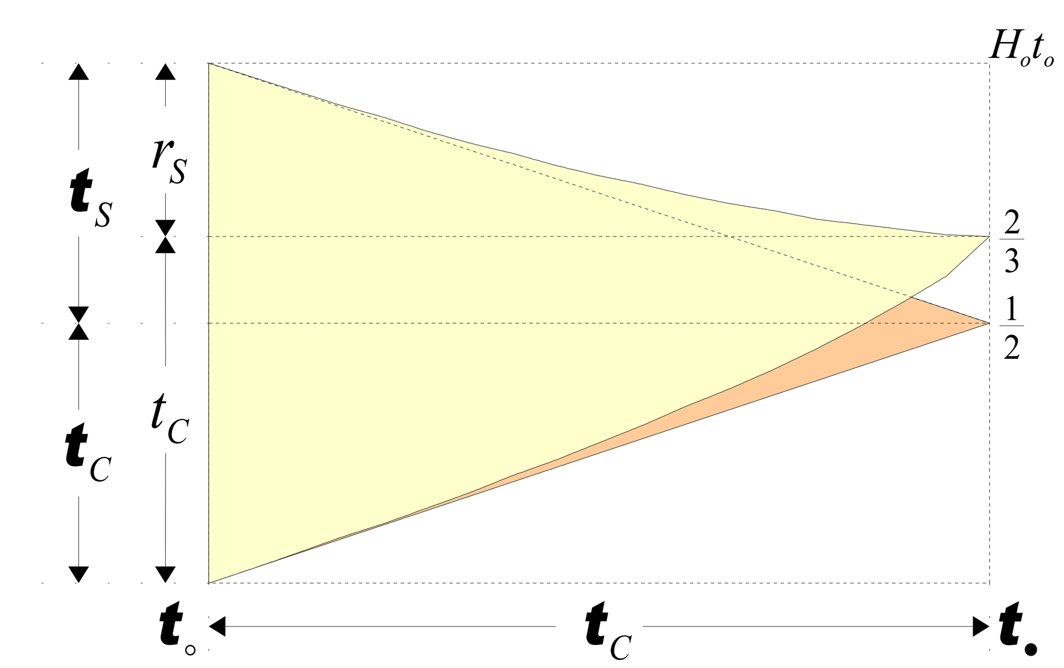


Fig 12 • **Expanding Space-Time** • The (orange) unity-time assumption implies that a distance in time is equivalent to a distance in space. The (yellow) normal-time geometry is skewed relative to an observation from the present age of the universe.

Temperature and Entropy

The natural entropy of a black hole is equal to the natural area of it's event horizon. We define the Planck Natural Unit of area as the surface area of a sphere of the Planck radius, and find the Planck entropy $S_\bullet$:

$$\boldsymbol{S}_{BH} = \boldsymbol{A}_{BH}$$

$$A_\bullet = 4\pi r_\bullet^2$$

$$S_\bullet = 8\pi^2k_B$$

Planck's original proposal used the Boltzmann constant k_B as the Planck Natural Unit of entropy. However, the correct unit above gives us a Planck Natural Unit of temperature $T_\bullet$ as follows:

$$e_\bullet = \sqrt{\frac{hc^5}{G}} = S_\bullet T_\bullet$$

$$T_\bullet = 4.49787(35)\times10^{30}K$$

Age of the Universe

The cosmological background temperature relates to redshift and thus natural time as follows:

$$T = T_\circ(1+z) \qquad \frac{T}{T_\circ} = \left(\frac{\boldsymbol{t}_\circ}{\boldsymbol{t}}\right)^{1/2}$$

Assuming the universe was the Planck temperature at the Planck time, then the following is true:

$$\boldsymbol{t}_\circ = \boldsymbol{T}_\circ^{-2}$$

Converting the temperature of the CMB (2.725K ±2mK) into Planck units, allows us to calculate the age of the universe in natural, unity & normal time:

$$\boldsymbol{T}_\circ = 6.0584(49)\times10^{-31}$$

$$\boldsymbol{t}_\circ = 2.7245(44)\times10^{60}$$

$$\breve{t}_\circ = 11.667(18)Gyr$$

$$t_\circ = 15.556(24)Gyr$$

Anderson Acceleration

The natural expansion of space can be observed by the apparent change in the uniform radial motion (acceleration) of a body using Doppler ranging:

$$\boldsymbol{a} = \frac{d}{d\boldsymbol{t}}\sqrt{\frac{\boldsymbol{t}_\circ - \boldsymbol{t}}{\boldsymbol{t}_\circ}}$$

$$\boldsymbol{a} = -\frac{1}{2\sqrt{\boldsymbol{t}_\circ(\boldsymbol{t}_\circ - \boldsymbol{t})}}$$

For $\boldsymbol{t}\ll\boldsymbol{t}_\circ$, the body should exhibit an approximate apparent acceleration (towards the observer) of:

$$\boldsymbol{a} \approx -1/2\boldsymbol{t}_\circ$$

Measurement to and from the body doubles the acceleration above and the final result is equivalent to the causal constant Planck Acceleration $a_{\bullet\bullet}$:

$$a_{\bullet\bullet} = a_\bullet\boldsymbol{t}_\circ^{-1} = 8.143(13)\times10^{-8}\ cm/s^2$$

Temporal Evolution

From a causal point of view (when $t_\circ$ is held static), the natural scale factor remains constant. However, from a temporal point of view (when $t_\circ$ increases), the natural scale factor does change. The overall scale factor (across far domain), increase at a rate of one cell (unit of space) per step (unit of time). The scale factor is typically related to redshift using the following relation:

$$\boldsymbol{R} = \boldsymbol{R}_\circ(1+z)^{-1}$$

Since we forced the natural scale factor to relate to redshift, the relation is not entirely valid. However, it does represent one of the important underlying assumptions built into the Friedmann solution: The absolute concept of unity space. We can finally state the temporal evolution of the system, which is equivalent to the Friedmann solution for w=−⅓:

$$\boldsymbol{R}_\circ = \boldsymbol{t}_\circ$$

$$\boldsymbol{t} = \boldsymbol{t}_\circ(1+z)^{-1}$$

Observational Confirmation

The first year WMAP results determined the age of the universe to be 13.7(2) billion years. This lies almost exactly between the unity and normal ages predicted by the theory. From a thermodynamic point of view, the universe will appear to have the normal age. However, in terms of geometry, the unity age gives an equally valid age for the universe. Unless these considerations are taken into account, then the observed age will most likely fall somewhere between the normal and unity ages.

Since the beginning of 1980, a team led by John Anderson at the Jet Propulsion Laboratory, observed an apparent weak, long range deceleration in four different space probes. A detailed analysis of ranging data from Pioneer 10 and 11 measured an anomalous acceleration of $(8.74\pm1.33)\times10^{-8}$ cm/s^2, directed towards the sun. This equates to a change of less than one mile per hour per 17½ years. This tiny, but significant observation is in direct concordance with the prediction of the theory.