Chapter 13

Cosmology I – The Spacetime Transformation Model

The Big Bang theory is one of only a few theories in science that enjoys virtually universal acceptance. Before about 1929 the "Steady State theory" was favored but since then there have been numerous experimental observations that support the Big Bang theory and disprove the Steady State theory. I am going to propose an alternative to the standard Big Bang model. This might be considered by some as the equivalent of scientific heresy. However, we will faithfully follow our starting assumption (the universe is only spacetime) to its logical conclusion.

As an introduction to the cosmological implications of our starting assumption, we will use a line out of the children's story of Alice in Wonderland. In this story Alice asks the question: "Is the room getting bigger or am I getting smaller?" Scientists do not ask the equivalent question about the universe. They always assume that the universe is getting bigger while their meter sticks and clocks stay the same. However, this assumption leads to numerous mysteries. How is it possible that distant galaxies are receding at faster than the speed of light? Is new spacetime continuously being created? Is mysterious dark energy required to explain the accelerating expansion of the universe? All of cosmology looks different when we assume that the universe is only spacetime and the properties of spacetime are changing.

Before Copernicus, it was assumed that the earth was the center of the universe. Now we know that we do not live in a special place in the universe, but we at least assume that both our size and our rate of time are constant. I am proposing that the final indignity to mankind is that spacetime is going through a transformation that contracts all physical objects, including the earth and our bodies. Furthermore, the rate of time is also slowing down. It is proposed that the spacetime field is undergoing a transformation which is responsible for what we perceive to be the expansion of the volume of the universe.

Suppose that we imagine going backwards in time from today. The distance between galaxies would decrease and the cosmic microwave background (CMB) photons would increase their energy. Today only a small percentage of the observable energy in the universe is in the form of electromagnetic (EM) radiation. However, going backwards in time we would reach a time when the dominant form of observable energy in the universe was EM radiation. What has happened to this energy that once dominated the universe? Individual photons are not disappearing. Even as photons lose energy they retain all their angular momentum. Electrons and protons appear to be immune from this energy loss, but we have to question whether our standard of energy remains constant over time.

When we assume that the universe is only spacetime both today and throughout its history, we get an entirely different perspective on cosmology. There still is something that can be designated the "Big Bang" but there is no singularity with infinite energy density. In fact, the energy density of the universe never exceeds Planck energy density $\sim 10^{113}$ J/m^3. All of this will be explained, but we will start by reviewing the current cosmological principles.

The Cosmic Microwave Background (CMB): The precise measurement of the CMB has had a profound impact on cosmology. The Planck Spacecraft has mapped the full sky distribution of the CMB to a resolution better than 0.1°. The age of the universe has been determined to be 13.8 billion years $\pm$ 0.4%. Also the universe has been determined to not have any large scale curvature. It is "flat" to a measurement accuracy of about 0.1%.[1],[2] The CMB was also mapped by the Wilkinson Microwave Anisotropy Probe (WMAP) which had lower resolution, but some of the data is more accessible and still quite accurate. Therefore, numbers quoted here will be a mixture of these two sources.

Analysis of the data from WMAP has also determined that about 380,000 years after the Big Bang, the energy in the universe was 10% neutrinos, 15% photons, 12% ordinary matter (baryonic matter), and 63% dark matter. For comparison the percentages quoted for today are: 4.9 % ordinary matter, 26.8% dark matter and 68.3% dark energy.

The 15% energy that was photon energy at 380,000 years has today been redshifted by a factor of about 1080. This has reduced the current energy content of these CMB photons to an almost insignificant percentage ($\sim$ 0.014%) of the total energy in the universe. Similarly, neutrinos and other relativistic particles have also lost momentum (kinetic energy) due to the redshift. Therefore, over 20% of the total observable energy present in the universe at an age of 380,000 has disappeared. If we extrapolate back further, the universe was radiation dominated and almost all the observable energy present in the early universe has disappeared (observable energy excludes vacuum energy). The question about what has happened to this observable energy will be discussed later

It can be shown that the energy that was present in ordinary matter and dark matter at 380,000 years is still approximately present in the universe today. The percentages look different because of the addition of dark energy and the subtraction of the energy in photons and neutrinos. Dark energy has never been observed, but it is required by the currently accepted cosmological model. The need for dark energy will also be discussed later.

The measurement of the CMB has also shown that the universe does have a preferred frame of reference. From any given location, the cosmic microwave background only appears isotropic

[1] http://lambda.gsfc.nasa.gov/product/map/dr4/pub_papers/sevenyear/cosmology/wmap_7yr_cosmology.pdf
[2] Astrophysical Journal Supplement 180: 225-245 February 2009

from a particular frame of reference called the "CMB rest frame". For example, the sun appears to be moving at about 369 km/s in the direction of the Virgo constellation relative to the CMB as seen from the sun's location. This relative motion produces a Doppler shift in the CMB that shows up as a redshift in the CMB in one direction and a blue shift in the CMB in the opposite direction (dipole anisotropy). This anisotropy is subtracted from CMB pictures to produce the speckled but uniform CMB pictures commonly exhibited showing only small temperature variations. Each location in the universe has a unique frame of reference that is stationary relative to the CMB.

Hubble Parameter: The expansion rate of the universe will be referred to as the "Hubble parameter $\mathcal{H}$". It is not a true constant since it changes over time. The expansion of the universe quoted by astrophysicists usually is given in units of kilometers/second/mega-parsec (km/s/Mpc). This might be convenient units for astrophysicists, but since we are standardizing on SI units, we will convert this into units of m/s/m. The conversion is: km/s/Mpc $\approx 3.24\times10^{-20}$ m/s/m. The Hubble parameter measured by the Planck spacecraft has been combined with other measurements to yield composite measurements ranging from about 67 to 68 km/s/Mpc. This book will use $\mathcal{H} = 67.8$ km/s/Mpc $= 2.2\times10^{-18}$ m/s/m. To put this in perspective, two points at rest relative to the local CMB rest frame and separated by 4.5×10^{17} m ($\sim$ 49 light years) would be moving away from each other at 1 m/s. The Milky Way galaxy and even galaxy clusters are gravitationally bound and do not expand with the expansion of spacetime. Galaxies separated by more than about 300 million light years exhibit this expansion.

The Hubble parameter has units of inverse seconds. If the universe expanded linearly from the Big Bang to today, then $1/\mathcal{H}$ would equal the age of the universe in seconds. Using the measured value, $1/\mathcal{H} = 4.5\times10^{17}$ seconds = 14.4 billion years compared to the 13.8 billion years age of the universe measured other ways by the Planck spacecraft.

Comoving Coordinates: The perspective of a unique CMB rest frame at each location has led to the concept that the universe can be modeled as having a "comoving coordinate system". This is a coordinate grid that expands with the Hubble expansion of the universe. Each point on this grid is in the CBM rest frame for that location. This is also called the "comoving frame". A comoving observer is the only observer that will see the universe (including the CMB) as isotropic. Galaxies are nearly in the comoving frame, so any velocity they have relative to the comoving frame is their "peculiar velocity".

At any given instant, all points in the CMB rest frame are experiencing the same rate of time if local gravitational disturbances are ignored. Another way of saying this is that on the scale where the universe is homogeneous (about 300 million light years), all points in the comoving frame are experiencing the comoving coordinate's cosmological time.

Comoving distance χ is the proper distance between two points (both in the comoving frame) at the present instant of comoving time. While comoving distance corresponds to proper distance at the present instant, comoving distance is imagined to remain at a fixed value of χ over time. In the past or future the proper distance between these two points changes with the Hubble flow but the comoving distance is a fixed designation on an expanding coordinate system. The cosmic "scale factor (a)" is a function of time and usually designated as: $a(t)$. This scale factor quantifies the relative expansion of the universe between two moments in time. The term l_t is proper distance between the two points at a different time (different ages of the universe). The relationship between these terms is:

$$\chi = l_\tau \, a(t)$$

The current scale of the comoving coordinate system is designated "a_o" and usually set to equal one $(a_o = 1)$.

The Λ-CDM Cosmological Model: Λ-CDM is an abbreviation for Lambda-Cold Dark Matter. This is currently considered to be the standard Big Bang model. In 1929 when Edwin Hubble discovered the redshift of galaxies (he called them nebula), the initial interpretation was that these were Doppler shifts due to relative motion of galaxies expanding into a preexisting void. Hubble proposed that there was a linear relationship between velocity and distance. The current interpretation is that the redshift is due to a cosmological expansion of the universe where space itself is being continuously created everywhere. One difference between Hubble's concept (a preexisting void) and cosmological expansion is that cosmological expansion is currently believed to be able to produce separation velocities that exceed the speed of light. Observations strongly support the general relativistic interpretation of a cosmological expansion over the special relativity interpretation of mass expanding into a preexisting void.

A detailed description of the Λ-CDM model will not be given here. However, there are several physical interpretations and predictions of this model that will be described to establish the current perspective of cosmologists. The favored Λ-CDM model is usually designated as: $\Omega_M = 0.31$ and $\Omega_\Lambda = 0.69$ with the Hubble parameter
$\mathcal{H} \approx 67.8$ km/s/Mpc $= 2.2\times10^{-18}$ m/s/m (in MKS units)

The matter density parameter $\Omega_M = 0.31$ represents that all forms of matter makes up approximately 31% of the critical density of the universe and the cosmological constant density parameter $\Omega_\Lambda = 0.69$ indicates that dark energy makes up about 69% of the critical density of the universe. Dark energy is the hypothetical energy that expands the universe and is associated with Einstein's cosmological constant Λ.

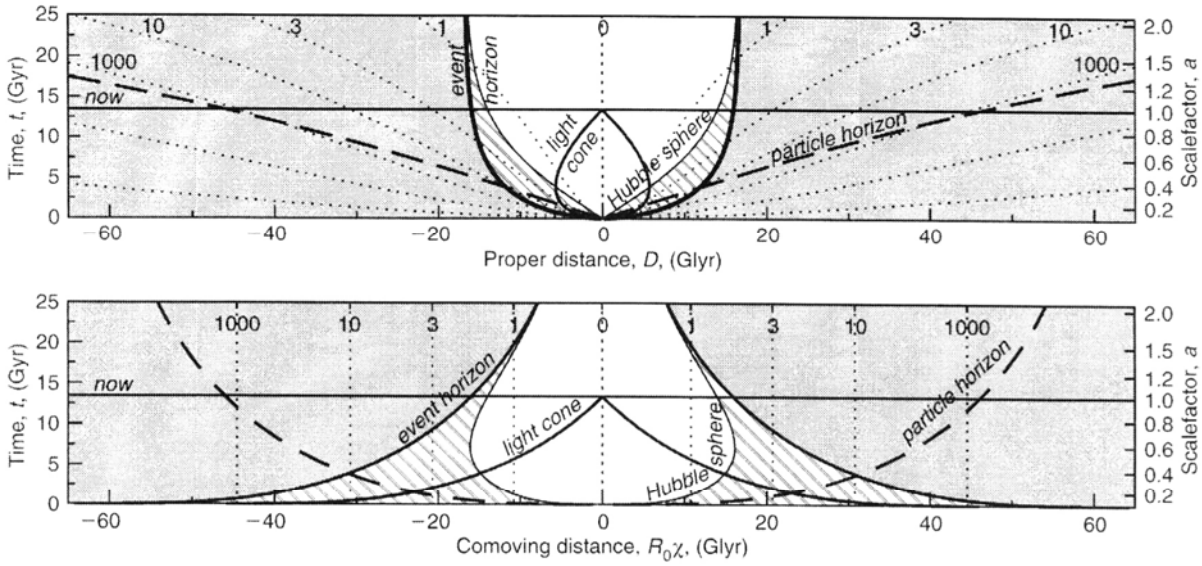

FIGURE 13-1 Spacetime diagrams showing some of the features of the Λ - CDM model of the expanding universe.

(From Davis and Lineweaver, Astronomical Society of Australia, 2004, 21, 97-109)

Figure 13-1 is taken from a very good article titled "Expanding Confusion: Common Misconceptions of Cosmological Horizons and Superluminal Expansion of the Universe"[3] Figure 13-1 is two spacetime diagrams that plot time versus proper distance D on the top panel and time versus comoving distance on the bottom panel. The panels are drawn from the perspective of an observer located at the intersection of the "now' line (13.8 billion years after the Big Bang) and the distance = 0 line. The lower panel has vertical world lines for objects currently with various redshifts ($z = 0$, 1, 3 etc.) because the comoving distance χ does not change over time. The proper distance changes over time but the comoving distance is a coordinate distance that expands with the comoving coordinate system. The two panels offer different perspectives and the following description applies to both panels.

The dashed line labeled "particle horizon" crosses the 13.8 billion year "now" line at about 46 billion light years. It is to be understood that even though a signal from the most distant source currently reaching us, called the particle horizon, has been traveling at the speed of light for 13.8 billion years, the current distance to that source is larger than 13.8 billion light years. This is because the cosmic expansion of the universe has continued to increase the volume of the universe and the distance between points after the speed of light signal has passed any location.

Next we will look at the line labeled "Hubble sphere". Currently the boundary of the Hubble sphere is 13.8 billion light years from us. This is the distance where space itself is supposedly

[3] T. M. Davis; C. H. Lineweaver; *Publications of the Astronomical Society of Australia* 2004, **21**, 97-109.

receding from us at a velocity equal to the speed of light (concept examined later). According to the Λ-CDM model, the space beyond the Hubble sphere is receding from us faster than the speed of light. This gives rise to an "event horizon".

The line labeled "event horizon" represents the furthest distance that we can receive current information. For example, according to the Λ-CDM model, galaxies that we currently observe as having a redshift of $z = 1.8$ are currently crossing our event horizon. This means that light being emitted by these galaxies today will never reach us because of the accelerating expansion of the universe. All galaxies with redshifts greater than 1.8 have already crossed our event horizon and will disappear from view sometime within the next 14 billion years (larger redshifts disappear sooner).

According to the Λ-CDM model eventually the Hubble sphere and the event horizon will be approximately the same distance. In the distant future the universe will have an event horizon at a constant proper distance of about 17 billion light years. Galaxies will continue to disappear from view as they are carried by cosmological expansion beyond this distance. Eventually only the gravitationally bound galaxies will remain visible. If the concept of accelerating expansion of the universe is carried to its logical conclusion, we would end with the "Big Rip" where expanding spacetime eventually tears apart our galaxy, then our solar system and eventually even atoms.

Problems with the Big Bang Singularity and Inflation: The most widely accepted model for the start of the universe is a "singularity" with no volume and infinite energy density. That starting condition requires that the laws of physics "break down". It also creates a problem for explaining how today the energy density of the universe is homogeneous on the large scale larger. Starting with a singularity results in inhomogeneous distribution, even on the large scale. Therefore, physicists postulate a period of "inflation" when the universe expanded much faster than the speed of light. This hypothesis would result in the portion of the universe that we can observe being homogeneous.

However, it is generally agreed that the universe extends far beyond our current particle horizon. Some cosmologists even suggest that the "extended universe" is infinite. We do not need to decide that question in order to do the following thought experiment. Suppose that we could obtain a map of the universe extending far beyond our particle horizon. Would the map reveal that the universe is inhomogeneous on the extended scale? Inflation supposedly did not really eliminate the inhomogeneties caused by starting from a singularity. It merely expanded the volume so much that any single observer does not see obvious large scale inhomogeneties. The implication is that today there are parts of the extended universe that have substantially different density than the density of our observable portion of the universe.

It has been established by WMAP space probe that the portion of the universe that we can observe has flat spacetime to within the 0.4% margin of error. Do we live in a special part of the universe that happens to have achieved this special condition? Surely if there are unobservable parts of the extended universe that have substantially different density, then they would not have flat spacetime. An important cosmological principle is that we do not live in a special part of the universe. This should apply even to the extended universe beyond our particle horizon. The implication is that 13.8 billion years after the Big Bang, all parts of the extended universe should have the same density. Inflation does not explain how the extended universe can be homogeneous.

Spacetime Transformation Model: We are about to start the description of an alternative cosmological model that will be referred to as the "spacetime transformation model". This model will be more fully explained in the next chapter, but key parts of the model will be presented in this chapter. Initially, these key parts will be explained using the familiar concepts and terminology of the current Big Bang model. When explaining the spacetime transformation model, the initiation of the transformation (the beginning of time) will be referred to as the "Big Bang". This is a highly descriptive term that is being adapted to express the start of a transformation of one form of spacetime to another. This was accompanied by a tremendous increase in proper volume, so the term "Big Bang" is still applicable.

If the universe is only spacetime, how does the spacetime field create new volume? Today, a lot of attention is being paid to the apparent acceleration of the expansion of the universe. While this is an important question, it is not possible to answer this question until we first understand how <u>**any**</u> new proper volume is created in the universe. If the expansion of the universe is imagined as mass/energy expanding into a preexisting void, then momentum would continue this expansion and there would be no mystery. However, the Λ-CDM model of cosmology says that the universe is undergoing a cosmological expansion. This expansion is the result of new volume continuously being created everywhere in the universe. This new volume is indistinguishable from previously existing volume. Therefore, the new volume must also contain vacuum energy with energy density of more than 10^{112} J/m^3. Suppose that we attempt to put this in perspective. The Hubble parameter is $\mathcal{H} \approx 2.2\times10^{-18}$ m/s/m. This means that each second, each cubic meter of spacetime is expanding by $(2.2\times10^{-18})^3$ m^3 $\approx 10^{-53}$ m^3. This small volume seems insignificant until it is realized that the energy density of this new volume is approximately Planck energy density $U_p = 10^{113}$ J/m^3. Therefore, 10^{-53} m^3 requires about 10^{60} J of vacuum energy. The mass of the Milky Way is about 10^{42} kg equivalent to an annihilation energy of about 2×10^{59} J. Therefore, each cubic meter in the universe seems to be adding the equivalent the Milky Way's energy each second.

This seems ridiculous, but it appears that there are only three choices to explain this discrepancy. Either 1) vacuum energy is canceled by some other equally vast offsetting effect; 2) a vast amount of new vacuum energy is being continuously added to the universe to maintain a specific

vacuum energy density or 3) a fixed amount of vacuum energy is being distributed over an increasing volume which vastly decreases the energy density of vacuum energy as the universe expands from the Big Bang today. All of these alternatives seem unappealing. The spacetime transformation model of the universe will propose a fourth explanation which involves the transformation of the properties of spacetime.

The addition of new volume to the universe is not some subtle effect that is taking place in remote parts of the universe between galaxies. It is possible to illustrate the scale of cosmic expansion using our own solar system as an example. Suppose that we consider a spherical volume with the radius of Neptune's orbit (radius $\approx 4.5 \times 10^{12}$ m). This solar system size spherical volume would contain all the major planets and have a volume of about 3.8×10^{38} m^3. Calculating from the Hubble parameter ($\mathcal{H} \approx 2.2 \times 10^{-18}$ s^{-1}), this volume would increase by about 10^{21} m^3 each second if the spherical volume expanded proportional to the Hubble expansion of the universe. To put this expansion in perspective, this solar system size volume is adding the equivalent of about earth's volume (1.08×10^{21} m^3) every second. We do not notice any change in the volume of the solar system or the Milky Way galaxy because these objects are gravitationally bound. The addition of new volume becomes obvious when distance (proper light travel time) is measured between galaxies that are not gravitationally bound together. Only after we have a plausible explanation for the creation of this new volume everywhere in the universe, can we seriously address the question about the nonlinearity in this creation process (accelerating expansion).

The new volume is also spacetime so a rephrasing of the question is: How does spacetime rearrange itself to creating new proper volume? If the universe is only spacetime, and if the universe appears to be expanding, then the properties of spacetime must be changing with time. Something must be changing because today it takes a longer time for light to travel between two galaxies than it did a billion years ago (assuming each galaxy is at rest relative to the CMB).

Proper Volume: What examples do we have of spacetime adjusting itself in a way that changes proper volume? In the example of the Shapiro experiment, the sun's gravity changed the spacetime between the earth and the sun in a way that increased the proper radial distance by about 7.5 km compared to the radial distance that would be expected from Euclidian geometry. This increase in radial distance increased the volume within a sphere that is 1 astronomical unit (1 AU) in radius by $\Delta V \approx 3.46 \times 10^{26}$ m^3 (previously calculated). This non-Euclidian increase in proper volume is more than 300,000 times the earth's volume. This volume increase was accompanied with a decrease in the rate of time.

Also, the rotar model has two lobes where the properties of spacetime are slightly distorted. The slow time lobe has a rate of time that loses 1 unit of Planck time in a time period of $1/\omega_c$. That slow time lobe has a volume that is larger than what would be expected from Euclidian geometry. The fast time lobe has less proper volume than would be expected from Euclidian geometry.

Again it appears as if there is an inverse relationship between proper volume and the rate of time.

Near the end of chapter 2 it was shown that the standard solution to the Schwarzschild equation has a 4 dimensional volume that is independent of the gravitational gamma Γ because the change in the time dimension offsets the change in the radial spatial dimension. In all these examples, there is an interconnection between the rate of time, the coordinate speed of light and proper volume. We will explore the following idea:

New proper volume is created when the rate of time decreases.

It is proposed that spacetime is able to exchange the absolute rate of time for proper volume. This concept is implied in the following equation:

$$\frac{dt}{d\tau} = \frac{dL_R}{dR} = \Gamma$$ note inverse relationship between dτ and dL_R

While dL_R/dR applies to the radial direction in the Schwarzschild coordinate system, the above equation also can be interpreted as showing an inverse relationship between the rate of proper time and proper volume even when applied to the entire universe. We see the proper volume of the universe increasing, but proving that this is coupled with a decreasing rate of time is more difficult. An absolute proof that the rate of time is slowing in the universe would require the comparison to a hypothetical coordinate clock outside of the universe. This is an impossible experiment, so instead we will start with several thought experiments.

Cavity Thought Experiments: First we will imagine a spherical shell with mass *m* and internal radius *r*. We will place this spherical shell in space where it is in an inertial frame of reference. If the spherical shell has mass, then on the outside surface of this spherical shell we would experience a gravitational acceleration accompanied by the standard time dilation and gravitational effect on volume. Inside this spherical shell, there would be no gravitational acceleration and we could consider this flat spacetime. However, the escape velocity from the shell is greater if we start from inside the shell compared to starting from the outside surface. Even though there is flat spacetime, inside the spherical shell we still have the gravitational effects that are a function of escape velocity and scale with Γ. This point was also made in chapter 2 with examples using a cavity at the center of the earth and the Andromeda galaxy. The gravitational effect on the rate of time, the coordinate velocity of light and on proper volume remains even when there is no gravitational acceleration. However, only the gravitational effect on the rate of time is easy to experimentally see so we will temporally concentrate on the gravitational effect on the rate of time.

Background Gravitational Gamma Γ: Previously we defined the gravitational gamma Γ and a closely related concept, the gravitational magnitude β. These were defined as follows:

$$\Gamma \equiv \frac{dt}{d\tau} = \frac{1}{\sqrt{1-\left(\frac{2Gm}{c^2R}\right)}} = 1/\sqrt{1-v_e^2/c^2} = \frac{1}{1-\beta}$$ Γ = gravitational gamma; v_e = escape velocity

$$\beta \equiv 1 - \frac{d\tau}{dt} = 1 - \sqrt{1-\frac{2Gm}{c^2R}} = 1 - \frac{1}{\Gamma}$$ β = gravitational magnitude

$$\Gamma \approx 1+\beta \quad \text{and} \quad \beta \approx \frac{Gm}{c^2r}$$ weak gravity approximations

Inside a cavity uniformly surrounded by mass m, there is a gravitational effect, but the gravitational gamma definition $\Gamma = \frac{1}{\sqrt{1-\left(\frac{2Gm}{c^2R}\right)}}$ needs to be reinterpreted. This equation presumes an isolated mass in an otherwise empty universe. The interior of a spherical shell does not meet this assumption. However, the definition of Γ that incorporates escape velocity v_e is easily definable: $\Gamma = 1/\sqrt{1-v_e^2/c^2}$. For example, a cavity at the center of the earth would have an escape velocity about 22% greater than the escape velocity starting from the earth's surface (assuming a uniform density approximation and ignoring air friction).

The other alternative definition for the gravitational gamma (stationary frame) also works for a cavity surrounded by mass: $\Gamma = dt/d\tau$. In this case, we define a coordinate clock far from the source of gravity with a rate of time dt and a clock in the cavity with rate of time $d\tau$. Actually, the definition $\Gamma = dt/d\tau$ is preferable because it is also applicable to the entire universe.

The reason for discussing cavities surrounded by mass is that our location in the universe has similarities to a cavity surrounded by mass. In fact, the universe is something like being surrounded by a shell that is increasing in mass every second. What would it be like to be inside a shell that is increasing its mass? (assuming inertial frame of reference) The rate of time would be slowing down and the coordinate speed of light would be slowing down, but we would not be able to directly detect these changes unless we had communication to an outside standard. However, it is proposed that we would notice something strange was happening. A careful experiment would reveal that light was undergoing a slight redshift. The wavelength of light propagating inside the cavity would increase with propagation time. A proof of this contention will be given in the next chapter to explain the redshift observed in the universe.

We often make the assumption that a location in space far from the earth and sun can be considered to be a location with zero gravity. It is true that there might be negligible gravitational acceleration, but we are still surrounded by all the mass/energy within the particle horizon for our location in the universe. We know from observations of the Cosmic Microwave Background (Planck space probe) that the universe is flat spacetime to within a 0.1% margin of error. This suggests that the universe extends infinitely beyond our particle horizon. However, only the mass/energy within our particle horizon can have any influence on us. The mass/energy within our particle horizon exerts a background gravitational effect which must

have greatly slowed down both the rate of time and the coordinate speed of light compared to a hypothetical universe without this influence. We will use a new name to discuss this subject.

Background Gravitational Gamma of the Universe Γ_u: The name "background gravitational gamma of the universe" and the symbol Γ_u will be used to represent the concept that the universe possesses a gravitational effect that produces no acceleration but affects the rate of time, proper volume, the coordinate speed of light and many other physical properties. With background gamma there is distributed mass/energy in all directions so we do not meet the Schwarzschild assumption of a single mass in an otherwise empty universe. However, the definition of Γ based on the effect on the rate of time is the same: $\Gamma_u = dt/d\tau_u$ where $d\tau_u$ is the rate of time in a frame of reference that is stationary relative to the cosmic microwave background (CMB) and far from localized sources of gravity. In this case dt is the coordinate rate of time which is either the rate of time in a hypothetical universe without gravitational influence where $\Gamma_u = 1$ or the rate of time at the instant the Big Bang started (when $\Gamma_u = 1$). This will be explained later.

To illustrate the concept of a background gravitational gamma, an example will be given using the Milky Way galaxy. This galaxy has a visible radius of about 50,000 light years, but dark matter is believed to extend to a radius of at least 150,000 light years. The sun's orbit is about 26,000 light years in radius around the galactic center. The galactic gravitational acceleration felt by the sun is due entirely to matter that is inside the sun's orbit. Matter and dark matter in the Milky Way galaxy that lies external to the sun's orbit does not produce any gravitational acceleration on the Sun. However, this external matter does still produce a gravitational effect in the sense that it affects the rate of time, the coordinate velocity of light, the gravitational potential, the escape velocity from the galaxy, the standard of energy, etc. In other words, this external matter is producing a significant background Γ at the sun's orbital distance.

It is interesting to estimate the background Γ of the Milky Way galaxy caused by the galaxy's mass external to the sun's 26,000 light year orbit. The total mass of the galaxy, including dark matter, is estimated at about 1.2×10^{42} kg. The mass inside the sun's orbit required to produce the required gravitational acceleration on the sun is only about 15% of this total mass of the galaxy. Therefore the mass of the Milky Way galaxy external to the sun's orbit is about 10^{42} kg. Almost all of this mass is dark matter that is spherically distributed around the Milky Way galaxy. For this calculation we will estimate that all the mass external to the sun's orbit can be simulated by a spherical shell 110,000 light years in radius with mass of 10^{42} kg. Substituting into $\beta \approx Gm/c^2r$ we obtain $\beta \approx 7 \times 10^{-7}$ (or $\Gamma \approx 1 + 7 \times 10^{-7}$). The earth's gravitational magnitude at the earth's surface is $\beta \approx 7 \times 10^{-10}$ (or $\Gamma \approx 1 + 7 \times 10^{-10}$). While neither the earth nor the Milky Way galaxy have a large effect on the absolute rate of time, the Milky Way's uniform background Γ slows down the rate of time about 1,000 times more than the earth's own gravity ($7 \times 10^{-7}/7 \times 10^{-10}$).

Extending the concept to the background gamma to the universe Γ_u, all the mass/energy within the particle horizon is creating a very large value of Γ_u. Individual stars and galaxies represent only a relatively small perturbation of curved spacetime in the flat and very large background Γ_u of the universe. (Black holes will be discussed later.) For example, if the universe had 99 % of the m/R ratio required to form a black hole, the background gravitational gamma of the universe would be: $\Gamma_u \approx 10$. Later we will attempt to calculate the actual current value of Γ_u of the universe. General relativity calculations normally ignores the background gamma of the universe which is the same as assuming that this background is $\Gamma_u = 1$. This is acceptable for all calculations involving discrete mass or even galactic clusters. However, when attempting to explain the expansion of the universe, this cannot be ignored.

Besides Γ_u, there is a related concept that is the background gravitational magnitude of the universe: β_u. The relationship between Γ_u and β_u is the same as the relationship between Γ and β. Some equations are simpler when expressed in terms of gravitational magnitude β rather than gravitational gamma Γ. The exact conversion between Γ and β is: $\beta = 1 - 1/\Gamma = 1 - d\tau/dt$. These relationships also hold for β_u. The gravitational magnitude β has a scale that ranges from 0 to 1 while the gravitational Γ has a scale that ranges from 1 to infinity

Isotropic and Homogeneous Universe: All points on the comoving coordinate system (CMB rest frame) perceive the universe to be isotropic and homogeneous. This includes the rate of time which is the same everywhere in the CMB rest frame. Since points on the comoving coordinates are expanding away from each other, what does it mean for these points to have the same rate of time at a given instant? This can be illustrated with a thought experiment. Suppose we have 3 spaceships located far from sources of gravity in intergalactic space. Each of the three spaceships is exactly stationary relative to the CMB for its location. The three spaceships are widely separated forming a straight line with the middle spaceship exactly halfway between the two outside spaceships. Suppose the two outside spaceships sent out a stable microwave signal at the 9.19 gigahertz corresponding to the frequency of their cesium atomic clocks. When the two signals reach the middle spaceship, the frequency would be slightly lower (redshifted) compared to the atomic clock on the middle spaceship due to cosmic expansion. However, the important point is that both the frequencies from the two outside spaceships would be exactly the same. The middle spaceship observes that both the outside spaceships were experiencing the same rate of time at the instant the signals left the spaceships. With relativity there can be confusion about different definitions of the term "simultaneous". Therefore, the concept of a "midpoint observer" specifies one way of defining simultaneous. The two outside spaceships are simultaneously experiencing the same rate of time according to the midpoint observer.

This means that all points on the comoving grid are experiencing the same rate of time according to midpoint observers. Therefore, this rate of time is used as coordinate rate of time in the Robertson-Walker metric. Now suppose that all three spaceships are stationary relative to each other. An extrapolation of the thought experiment shows that the even if the three spaceships

are moving relative to the CMB but stationary relative to each other, the midpoint observer will still see that the outside spaceships are experiencing the same rate of time. This concept can be extended to any two points in the universe in the same frame of reference.

On the scale where the universe is homogeneous, any two points in the same frame of reference experience the same rate of time according to a midpoint observer.

No Large Scale Gravitational Acceleration: This thought experiment will be explained using the rotar model of an electron and the explanation for gravity previously developed. Suppose that we place an electron (rotar) in intergalactic space and ignore any locally generated forces. We are only interested in examining gravity on the scale larger than 300 million light years where the universe is homogeneous. We are going to test the large scale gravity of the universe using the rotar model of an electron. Recall that a rotar experiences gravitational acceleration when there is a rate of time gradient across the rotar. This causes the vacuum energy to exert an unbalanced pressure on opposite sides of the rotar. This produces a net force that is the gravitational force. The acceleration of gravity (g) was previously shown to be:

$$g = c^2\left(\frac{d\beta}{dr}\right) = -c^2\frac{d\left(\frac{d\tau}{dt}\right)}{dr} \qquad g = \text{gravitational acceleration}$$

It was previously shown that the distance designated in the denominator (dr) is proper length, not coordinate length (circumferential radius) from general relativity. If there is no gradient in the rate of time, then $d(d\tau/dt)/dr = 0$ and $g = 0$. There is no gravitational acceleration when there is no gradient in the rate of time. Two points on the opposite sides of the quantum volume of a rotar can be considered to be two points in the same frame of reference. In a homogeneous and isotropic universe, the same rate of time is present on opposite sides of the rotar (according to the midpoint observer). There is no gravitational acceleration on the homogeneous scale of 300 million light years or larger. All this might seem obvious, but it implies that the universe is not struggling to expand against a gravitational force that is attempting to collapse the universe. The gravity of localized objects like stars and galaxies can curve spacetime on a local scale, but there is not a rate of time gradient in the universe on the scale where the universe is homogeneous.

If there is no large scale rate of time gradient in the universe, then there is no tendency for there to be gravitational deceleration or acceleration at this scale.

It might be argued that dark energy is currently providing something like anti-gravity. To defend this position it would have to be argued that gravity is currently producing a rate of time gradient that is attempting to collapse the universe but dark energy is producing an opposite rate of time gradient. The combination offset each other and eliminates any large scale rate of time gradient thereby eliminating large scale gravitational acceleration. However, even this argument has an

obvious flaw. Dark energy only became a significant fraction of the energy in the universe roughly 7 billion years ago. It would have to be argued that prior to this time there was a large scale rate of time gradient in the universe. This is counter to the assumptions contained in the Robertson-Walker metric. It is not possible to have an isotropic universe if there is a large scale rate of time gradient. In fact, if there was a large scale rate of time gradient present when the CMB radiation was emitted, evidence of this rate of time gradient would be preserved as anisotropy in the CMB unless we happen to be located at the exact center of the rate of time gradient.

Rate of Time Gradient in a Dust Cloud: It is an axiom of general relativity that a distributed cloud of dust (no pressure) should experience a uniform gravitational collapse. If the cloud is divided into spherical volumes of successively larger radii, then a particular dust particle (the test particle) in the cloud experiences gravitational acceleration only from the gravity of dust particles within the smaller radii spheres. Mass that lies outside the spherical volume containing the test particle does not contribute to the gravitational acceleration. Enlarging the radius of the imaginary spherical volume increases the enclosed mass. The net effect is that the collapse of the dust particles happens everywhere.

However, gravitational acceleration does not happen in the abstract. To have gravitational acceleration, the cloud of dust particles must have a definable rate of time gradient. It takes a rate of time gradient of about 1.11×10^{-17} seconds/second/meter to produce acceleration of 1 m/s^2. It would be possible to draw a three dimensional map showing the equivalent of isobar lines within the cloud except depicting regions of constant rate of time. A dust cloud or a galaxy does have rate of time contours that can be mapped. However, the universe has (and always had) the same rate of time everywhere on the large scale addressed by the comoving coordinate system. Is it possible to propose a model of the universe that does not have a rate of time gradient on the scale of the comoving coordinate system? Furthermore, does such a model follow logically from starting the universe as Planck spacetime? These questions will be examined by starting with a thought experiment.

Dust Particle Cloud Thought Experiment: Suppose that the previously mentioned cloud of dust particles is uniformly distributed in space over a volume about the size of the earth. Also, suppose that it is possible to turn off the gravity of all the dust particles in the cloud. This is an unrealistic assumption for a cloud of dust but it will be shown that it is not unrealistic for the beginning of the universe. Therefore attempt to follow this hypothetical thought experiment. After turning off the gravity of each dust particle, the gravitational magnitude within the cloud would quickly drop to $\beta = 0$ which is equivalent to $\Gamma = 1$. The proper rate of time everywhere within the cloud would be equal to the coordinate rate of time, therefore we would start with $d\tau = dt$ or $\Gamma = dt/d\tau = 1$. There obviously would be no rate of time gradient.

Next, the gravity of all the particles is simultaneously turned on. At speed of light propagation, there would be a period of time where the proper rate of time $d\tau$ would be slowing down while the gravitational influence of successively more distant particles is becoming established. For example, it takes about 20 milliseconds for the gravity of a particle at the center of this earth size cloud to affect the rate of time of particles near the outer "surface" of the spherical cloud and vice versa. It would take about 40 ms for the most distant particles on opposite sides of the cloud to make gravitational contact. Therefore, it takes about 40 ms for the mature gravitational acceleration (mature rate of time gradient) within the cloud to become fully established. Since we are defining the gravitational gamma as $\Gamma = dt/d\tau$, we could characterize the establishment of gravity at a particular location in the cloud by referring to the value of Γ as a function of time after the gravity was turned on.

Suppose that we look just at the first few milliseconds after turning on the gravity. Also we will examine several points (test points) within the cloud that are close enough to the center of the cloud that there is not enough time to establish gravitational communication with the boundary condition that occurs at the outer surface of the cloud. In the first few milliseconds the gravitational Γ is increasing exactly the same way at each of these test points. Even though the rate of proper time is slowing (Γ is increasing), there is no gradient in the rate of proper time. This is because all the test points (and all other points far from the surface) have undergone exactly the same amount of gravitational interaction with their surrounding particles. The lack of a rate of time gradient means that there would be no gravitational acceleration attempting to collapse the cloud during the first few milliseconds after gravity is turned on in this thought experiment. There is no tendency towards gravitational collapse only during the nonequilibrium condition of an increasing value of the background Γ. Within the dust cloud there is flat spacetime while Γ is increasing. This flat spacetime does not require a "critical density". The low density of the dust cloud is vastly less than meeting the conditions of a "critical density", yet during the nonequilibrium phase of increasing Γ the dust cloud does achieve flat spacetime (no gravitational acceleration). In fact, any homogeneous density can achieve flat spacetime provided that the nonequilibrium condition of an increasing background Γ is somehow achieved.

Immature Gravity: This thought experiment describes a condition that will be called "immature gravity" or the nonequilibrium condition where the gravitational influence of distant mass/energy is in the process of being established. This is to be contrasted to the "mature gravity" condition where there has been sufficient time to establish the gravitational gradients resulting from the existence of distant boundary conditions (distant changes in density). In this example, after about 40 ms there are differences in the rate of time throughout the cloud because of different distances to the cloud boundary. The rate of time gradient produces gravitational acceleration that was previously missing. This is the mature gravity condition we normally assume when we talk about the uniform gravitational collapse that we expect from a cloud of particles. These concepts can be illustrated using the following figures.

Figure 13-2 shows a volume deep within the dust cloud. Suppose that this is a snap-shot about 1 ms after the gravity was "turned on". The circle labeled "particle horizon for point O" would have a radius of about 300,000 m which represents the speed of light gravitational contact established from point "O" after 1 ms. This horizon is actually an expanding sphere and the figure is a cross sectional representation of a moment in time. There is also another point designated "X" that is relatively close to point × compared to the particle horizon. For example, suppose point "X" is separated by 30,000 m from point "O". This separation distance is about 10% of the distance to the particle horizon after 1 ms. However, it should be noted that point "X" has a different expanding particle horizon designated by the double line circle. After 1 ms this particle horizon is also a sphere about 300,000 m in radius, but centered on point "X".

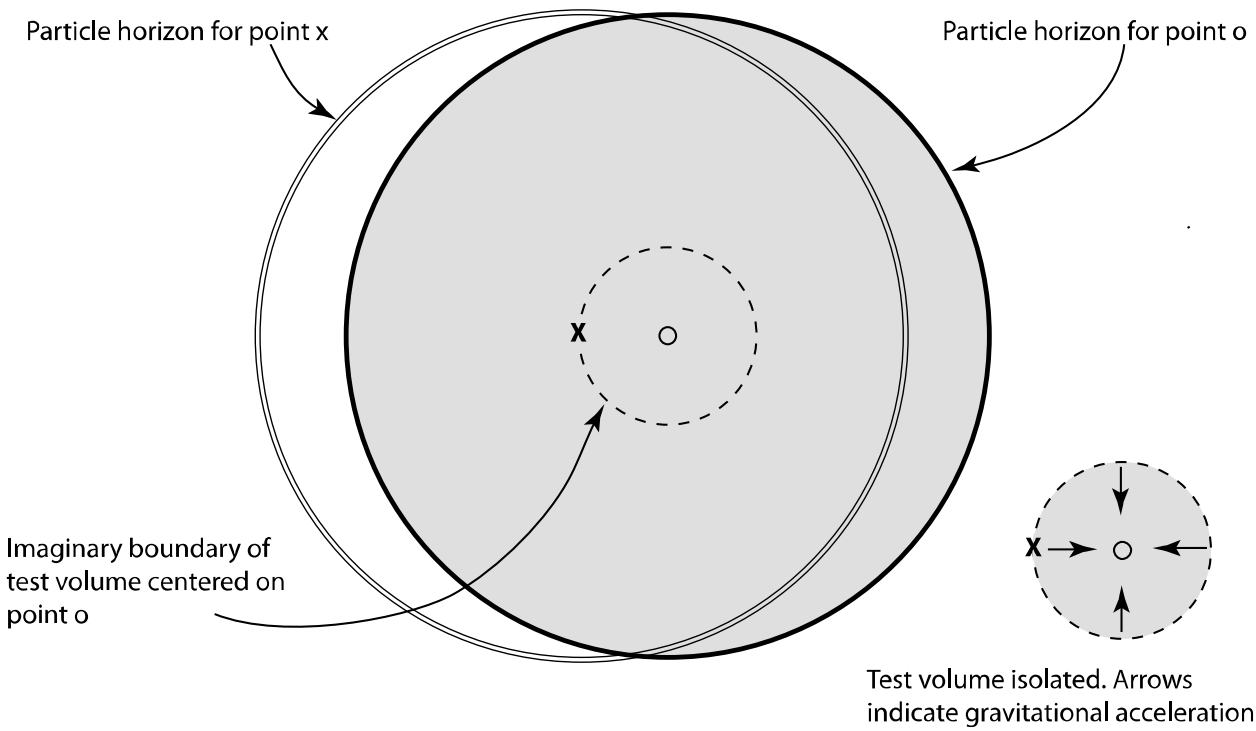

FIGURE 13-2 Observational universe as seen from point o

Figure 13-2 also shows a "test volume". This is a an imaginary sphere that is centered on point "O" and has a radius equal to the distance between point "O" and point "X" (about 30,000 m). Therefore, after 1 ms there has been enough time for the center of this 30,000 m radius spherical volume to establish gravitational contact with all the other dust particles within the test volume (0.2 ms is required for opposite edges to establish gravitational contact). Now we are going to examine the gravitational forces on dust particles within the test volume if the test volume is isolated as shown in the lower right hand corner of figure 13-2. This isolated illustration shows both points "O" and "X". If this small test volume is isolated as shown, then after 0.2 ms all particles in the test volume have sufficient time to establish gravitational contact with the boundary of the test volume. If the test volume is isolated as shown, the "mature" rate of time

gradient would be established within the test volume after 0.2 ms. In this case, particles within this test volume would start to undergo a gravitational collapse and a dust particle at point "X" experiences a gravitational force towards point "O" as shown by the arrow.

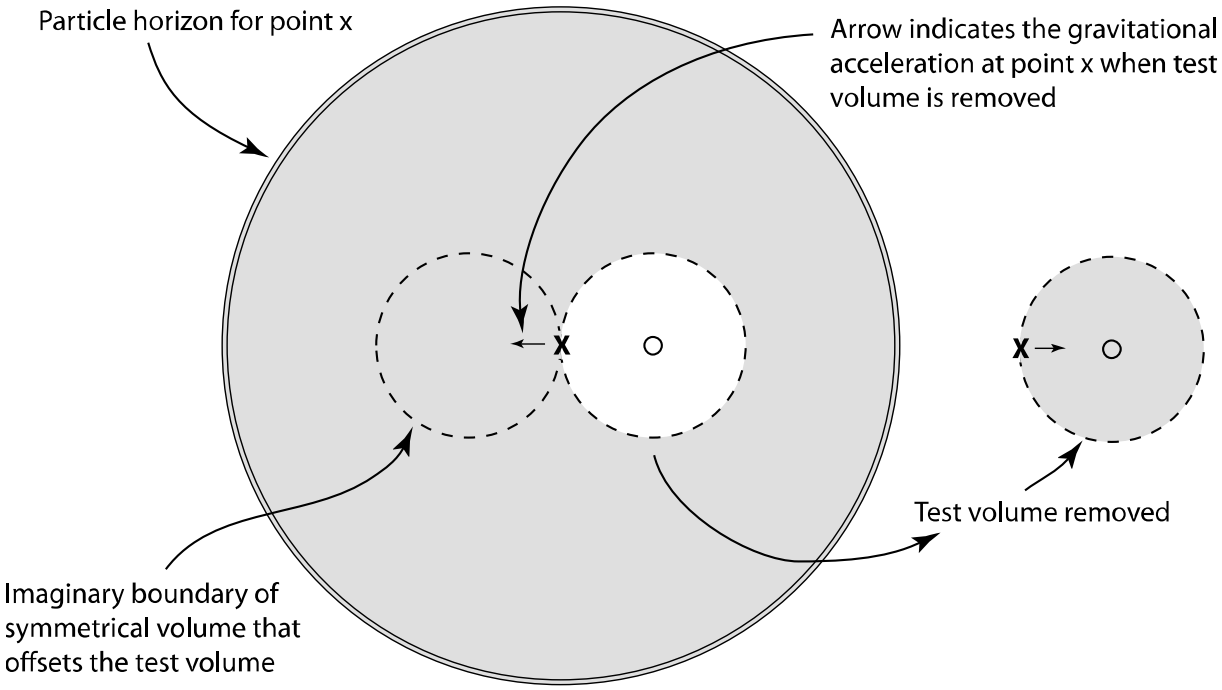

FIGURE 13-3 Observational universe as seen from point x. When test volume is removed, point x experiences a gravitational acceleration in the direction shown. When the test volume is present, there are balanced forces at point x and no net gravitational acceleration.

Figure 13-3 shows a different perspective centered on point "X". Therefore the particle horizon in figure 13-3 is a sphere centered on point "X". Now we are going to examine the forces on point "X". In the previous figure, we concluded that a dust particle at point "X" had a force towards point "O" after 0.2 ms when the test volume was isolated. From this new perspective shown in figure 13-3, suppose that we were to physically remove the test volume as shown to the right. Now 1 ms after gravity has been "turned on" the dust particle at point "X" has unbalanced force from the comparable volume to its left that is designated as "the symmetrical volume that offsets the test volume". The length and direction of this arrow represents the gravitational force on a dust particle. This force arrow is pointing into the "symmetrical volume" and exactly offsets the length and direction of the force arrow pointing towards point "O" in the test volume. With the test volume removed, point "X" would experience a gravitational force in the direction of the arrow pointing to the center of the "symmetrical volume". However, if the test volume is present and point "X" is surrounded by a homogeneous distribution of particles, then there is no net force on a dust particle located at point "X". There is also no rate of time gradient and no net gravitational acceleration.

The point of figures 13-2 and 13-3 is to illustrate that the immature gravity (increasing background Γ) creates a unique condition where there is no rate of time gradient and no tendency for gravitational collapse. Both point "O" and point "X" had their own particle horizons that were partly overlapping, but also each point had a horizon that was uniquely centered on them. This is the condition where all the gravitational forces are balanced and there is no tendency towards a gravitational collapse. Another way of saying this is that the conditions shown create a rate of time that is the same everywhere as defined by a midpoint observer at any given instant. It is ironic that the condition where there is no rate of time gradient (midpoint observer perspective) only happens in immature gravity where the rate of time is continuously decreasing relative to an outside constant rate of time.

Observable Effects of an Increasing Γ: The slowing of the rate of time when Γ is increasing would not be obvious within the cloud while it is happening because it would not be possible to compare the proper rate of time with coordinate rate of time using speed of light communication. However, it will be shown that the condition of a homogeneous increase in the background gravitational gamma would theoretically produce 1) an increase in the proper volume of the dust cloud and 2) would produce a slight redshift in radiation coming from other parts of the dust cloud. The proof for this statement will be given in the next chapter once an easier model for analysis has been introduced.

Implications of an Increasing Γ_u in the Universe: At the start of this chapter, the statement was made that before we can attempt to understand the apparent acceleration in the expansion of the universe, it is first necessary to understand why there is any expansion in the universe. It is proposed that the reason for the apparent expansion of the universe is that the background gravitational gamma Γ_u of the universe is presently increasing. Furthermore, Γ_u was always increasing over the lifetime of the universe but the rate of increase has been different during different epochs.

The purpose of the previous thought experiment is to introduce the concept of immature gravity using a model that is easier to understand than the entire universe. However, a cloud of dust starting with the gravity turned off is not a perfect analogy for the universe. The dust cloud illustrates how it is possible for there to be no rate of time gradient (midpoint observer perspective) as long as the background Γ is increasing, but the example describes a condition where there is only a minute change in Γ. Scale does matter. The change in Γ_u experienced by the universe in its first moments after gravity is "turned on" (the start of the Big Bang) compared to the dust cloud over a similar time period is a difference of more than a factor of 10^{30}. This enormous difference introduces many other differences between the universe and the cloud that will be described.

To my knowledge, no one has mathematically analyzed the implications of living in a universe where the background Γ_u is increasing as a function of the age of the universe. The Schwarzschild

solution to Einstein's field equation assumed a single source of static gravity in an otherwise empty universe. The solution describes the effect on spacetime that surrounded this static source of gravity. The Friedman equation assumes a uniform distribution of matter in the universe. However, even the Friedman solution assumes a mature gravitational distribution. The standard Big Bang model also implies a mature gravitational distribution. It is proposed that this is an erroneous assumption that ultimately leads to the need to invent dark energy.

Note to the Reader: *We will divert from the dust cloud example and immature gravity for a short time to introduce additional properties of spacetime. We will then combine all these concepts to develop a model of the expanding universe.*

Energy Density of Planck Spacetime: Until now, this book has ignored numerical factors near 1. From observations and calculations, the energy density of the universe as a function of time is well known. In order for a theoretical model to be credible, it is necessary to be able to match observations. Therefore, it is necessary to introduce a missing numerical factor into the definition of Planck energy density to determine the energy density of Planck spacetime. It is necessary to carefully define the energy density of Planck spacetime because this is proposed to be the starting energy density of the universe and this value affects the evolution of the universe.

Planck energy density is defined as $U_p = c^7/\hbar G^2 \approx 4.6 \times 10^{113}$ J/m^3. This definition describes the energy density that would occur if Planck energy E_p was contained in a cube with dimensions of Planck length on a side $(U_p = E_p/L_p^3)$. This definition lacks dimensionless numerical factors. Even though the energy density of Planck spacetime is closely related to Planck energy density, they differ by a dimensionless constant. For cosmology, a more reasonable definition of energy density would be based on the volume of a sphere that is Planck length in radius rather than a cube that is Planck length on a side. The difference between these two volumes is $(4/3)\pi$.

Zero Point Energy: There is one other dimensionless numerical factor that must also be included. It is proposed that vacuum energy is equivalent to zero point energy. Zero point energy is the lowest energy that a quantum mechanical system may have. The energy of the ground state of a quantum harmonic oscillator is:

$E = ½\, \hbar\omega$ zero point energy

It is proposed that Planck spacetime was the highest zero point energy density possible. The dipole waves in spacetime can be visualized as quantum harmonic oscillators. The highest possible zero point energy density can be visualized as a quantum oscillator that is oscillating at the highest possible frequency in the smallest possible volume. The highest possible frequency is Planck angular frequency: $\omega_p = \sqrt{c^5/\hbar G}$. The zero point energy of this oscillator is:

$E = ½\, \hbar\omega_p = ½ \sqrt{\hbar c^5/G} = ½\, E_p \approx 9.78 \times 10^8$ J.

Therefore, the highest energy density of the spacetime field is to have this energy *(½ E_p)* in the volume of a sphere that is Planck length in radius. This energy density of Planck spacetime will be identified by the symbol U_{ps}.

$$U_{ps} \equiv ½ \frac{E_p}{\left(\frac{4\pi}{3}\right)L_p^3} = \left(\frac{3}{8\pi}\right)\left(\frac{c^7}{\hbar G^2}\right) = k' U_p \qquad \text{where: } k' \equiv \frac{3}{8\pi}$$

$U_{ps} \approx 5.53 \times 10^{112}$ J/m^3 $\qquad$ $U_{ps} \equiv$ energy density of Planck spacetime

The correction factor $3/8\pi$ will also be used frequently and will be identified by the symbol $k' = 3/8\pi$. A sphere Planck length in radius which has spherical Planck energy density contains energy of ½ $E_p \approx 9.78 \times 10^8$ J. However, we will often round this off to about a billion Joules (10^9 J). The constant $k' = 3/8\pi$ is the conversion factor between Planck spacetime energy density U_{ps} and Planck energy density $(U_p = U_{ps}/k')$. These concepts are expressed using energy density *(U)* rather than mass density *(ρ)* because mass is a measurement of inertia. Waves in spacetime are naturally expressed in units of energy density rather than units of mass density which implies inertia.

Difference between Planck Spacetime and Vacuum Energy: Planck spacetime at the start of the Big Bang possessed the same proper energy density as vacuum energy today. Therefore, what is the difference? One of the key differences is hidden in the qualification of "proper energy density". Planck spacetime had a background gamma of the universe of $\Gamma_u = 1$ while today the value of Γ_u is an extremely large number that will be calculated later. This large value of Γ_u affects everything including the rate of time and our standard of a unit of energy. Even though one Joule today appears to be the same as one Joule a billion years ago or one Joule at the Big Bang, these are comparisons of proper values that do not take into account the effect of a different value of Γ_u. On an absolute scale of energy that compensates for the change in Γ_u, one Joule today is far less energy than one Joule when $\Gamma_u = 1$ at the start of the Big Bang (explained below).

Another difference is that vacuum energy has no quantized angular momentum (no spin) while at the start of the Big Bang 100% of the energy in Planck spacetime possessed quantized angular momentum. The lack of quantized angular momentum in vacuum energy means that this is a perfect superfluid that does not interact with our observable universe except through subtle quantum mechanical interactions. There are no fermions (half integer spin) or bosons (integer spin) in "pure" vacuum energy. We would say that vacuum energy has a temperature of absolute zero. Even though there is energy density, vacuum energy is incapable of giving kinetic energy (temperature) to particles. On the other hand, in Planck spacetime at the start of the Big Bang each of the *½ E_p* units of energy (zero point energy) possessed *ħ* of angular momentum. This results in the highest possible interaction with other quantized units of energy. The temperature of Planck spacetime had the highest possible temperature for zero point energy which is equal to ½ Planck temperature (½ $\mathbb{T}_p \approx 7 \times 10^{31}$ °K).

Proposed Alternative Model of the Beginning of the Universe: The alternative model proposed here starts the universe not as a singularity but as Planck spacetime with volume and finite energy density. Recall that Planck spacetime has a spherical correction factor and a zero point energy correction factor that total $3/8\pi \approx 0.12$ compared to Planck energy density. However, Planck energy density eliminates numerical factors by assuming a cubic volume. Therefore, Planck spacetime is the highest zero point energy density achievable. What is the implied rate of time (or the implied coordinate speed of light) required to achieve the highest possible energy density on an absolute scale? This question can also be stated as follows: What value of the gravitational gamma is required to achieve Planck spacetime? The highest possible energy density on an absolute scale that takes into consideration the value of Γ can only be achieved if $\Gamma = 1$. If $\Gamma > 1$ then the rate of time is slower than coordinate rate of time and the unit of energy is less than the coordinate unit of energy. The theoretical largest energy density on an absolute scale can only be achieved at the theoretical fastest rate of time which is also the fastest coordinate speed of light.

Therefore, Planck spacetime has what might seem like a contradiction. The highest possible energy density starts with a rate of time that we would expect to find in a hypothetical empty universe (no slowing of time caused by gravitational fields). If we are truly at the beginning of time, then there was no prior time for gravity to become established. There is no contradiction for $\Gamma = 1$ if this was the starting condition.

The source of Planck spacetime is an open question. Perhaps spacetime merely came into existence as Planck spacetime or perhaps this is a phase change in a repeating cycle. In either case, we assume that Planck spacetime starts with a rate of time commensurate with $\Gamma_u = 1$. This assumption means that at the start of the Big Bang the rate of proper time equaled the rate of coordinate time ($d\tau_u = dt$ at the beginning).

Extending the Dust Cloud Example: Previously we had the thought experiment involving a cloud of dust distributed in space. In this thought experiment we imagined eliminating all gravitational effects from this cloud of particles (gravity turned off). This means that we started with a background gravitational gamma of $\Gamma = 1$. Then we "turned on" gravity everywhere. The starting condition for the entire universe is proposed to be similar in some respects to this thought experiment. Planck spacetime had an energy density roughly 10^{100} times larger than the energy density of the dust cloud but Planck spacetime was not a singularity. Planck spacetime had an extremely uniform energy density because the energy density was determined by the limitations of spacetime itself. Therefore, it is proposed that the universe started with the finite energy density of Planck spacetime. This quantifiable condition was the starting condition for the evolution of the universe.

There was no preexisting gravity present in this volume, so when time started the waves in spacetime began to distort because of the nonlinearity of spacetime. The background Γ_u of the universe began to rapidly increase from the starting condition of $\Gamma_u = 1$ of Planck spacetime. This is similar to gravity being "turned on" in the thought experiment, except the changes brought about by an increasing Γ_u were vastly larger than occurred in the thought experiment. Rather than an almost imperceptible effect on proper volume in the thought experiment, there was a tremendous increase in the proper volume of the universe as Γ_u rapidly increased. The rate of time in the universe slowed and the coordinate speed of light slowed. All of this produced the immature gravity condition. This immature gravity lacks gravitational acceleration on the large scale of homogeneity as previously described in the dust cloud example.

Comparison to the Big Bang Model: We are now beginning to resolve the difference between two models of the universe. The Big Bang model does not attempt to explain the process which results in cosmic expansion. Matter is not expanding into a preexisting void. Instead, the Big Bang model has a vast expansion in the volume of the universe but no explanation is given as to how new volume is created. The proposed model of the universe that starts with Planck spacetime will be called the "spacetime transformation model". This model attributes the expansion in proper volume to a change in the properties of spacetime that can be quantified as a continuous increase in Γ_u. Most important, there is a uniform increase in Γ_u everywhere which implies that there is no large scale gravitational gradient attempting to collapse the universe. This contrasts with the Big Bang model of the universe which has gravity attempting to slow down the expansion of the early universe. The following quote by P. J. E. Peebles in the book "Principles of Physical Cosmology" describes the current reasoning.

> "Newton's iron sphere theorem says that the Newtonian gravitational acceleration inside a hollow spherical mass vanishes. The relativistic generalization is that spacetime is flat in a hole centered inside a spherically symmetric distribution of matter.
>
> Now we are in a position to find the relation between the mass density, ρ, and the local rate of expansion or contraction of the material. We are considering a spatially homogeneous and isotropic mass distribution. Suppose the matter within the space within a sphere of radius *r* is removed and set to one side. Then spacetime is flat within the sphere. Now replace the matter. If *r* is small enough, we have placed a small amount of material into flat spacetime. Therefore, we can use Newtonian mechanics to describe the gravitational acceleration of the material."

This goes on to show that the spherical volume with homogeneous density has gravitational acceleration that attempts to contract the distributed mass. When this reasoning is applied to the entire universe it naturally results in gravity opposing the expansion of the universe. Even if the universe is undergoing accelerated expansion because of dark energy, the Big Bang model

has gravity attempting to contract the universe. This sounds reasonable and it has been accepted by generations of physicists. However, it is proposed to be wrong.

If we assume that the universe has immature gravity and an increasing Γ_u, then the fallacy in the above reasoning is that removing a spherical volume of homogeneous density material from the universe would **not** leave a void with flat spacetime. Instead, the remaining void would have negative curvature which has gravitational acceleration away from the center of the void. Figure 13-3 showed that point "X" on the edge of the void has gravitational acceleration away from point "O" at the center of the void. Point "X" in figure 13-3 is not unique. All other points within the void also have gravitational acceleration away from point "O" at the center of the hypothetical void. This negative curvature effect can be understood since each point in the void can be thought of as existing in a spherical particle horizon centered on them. Therefore these other points within the void are similar to point "X" and also have a gravitational acceleration vector pointing away from the central point "O". These vectors exactly offset the gravitational acceleration towards point "O" caused by the test volume. Replacing the test volume would result in offsetting vectors that eliminate any gravitational acceleration. The immature gravity described here has no tendency towards gravitational collapse of the universe on the current scale of homogeneity (~ 300 million light years).

The previous paragraph might be misunderstood if quickly read, so here is another attempt. On the large scale of 300 million light years, there is flat spacetime. However, on the smaller scale of 1 million light years there can be positively curved spacetime near a galaxy or negatively curved spacetime in a volume of space without any matter. Suppose matter was uniformly distributed throughout the universe so that every cubic meter of space possessed uniform energy density of about 10^{-9} J/m^3. Also, the universe extends perhaps infinitely, but definitely far beyond out present particle horizon. Then the universe would have flat spacetime even on the small scale. The matter in each spherical volume 1 meter in radius would be producing a gravitational field which would tend to collapse the matter to the center of the sphere if that spherical volume was isolated like the "test volume" in figure 13-3. However, in the actual universe the immature gravity condition is producing an offsetting negative curvature, so the combination results in flat spacetime.

Low Density Regions of the Universe: On the scale smaller than 300 million light years the universe is currently not homogeneous. There are volumes containing galactic clusters which have above average density and volumes of space between the galactic clusters with below average density. These volumes with below average density should exhibit negative curvature analogous to the void previously discussed. A low density region in the universe would have a similarity to the concept of an electronic "hole" in a semiconductor (electrons and holes). A volume of a semiconductor that is missing an electron is the equivalent of a positive electrical charge. Similarly, a low density region in the universe (missing mass compared to the average) exhibits the repulsive properties as if the missing mass had anti-gravity properties (had an

inverse rate of time gradient). This effect only happens if the universe has the immature gravity characteristic.

If low density regions of the universe exhibit something like anti-gravity, this would substantially speed the rate of formation of stars and galaxies in the early universe. Any matter within the low density regions of the early universe would tend to be expelled. Furthermore, the anti-gravity acceleration would extend into the edges of surrounding higher density regions. This would tend to drive these high density regions to even greater density. The average density of the early universe was much greater than today. Therefore the repulsive gravitational acceleration of low density regions of the early universe would be much greater than today. Modeling galaxy formation in the early universe should take this proposed effect into consideration.

Scaling Factor Based on Planck Spacetime a_u: The comoving coordinate system uses "a_o" to represent the present scaling factor of the coordinate system and the scaling is usually based on the convention of considering the current scale of the universe as $a_o = 1$. This is convenient since a model of the universe that starts with a singularity does not have any absolute scaling factor from the start of the Big Bang. However, the concept that the universe started as Planck spacetime means that the spacetime transformation model does have a definable initial size and rate of time at the start of the Big Bang. It is natural that we would choose this absolute starting condition as the basis of our scaling factor. Therefore we will use the symbol "a_u" to represent the scaling factor relative to the scale of the universe when it was Planck spacetime at the start of the Big Bang.

Therefore the spacetime transformation model sets $a_u \equiv 1$ for Planck spacetime when the universe was 1 unit of Planck time old and $\Gamma_u = 1$. According to this proposal, at the start of the Big Bang Planck spacetime had energy density of about $U_{ps} \approx 5.53 \times 10^{112}$ J/m^3 and 100% of this energy was "observable". Another way of saying this is that all the energy in Planck spacetime had quantized angular momentum. Today almost all the energy density in the universe is in the form of vacuum energy which lacks any quantized angular momentum. Therefore only roughly 1 part in 10^{122} today has quantized angular momentum and is "observable" to us and out instruments. We only interact with the vast energy density in vacuum energy through quantum mechanical effects. These numbers then become the basis for gauging the scale of the universe at any other time in the history of the universe.

Cosmic Expansion from Γ_u: What happens to the comoving coordinate system when there is an increase in the background gravitational gamma of the universe Γ_u? In chapter 2 we did a thought experiment involving two concentric shells. The changes that occur when mass is introduced inside the inner shell are: 1) the rate of proper time $d\tau_u$ slowed compared to coordinate time dt and 2) the proper volume between the two shells increased. We live in a universe which is proposed to have started with a background gravitational gamma $\Gamma_u = 1$ and this value then started to increase at the beginning of time (at the Big Bang). We also know that

the proper volume of the universe rapidly increased initially and the proper volume of the universe continues to increase today (the so-called cosmic expansion).

Assuming that the universe is only spacetime, there appears to be only one way that the universe can rearrange itself to increase its proper volume. I am proposing that the reason for the observed cosmic expansion is that the background gravitational gamma Γ_u of the universe is continuously increasing towards $\Gamma_u = \infty$. This is a transformation in the characteristics of spacetime. When the background gravitational gamma of the universe Γ_u increases, proper volume increases, the rate of time decreases and the coordinate speed of light decreases proportional to $1/\Gamma_u^2$. It will be shown later that the model being developed results in new mass/energy continuously coming into view at our particle horizon. The proposal is that the rate of time continues to get slower, but we are unaware of this change because we cannot directly compare our rate of time to either the rate of time yesterday or the rate of time in a hypothetical static universe that is not undergoing any change. This obviously is a different model than the Λ-CDM model currently considered to be the cosmological standard.

The proposal is that the expansion of the proper volume of the universe is caused by the background gravitational gamma of the universe Γ_u increasing.

We can see if this proposal is compatible with the Robertson-Walker metric (hereafter R-W metric). The highly successful R-W metric has been called the standard model of modern cosmology. It assumes an isotropic and homogeneous universe and a spherical coordinate system that expands with the "Hubble flow" so that the coordinate system remains in the CMB rest frame everywhere. The standard way of writing the R-W metric is:

$$dS^2 = c^2dt^2 - a^2(t)[\frac{dr^2}{1-kr^2} + r^2(d\theta^2 + sin^2\theta d\phi^2)]$$

where $a(t)$ is the scale factor of the universe and r is physical distance. The convention is to use the current scale factor of the universe as $a_o = 1$. Therefore $a(t)$ is usually scaled into the future or past from the current scaling factor and "r" is set equal to the current distance between two points which can be considered a unit of length. However, it is also possible to choose some other standard for "a" and "r" if there is a compelling reason. In our case, we have a very compelling reason to choose a different standard for "a" and "r" because unlike the Λ-CDM model, we have an exact scale for the universe at the beginning of the beginning of time (at the start of the Big Bang). Therefore this scale factor which changes with time but was $a_u = 1$ when the universe was Planck spacetime will be designated $a_u(t)$. Also the physical length between two points will use as its standard the length when the universe was Planck spacetime ($\Gamma_u = 1$). This length standard (coordinate length) will be designated $\mathbb{R}$. Therefore, rewriting the R-W metric with these changes we have:

$dS^2 = c^2dt^2 - a_u^2(t)\,(\frac{d\mathbb{R}^2}{1-k\mathbb{R}^2} + \mathbb{R}^2 d\Omega^2)$ R-W metric where $d\Omega^2 = (d\theta^2 + sin^2\theta d\phi^2)$

The spatial curvature term is k and in the general case "k" can take values of +1, 0 or – 1. However, analysis of the CMB using experimental data from WMAP has established that spacetime on the large scale is flat to better than 0.4% experimental accuracy. Therefore, we are going to assume a flat universe and set $k = 0$. We can determine the spatial metric for a flat universe by setting $dt = 0$ and follow a radial ray by setting $\Omega = 0$.

$dS^2 = c^2dt^2 - a_u^2(t)\,(\frac{d\mathbb{R}^2}{1-k\mathbb{R}^2} + \mathbb{R}^2 d\Omega^2)$ set $k = 0, dt = 0, \Omega = 0$ and $dS = cd\tau = dL$

$dL^2 = a_u^2(t)d\mathbb{R}^2$

$a_u(t) = \frac{dL}{d\mathbb{R}}$

The proposed physical interpretation of this is that the reason that the scale factor increases is because proper length contracts relative to coordinate length $\mathbb{R}$ when the universe had $\Gamma_u = 1$ or compared to a unit of length in a hypothetical empty universe. If a unit of proper length L is smaller than a unit of coordinate length $\mathbb{R}$, then progressing in the radial direction the rate of change in proper length dL will be greater than the rate of change in $d\mathbb{R}$. This ratio is equal to the scale factor $a_u(t)$. Since the spacetime field is homogeneous and isotropic on the large scale, this applies to all spatial directions since the choice of a "radial" direction is arbitrary. The relationship to the gravitational background of the universe Γ_u is proposed to be:

Seventh Starting Assumption: $\Gamma_u(t) = a_u(t) = \frac{dL}{d\mathbb{R}}$

It is not possible to conclusively prove this equation. Therefore, this equation is an assumption. However, it is possible to support its validity by showing that it is compatible with observations and gives a compelling model of the universe. The proper volume of the universe is indeed expanding. This equation is a key step in explaining why the universe is undergoing what appears to be a cosmic expansion. The Big Bang model does not go far enough to explain the underlying physics behind the proper volume expansion of the universe.

This equation allows us to estimate the value of Γ_u of the universe today because we know the initial scale of Planck spacetime and we can estimate the expansion that has occurred since the universe had the energy density of Planck spacetime. We will proceed by assuming $\Gamma_u = a_u$ to obtain other insights. If the answers obtained by the use of this equation are reasonable, this can also serve as a check on the equation.

The appeal of the concept that the universe is undergoing an increase in Γ_u is that: 1) it explains the apparent cosmic expansion of the universe 2) it gives the correct redshift to light from distant

galaxies (proven later), 3) it gives a universe with a uniform rate of time on the comoving grid and 4) it eliminates the mystery of expanding space supposedly carrying galaxies away from us at faster than the speed of light 5) it is one of several steps that eliminate the need for dark energy 6) it solves the mystery of how the energy density of vacuum fluctuations (zero point energy) can remain constant when the proper volume of the universe expands.

Coordinate Rate of Time *dt*: As explained previously, the definition of the coordinate rate of time (designated *dt*) used by the spacetime transformation model is the rate of time when $\Gamma_u = 1$. This only occurred in our universe during the first Planck unit of time in the age of the universe. Therefore, the coordinate clock can be imagined as a clock that continues to run at the rate of time that was present at the beginning of time. This is also the rate of time that would occur in a hypothetical empty universe where always $\Gamma_u = 1$. After the first unit of Planck time, the background Γ_u of the universe began to increase ($\Gamma_u > 1$) and the rate of proper time in the universe $d\tau_u$ decreased relative to the coordinate rate of time. The gravitational gamma of the universe can also be defined by the following temporal relationship:

$\Gamma_u = dt/d\tau_u$

Coordinate and Hybrid Speed of Light: The symbol "*dt*" in the R-W metric represents the rate of time in the comoving coordinate system. This is actually the proper rate of time in the CMB rest frame of the universe. We need to substitute a different symbol because we want to use "*dt*" as the coordinate rate of time when $\Gamma_u = 1$. The rate of time used in the R-W metric is actually the proper rate of time in the universe (the rate of time on the cosmic clock). Therefore in the R-W metric we will make the following substitution $dt \rightarrow d\tau_u$. Also making the substitution of a_u and $\mathbb{R}$ previously discussed, we have:

$$dS^2 = c^2 d\tau_u^2 - a_u^2(t)\left(\frac{d\mathbb{R}^2}{1 - k\mathbb{R}^2}\right) + \mathbb{R}^2 d\Omega^2 \qquad \text{modified R-W metric}$$

Combining these substitutions with substitutions previously explained we have:
Set: $dS = 0,\ d\Omega = 0,\ k = 0,\ a_u(t) = \Gamma_u$

$$c^2 d\tau_u^2 = a_u^2(t) d\mathbb{R}^2$$

$$c = a_u(t)\left(\frac{d\mathbb{R}}{d\tau_u}\right) \qquad \text{set } a_u(t) = \Gamma_u(t) \qquad \text{and } \frac{d\mathbb{R}}{d\tau_u} \equiv \boldsymbol{C}$$

$$\boldsymbol{C} = \frac{c}{\Gamma_u(t)} = \frac{d\mathbb{R}}{d\tau_u} = \text{hybrid speed of light (coordinate length and proper rate of time)}$$

Next we will determine the coordinate speed of light ($\mathbb{C} = d\mathbb{R}/dt$) which references the coordinate rate of time dt and the rate of change of coordinate length $d\mathbb{R}$ both in a hypothetical empty universe where $\Gamma_u = 1$. The definition of dt used for the remainder of this book is the rate of time in a hypothetical $\Gamma_u = 1$ universe. Therefore: $dt \equiv \Gamma_u(t) d\tau_u$.

$$c = \Gamma_u(t)\left(\frac{d\mathbb{R}}{d\tau_u}\right) \quad \text{set } d\tau_u = \frac{dt}{\Gamma_u(t)}$$

$$c = \Gamma_u^2(t)\left(\frac{d\mathbb{R}}{dt}\right) \quad \text{set } \mathbb{C} = \frac{d\mathbb{R}}{dt}$$

$$\mathbb{C} = \frac{c}{\Gamma_u^2(t)} = \frac{d\mathbb{R}}{dt} = \text{coordinate speed of light}$$

There are times when it is necessary to use the coordinate speed of light $\mathbb{C}$ but usually the hybrid speed of light $\boldsymbol{C}$ is adequate and simpler. When possible, it is more convenient and intuitive to use the proper (comoving) rate of time. If we are determining the time required for light to travel a distance between two stationary points, we usually want the answer expressed in units of proper time that would be recorded on the cosmic clock. The difference between the hybrid speed of light $\boldsymbol{C} = d\mathbb{R}/d\tau_u$ and the proper speed of light $c = dL/d\tau_u$ is the difference between a unit of coordinate length $\mathbb{R}$ and a unit of proper length L. The reason that it takes more time for light to travel between two distant galaxies today than it did a billion years ago is that the hybrid speed of light is less today than it was a billion years ago. The distance between these two galaxies is constant when measured in units of coordinate length $\mathbb{R}$. A slowing hybrid speed of light implies that a unit of proper length, (such as 1 meter today) is contracting relative to a unit of coordinate length (such as 1 meter when $\Gamma_u = 1$).

Reconciliation With Proper Length Being Constant: Clearly the physical interpretation that is emerging is that a unit of proper length contracts when Γ_u increases. In chapter 3 it was proposed that it was an acceptable basis of a coordinate system to consider a unit of proper length, such as a meter, to be the same everywhere in the universe. A meter in a location with a large gravitational Γ was considered to be the same as a meter in a location far from any source of gravity which we were previously calling "zero gravity". How is it possible to reconcile the view that proper length is contracting as Γ_u increases with the view in chapter 3 that proper length is constant everywhere in the current universe?

The answer is that the "normalized" coordinate system of chapter 3 used the equation $L_o = L_g$. This does not imply that L_o and L_g are constant over time. It merely says that this coordinate system assumes that in a stationary frame of reference, a unit of length in a zero gravity location (L_o) is the same as a unit of length in a location with gravity (L_g) at a given instant in time (midpoint observer perspective). Both of these lengths can be simultaneously contracting as the universe ages and yet maintain $L_o = L_g$. More will be said about this in chapter 14.

Planck Sphere: We will now define terms necessary to quantify and analyze the evolution of the universe. Planck spacetime has energy density equivalent to a sphere that is Planck length in radius containing the maximum zero point energy permitted by the properties of spacetime. This maximum energy is equal to ½ Planck energy (½ $E_p \approx 9.78 \times 10^8$ J). Most important, Planck

spacetime has $\Gamma_u = 1$ and all the energy possesses quantized angular momentum. The implications of these conditions will be explained later.

We will call the basic quantized unit of Planck spacetime a "Planck sphere". Besides having a radius of Planck length it also has quantized angular momentum of ħ (perhaps $\frac{1}{2}\hbar$). The choice between these two will have to be worked out by others, but $\hbar$ is more reasonable and we will use $\hbar$ in the following discussion. The concept of a Planck sphere is introduced primarily because this is a convenient reference to help us visualize the apparent expansion of the universe in units of proper length. We can describe what happens to the radius, energy and angular momentum that are initially in the Planck sphere. In this way the evolution of the Planck sphere becomes an easy reference for what happens to all the spacetime in the universe.

Angular Momentum in Planck Spacetime: Besides having energy density, Planck spacetime also must have a distributed density of quantized angular momentum. Our current universe possesses quantized angular momentum primarily in the form of CMB photons. Currently the CMB has the photon density of a 2.725° K black body cavity which is about 4×10^8 photons/m^3. The angular momentum ($\hbar$) possessed by this vast number of photons exceeds by a factor of about 10^8 the internal angular momentum possessed by baryonic matter in the universe (ignoring dark matter). If we simply imagine reversing time, all the CMB photons would be compressed and blue shifted until each photon was reduced to a sphere that is Planck length in radius. This idea can be checked with a plausibility calculation that will be made later.

Starting the Universe from Planck Spacetime: The remainder of this chapter will look at the evolution of the universe. This combines the concepts of an increasing Γ_u and Planck spacetime with the Big Bang model of expanding spacetime. This combination allows us to introduce new ideas in the familiar context of the Big Bang model. In the next chapter we will drop the Big Bang model and switch completely to the proposed spacetime transformation model that is more compatible with the premise that the universe is (and always was) only spacetime.

We are setting the stage for the start of the Big Bang. In this thought experiment we are going to witness the Big Bang from the vantage point of an infinitely small point that is at the center of a Planck sphere at the start of the Big Bang. From this vantage point we are going to pay particular attention to what happens to the approximately one billion Joules ($\frac{1}{2}\ E_p$) that is the energy of the Planck sphere that surrounds our infinitely small vantage point. All of this energy is initially within a distance of Planck length of our location.

We will imagine that we can watch the evolution the universe (watch the Big Bang) from our infinitely small vantage point within Planck spacetime. We are also going to equip ourselves with two clocks that will start running the moment that time starts to progress forward at the start of the Big Bang. Both of these clocks are digital clocks that run in quantized increments of Planck time ($\sim 5.4 \times 10^{-44}$ second steps). One of these clocks will be called the "cosmic clock"

that measures the proper age of the universe in the comoving frame of reference. Time on the cosmic clock, expressed in dimensionless Planck units of time, will be designated with the symbol $\underline{\boldsymbol{\tau}}_u$ (bold and underlined designates Planck units) and defined as:

$\underline{\boldsymbol{\tau}}_u \equiv \tau_u/t_p$.

The other clock will be called the "Γ=1 clock". This is a hypothetical clock that runs at the rate of time of an empty universe where the background gravitational Γ_u is always equal to 1. Time on the Γ=1 clock also is in Planck units of time and designated as $\underline{\boldsymbol{t}}_u$. Since the universe started with $\Gamma_u = 1$, the Γ=1 clock can also be thought of as a clock that continued running at the rate of time that was present at the beginning of the Big Bang. This clock is keeping coordinate time which is the "dt" term in the equation: $\Gamma_u = dt/d\tau_u$.

The Big Bang Starts: Now for the big event: Time starts and the Big Bang has begun. Actually, the observable, proper energy density defining Planck spacetime only exists in this form during the first unit of Planck time. After this brief time the observable energy density (energy with spin) rapidly drops to less than $U_{ps} = 5.53 \times 10^{112}$ J/m^3 and Γ_u rapidly increases ($\Gamma_u > 1$). However, the total energy density of the universe remains constant when we add together the vacuum energy density (no spin) plus the observable energy density (with spin) as explained later. It is not possible to talk about what happens "before" time starts to progress (when $\underline{\boldsymbol{t}}_u = 0$) because this implies that the rate of time has stopped and there is no motion of waves in spacetime. We will adopt the position that there was no time "before" $\underline{\boldsymbol{t}}_u = 1$. In order for the spacetime field to be energetic, there must be moving dipole waves in spacetime (there must be dynamic spacetime). There is no energy in static spacetime. If the spin in each Planck sphere is $\hbar$, then this is the equivalent of one photon per sphere. Initially the energy of this single photon per Planck sphere would be equal to the maximum zero point energy which is ½ E_p. Another way of saying this is that all the energy of Planck spacetime had quantized angular momentum and was "observable" energy. Today only about 1 part in 10^{122} of the total energy in the universe has quantized angular momentum and is "observable".

We are going to assume that time starts simultaneously everywhere within the Planck spacetime. This obviously requires either faster than speed of light communication or some other way of synchronizing the start of time. The only justification for this assumption is that observations today indicate a simultaneous initiation of the Big Bang. Perhaps this can be rationalized by assuming that in this highest possible energy density, the entire universe was like a single particle that exhibited the instantaneous communication of entanglement or unity. We will not dwell on this point. This assumption seems more understandable than starting with a singularity, but ultimately the simultaneous initiation of the Big Bang (simultaneous starting of time) is just a starting assumption.

At the instant that the Big Bang starts, our imagined vantage point is completely isolated. There has been no time for any communication with any of the surrounding energy in Planck spacetime and there has been no nonlinear distortion of the waves in spacetime that constitute Planck spacetime. This means that at the start of the Big Bang there is no preexisting gravitational effects – no preexisting gravitational acceleration and for the first unit of Planck time, $\Gamma_u = 1$ everywhere in the universe. Therefore, for the first unit of Planck time, the cosmic clock and the $\Gamma=1$ clock both run at the same rate of time $(d\tau_u = dt)$. This starting condition is similar to the dust cloud thought experiment where we started with gravity "turned off".

Increasing Value of Γ_u: The first tick of Planck time was easy because it happens with $\Gamma_u = 1$. Our "particle horizon" was equal to Planck length which is the boundary of the Planck sphere. The question is: What happens with subsequent ticks as our particle horizon expands beyond the boundary of our Planck sphere? Speed of light contact is being made with adjacent waves in spacetime just beyond the boundary of our Planck sphere. The nonlinearity of spacetime begins to affect these waves causing an increase in the background gravitational gamma from $\Gamma_u = 1$ to $\Gamma_u > 1$. The rate of time slows and proper volume increases, but there is no time gradient. All points are experiencing the same rate of time so there is no tendency for gravitational attraction or gravitational collapse. This is the start of the immature gravity condition that continues today. A uniformly increasing Γ_u eliminates the time gradient necessary for gravitational attraction.

For the first unit of Planck time the cosmic clock and the $\Gamma = 1$ clock were synchronized. However, all subsequent ticks exhibit the fact that the cosmic clock has a rate of time that is slowing relative to the $\Gamma=1$ clock. Also the proper distance to the boundary of the Planck sphere increases. Both of these effects are the result of Γ_u increasing which in turn is the result of the nonlinear effects of spacetime accumulating. The waves in spacetime responsible for the energy density of Planck spacetime have begun to distort. Unlike the gravity produced by an isolated mass, inside the early universe the stressed spacetime is a homogeneous distribution of energy that extends beyond our particle horizon. This wave distortion would produce an increase in the background gravitational gamma Γ_u similar to the increase in the background Γ in the dust cloud thought experiment. However, because the universe started with the maximum possible quantized energy density, the effects on volume and the rate of time are vastly larger than in the dust cloud thought experiment.

Spacetime Evolves into Different Types of Energy: The distortion free oscillating spacetime (Planck spacetime) that was present during the first tick of the cosmic clock begins to exhibit distortion for all subsequent ticks. The nonlinearity of spacetime causes the waves in spacetime to distort. The distorted waves can be through of as being split into three component parts. These three components are:

1) The distortion free component of the original waves in spacetime that retain the original quantized angular momentum (spin). This is proposed to become the source of everything in the universe that we can sense today (all fermions and bosons).
2) The non-oscillating component (the A_β^2 component of chapter 6) that results when the waves in spacetime are distorted by the nonlinearity of spacetime. This is responsible for gravitational effects and also responsible for the background Γ_u of the universe.
3) The high frequency oscillating component of gravity (the $A_\beta cos2\omega t$ component described in chapter 6) proposed to be responsible for vacuum energy. This component lacks angular momentum and becomes the vacuum fluctuations component of the universe today.

Therefore starting with Planck spacetime means that any nonlinear distortion caused by an interaction of waves in spacetime (gravitational contact with surrounding energy) must increase Γ_u. However, as Γ_u increases this also increases proper distance between stationary points and decreases the rate of time. New energy is always adding its gravitational influence as the particle horizon expands and new energy comes into view. As Γ_u increases, the proper distance to the particle horizon increases even faster than the speed of light because our unit of length is also shrinking relative to coordinate length $\mathbb{R}$. The value of Γ_u increases towards infinity.

Avoiding Gravitational Collapse: What prevents Planck spacetime from collapsing into a singularity? In fact, when $\underline{\tau}_u = 1$ each Planck sphere appears to contain the exact amount of energy required to become a black hole with a Schwarzschild radius equal to Planck length. Even today the proper energy density of spacetime is approximately the same as the energy density of Planck spacetime. According to general relativity, energy in any form produces gravity. Therefore, general relativity considers the energy density of the spacetime field required by quantum mechanics to be a ridiculously large number ($\sim 10^{120}$ times larger than the critical energy density of the universe). What prevents the energy density of the spacetime field from collapsing into a black hole? A partial answer will be given here and additional details will be given in the next chapter.

Think of the energy density of the spacetime field as being the necessary ingredient to give the spacetime field properties such as a speed of light, impedance, a gravitational constant, elasticity, etc. Therefore it is an oversimplification to say that energy in any form creates gravity. The more correct statement would be that any form of energy that possesses quantized angular momentum creates gravity. In other words, fermions and bosons create gravity. The dipole waves in spacetime that form vacuum energy lack angular momentum and are part of the fabric of spacetime. They have superfluid properties and are as homogeneous as quantum mechanics allows. They are also the necessary ingredient required to support the existence of fermions and bosons.

When rotars with their quantized angular momentum are introduced into an otherwise homogeneous volume of the spacetime field, this is adding an **additional energy density** to the previously homogeneous energy density of the spacetime field. For example, if there was a rotar with Planck energy, then this rotar would have a quantum radius equal to Planck length. The energy density of such a rotar would be equal to the energy density of an equivalent volume of the spacetime field. Therefore, introducing such a rotar into a previously homogeneous volume of the spacetime field would **double** the energy density of that volume of the spacetime field. This doubling reaches the theoretical limit of the properties of the spacetime field and results in the creation of a black hole.

There are no fundamental particles (rotars) with Planck mass/energy. The conditions which create a stellar size black hole or a super massive black hole do not match the total energy density of the spacetime field ($\sim 10^{113}$ J/m^3). However, they do match the interactive energy density U_i previously discussed in chapter 4. Recall from chapter 4 the following:

> The interactive energy density $U_i = F_p/\lambda\!\!\!^{-2}$ is a very large energy density. How does this energy density compare to the energy density of a black hole (symbol U_{bh})? We will designate the black hole's energy as E_{bh} and its defined Schwarzschild radius as $R_s \equiv Gm/c^2$. Ignoring numerical factors near 1 we have:
>
> $$\mathrm{U_{bh}} = \frac{E_{bh}}{R_s^3} = \left(\frac{R_s c^4}{G}\right)\left(\frac{1}{R_s^3}\right) = \frac{F_p}{R_s^2}$$

Therefore, since $U_i = F_p/\lambda\!\!\!^{-2}$ and $U_{bh} = F_p/R_s^2$ it can be seen that if $\lambda\!\!\!^{-} = R_s$ then $U_i = U_{bh}$.

Adding additional energy to a specific volume by introducing matter increases the total energy density and produces the gravitational effects described by general relativity. The largest force that the vacuum energy/pressure can exert is Planck force ($F_\mathrm{p} = c^4/G$). With the rotar model it was stated that the energy density of a rotar implied a specific pressure. This pressure needed to be contained by an offsetting pressure exerted by vacuum energy/pressure. Likewise, the matter of a larger body such as a star has a collective energy density that must be stabilized by offsetting pressure from vacuum energy/pressure. The pressure on a star can be considered as two opposing forces exerted on opposite hemispheres of the star. The maximum force that the spacetime field can exert is Planck force. Therefore the conditions which form a black hole occur when the spacetime field is asked to exert this maximum force. The energy density of a black hole (ignoring numerical factors near 1) is $U_\mathrm{bh} = F_\mathrm{p}/R_\mathrm{s}^2$. The point is that the energy density of spacetime does not form a black hole. Instead, a black hole forms when additional energy density (matter) in introduced to a volume and equals the interactive energy density where $\lambda\!\!\!^{-} = R_s$ in the equation $U_i = F_p/\lambda\!\!\!^{-2}$.

When the universe started at the beginning of the Big Bang ($\underline{\tau}_u = 1$), 100% of the energy of Planck spacetime possessed quantized angular momentum. There was no vacuum energy during the first unit of Planck time. Therefore, the total energy density of a Planck sphere did not form a black hole and the particle horizon was equal to Planck length. The possibility of forming black holes only occurred later when some of the energy of Planck spacetime was converted to vacuum energy. Then it became possible to overload a particular volume of the spacetime field with the combination of vacuum energy and energy with quantized angular momentum (multiple rotars and/or photons). In chapter 14 we will see how it is possible for the proper energy density of the spacetime field to remain constant while the proper volume of the universe expands.

Three Epochs in the Evolution of the Universe: The rate of expansion of the universe (rate of change of Γ_u) is currently believed to have gone through 3 different phases. The following calculations use the current estimates for the rates of expansion of the universe and the current estimates of age of the universe when transitions occur. As improved estimates become available, they should be substituted for the following preliminary estimates.

The first phase is the radiation dominated epoch and is currently believed to have started with the Big Bang and ended roughly 70,000 years after the Big Bang. During this epoch, the scaling factor of the universe grew as: $a_u(t) = \underline{\tau}_u^{1/2}$. Next came the matter dominated epoch from roughly 70,000 years after the Big Bang to about 5 billion years after the Big Bang. The matter dominated epoch is believed to have a scaling factor that grew with a slope characteristic of $\underline{\tau}_u^{2/3}$. However it is not accurate to say that $a_u(t) = \underline{\tau}_u^{2/3}$ because during the radiation dominated epoch the slope was different. Therefore, we will say that during the matter dominated phase the change in scaling factor is $\Delta a_u(t) = \Delta\underline{\tau}_u^{2/3}$. From about 5 billion years until the present we are in what is referred to as the "dark energy" dominated epoch. During this phase a first approximation of the change scaling factor can be described as: $\Delta a_u(t) = \Delta\underline{\tau}_u$. However, the change in scaling factor appears to be more complex than this because the change in the scale factor is probably accelerating. The Λ-CDM model of cosmology has parameters that can be adjusted to permit it to match observations. Fortunately, the key points of the proposed spacetime transformation model can be stated without requiring a precise equation for the scale factor in the "dark energy" dominated epoch.

Radiation Dominated Epoch: The standard Big Bang theory (without inflation) has the scale factor of the universe increase proportional to the square root of time during the radiation dominated epoch $a_u(t) = \underline{\tau}_u^{1/2}$. Even the model of the universe that includes inflation starts off with the scale factor increasing proportional to $\underline{\tau}_u^{1/2}$ between the start of the Big Bang and about 10^{-37} second after the start. The inflation model then has a brief period where a vast exponential expansion takes place. This is then followed by a return to expansion proportional to $\Delta\underline{\tau}_u^{1/2}$.

The spacetime wave model proposed here does not need the hypothetical inflationary exponential expansion to make the universe homogeneous, isotropic and spatially flat. All of this

automatically follows from starting the universe at the highest possible energy density that spacetime can support - Planck spacetime. This energy density is as homogeneous as quantum mechanics allows. These quantum mechanical fluctuations are traceable to the Planck length/time limitation of wave amplitude in the model of the universe based on waves in spacetime. These quantum fluctuations provide the small amount of inhomogeneity required to seed the eventual gravitational formation of stars and galaxies. The symbols and equations that we will be using to characterize the radiation dominated epoch are:

$a_u(t) = \Gamma_u = \underline{\boldsymbol{\tau}}_u^{1/2} = \sqrt{\tau_u/t_p}$ radiation dominated epoch relationships

The Universe at $\underline{\boldsymbol{\tau}}_u = 9$: We will illustrate some important concepts about the early stages of the expansion of the universe with an example. Previously an imaginary vantage point at the center of a Planck sphere was described. Suppose that we return to that infinitely small vantage point and look at the changes that occur 9 units of Planck time ($\underline{\boldsymbol{\tau}}_u = 9$) after the start of the Big Bang. From $\underline{\boldsymbol{\tau}}_u^{1/2} = \Gamma_u$ we obtain that at $\underline{\boldsymbol{\tau}}_u = 9$ the background gravitational gamma of the universe is: $\Gamma_u = 3$. This has a profound effect on spacetime. The scale factor of the universe relative to Planck spacetime (a_u) has tripled. Therefore, the Planck sphere that started with a radius of Planck length l_p now has a proper radius 3 times as large ($r = 3\, l_p$). However, the coordinate radius always assumes $\Gamma_u = 1$, therefore the coordinate radius of the Planck sphere (measured in units of $\mathbb{R}$) remains constant at 1 unit of Planck length ($\mathbb{R} = 1$)

The Hubble sphere with radius r_h around the origin point, has a proper radius of $r_h = c\tau_u$ so when $\underline{\boldsymbol{\tau}}_u = 9$ then $r_h = 9\, l_p$. The Hubble sphere defines the distance where objects seem to be receding at the proper speed of light. The proper distance to the particle horizon (designated r_{ph}) at an instant in time is larger than the Hubble sphere at that same instant in time. This is because the instantaneous proper distance to the particle horizon includes distance that has expanded after a speed of light signal has passed any point. During the radiation dominated epoch it can be shown that the proper distance to the particle horizon is always twice the radius of the Hubble sphere. At age of the universe τ_u, the radius of the particle horizon is $r_{ph} = 2c\tau_u = 18\, l_p$ when $\underline{\boldsymbol{\tau}}_u = 9$ or $\tau_u = 4.85 \times 10^{-43}$ s. Today the value of Γ_u is much larger than 3 (calculated later). Therefore the proper dimensions quoted when $\underline{\boldsymbol{\tau}}_u = 9$ and $\Gamma_u = 3$ would be different today because Γ_u is much larger. However, the coordinate dimensions (measured in units of $\mathbb{R}$) always are constant because they do not scale with Γ_u.

Any signal obtained from the particle horizon has infinite redshift but a signal emitted from inside the particle horizon has less of a redshift. The gravity of an apparently receding mass is less than the gravity of a stationary mass at the same distance. Therefore, the redshift at various distances also affects gravity. It is the combination of the gravity of all the energy inside the particle horizon that together is increasing the background gamma at our observation point. Since all other observation points are experiencing a similar gravitational effect, the background

gravitational gamma of the universe is increasing homogeneously because Planck spacetime started off at the maximum homogeneity permitted by quantum mechanics.

We will now return to our example of the universe when it was 9 units of Planck time old ($\underline{\tau}_u = 9$). At this instant we had: $\Gamma_u = \underline{\tau}_u^{1/2} = dt/d\tau_u = 3$. The rate of proper time shown on the cosmic clock has slowed to a third the rate of time shown on the Γ=1 clock. Also the hybrid speed of light $\boldsymbol{C} = d\mathbb{R}/d\tau_u$ has slowed to a third the proper speed of light expressed by the universal constant $c = dL/d\tau_u$ because of the difference between $d\mathbb{R}$ and dL. Therefore:

$$\boldsymbol{C} = \frac{c}{\Gamma_u} = c/\underline{\tau}_u^{1/2} \qquad \text{(assumes radiation dominated epoch)}$$

The Planck sphere initially contained about 10^9 Joules during the first unit of Planck time when the universe was Planck spacetime. All this energy initially possessed $\hbar$ of quantized angular momentum. Therefore these initial waves were photons in maximum confinement. However, energetic photons can be converted to particles. For example, it has been experimentally proven that two 511,000 eV photons can be converted to an electron/positron pair.

When $\underline{\tau}_u = 9$ and $\Gamma_u = 3$ the photon-like waves have been redshifted by a factor of 3. Therefore, the proper volume of the Planck sphere has increased by a factor of 27 and the "observable energy" (possessing quantized angular momentum) in the Planck sphere has decreased because of redshift by a factor of 3 to about 0.33 billion Joules. Where did the difference in energy go?

Lost Energy Becomes Vacuum Energy: When physics students hear about the cosmic redshift decreasing the energy of photons, they often ask where the energy went. Answers often involve a discussion of stretched wavelengths, and eventually imply that conservation of energy does not apply to the cosmic expansion of the universe. The proposed spacetime transformation model gives a different answer. When the proper volume of the universe expands, a photon loses energy but retains 100% of its proper angular momentum. Therefore the lost energy possesses no angular momentum.

It is proposed that all the observable energy lost by photons is being converted to vacuum energy (zero point energy) that is in a superfluid state that cannot possess angular momentum. In fact, it is not only photons that are losing energy to cosmic expansion. Neutrinos and other relativistic particles (moving relative to the local CMB rest frame) are also losing substantial amounts of observable kinetic energy. This lost energy is also being converted to vacuum energy. In the next chapter we will attempt to calculate the ratio of vacuum energy density to observable energy density in the universe today.

Radiation-Matter Equality Transition: The radiation dominated epoch ended when the energy density in radiation fell to eventually equal the energy density of matter in the universe. The proper energy of matter (such as an electron) does not decrease when Γ_u increases so

eventually radiation energy density falls to equal the average energy density of matter. This transition is called the radiation/matter equality and occurred about 70,000 years after the Big Bang. Before the WMAP probe accurately measured the CMB, this transition was thought to have occurred earlier, perhaps 10,000 years after the Big Bang. However, analysis of the WMAP data has determined that the energy content of the universe at 380,000 years after the Big Bang was 15% radiation, 10% neutrinos, 12% baryonic matter and 63% dark matter. Since both radiation and neutrino energy decrease in energy at virtually the same rate (assuming no new sources), the breakdown at 380,000 years can be generalized as 25% radiation-like energy and 75% energy in matter. These numbers imply the radiation/matter equality occurred about 70,000 years after the Big Bang ($\underline{\boldsymbol{\tau}}_u \approx 4.09 \times 10^{55}$ Planck units of time). It is possible to calculate the value of the background gravitational gamma at the radiation/matter equality transition. This background gamma is important for later calculations and will be designated as: Γ_{eq}.

$\Gamma_u = \underline{\boldsymbol{\tau}}_u^{1/2}$ set $\underline{\boldsymbol{\tau}}_u \approx 4.09 \times 10^{55}$ ($\approx$ 70,000 years)
$\Gamma_{eq} \approx 6.4 \times 10^{27}$ $\Gamma_{eq} = \Gamma_u$ at the radiation/matter equality transition

Therefore, about 70,000 years after the Big Bang the absolute scale factor of the universe was: $a_u = \Gamma_{eq} \approx 6.4 \times 10^{27}$. This means that the Planck sphere increased in radius from Planck length ($\sim 10^{-35}$ m) to about 10^{-7} m (obtained from $l_p \times 6.4 \times 10^{27} \approx 10^{-7}$ m). Furthermore, the redshift that occurred during the radiation dominated epoch decreased the proper energy of radiation by a factor equal to Γ_{eq}. This means that the "observable" energy in the Planck sphere decreased by a factor equal to Γ_{eq} from about a billion Joules to about 1.53×10^{-19} J. All the missing observable energy (i.e. energy possessing angular momentum) was converted to vacuum energy. Therefore the total energy in the Planck sphere (observable energy plus vacuum energy, both measured in units of coordinate energy) remained constant at about 9.78×10^8 Joules at the end of the radiation dominated epoch (discussed later). This can be confusing since there are two different standards for energy the same way that there are two different standards of length (proper and coordinate). The conclusion is that the energy density of the universe has not changed from the Big Bang to today if vacuum energy is included in the energy density. What has changed is that the "observable" energy density of the universe (excludes vacuum energy) has decreased by a factor of about 10^{122}.

After the radiation dominated epoch ended, the next phase was the matter dominated epoch which lasted from about 70,000 years to about 5 billion years after the Big Bang. The scale factor (and Γ_u) during this epoch scales proportional to $\Delta\underline{\boldsymbol{\tau}}_u^{2/3}$. The current epoch is usually referred to as the dark energy dominated epoch and extends from about 5 billion years to the present. The scale factor and Γ_u during this epoch might be linearly increasing proportional to $\Delta\underline{\boldsymbol{\tau}}_u$ or it might be increasing faster than linearly in which case it would be an exponential increase. This is the famous accelerating expansion of the universe and the exact representation of this phase will be left to the astrophysicists.

Γ_{uo} Calculation from Expansion: Our objective here is to determine the current value of the background gravitational gamma for the universe designated Γ_{uo}. We have calculated the value $\Gamma_{eq} \approx 6.4 \times 10^{27}$ for the radiation dominated epoch. The remaining part of the calculation required to determine Γ_{uo} is greatly helped by the fact that the redshift from the radiation/matter equality to the present has been experimentally measured by WMAP. The following quote is from the 5 Year WMAP report[4]; "The equality redshift z_{eq} is one of the fundamental observables that one can extract from the CMB power spectrum[5]". The term "equality redshift z_{eq}" is the value of the redshift since the radiation/matter transition (equality) to the present. This redshift has been measured by WMAP and found to be: $z_{eq} = 3253 \pm 88$. Therefore this number includes all of the redshift that occurred during both the matter dominated epoch and the dark energy dominated epoch until now. This single number includes even accelerated expansion.

Therefore since the redshift z_{eq} equals the change in scaling factor since equality, we can simply multiply this times the previously calculated value of Γ_u prior to radiation/matter equality to obtain the total value of the background gravitational Γ_u of the universe today. We make use of the contention that $\Gamma_u = a_u$ therefore the current values are $\Gamma_{uo} = a_{uo}$.

$\Gamma_{uo} = \Gamma_{eq}\, z_{eq} = 6.4 \times 10^{27} \times 3253$
$\Gamma_{uo} \approx 2.1 \times 10^{31}$ Γ_{uo} calculated from cosmological expansion

This calculation of Γ_{uo} and a_{uo} simply extended the starting assumption (the universe is only spacetime). This means that we begin the universe with Planck spacetime at one unit of Planck time old ($\underline{\boldsymbol{\tau}}_u = 1$) rather than starting with a singularity at $\boldsymbol{\tau}_u = 0$. The calculated expansion incorporated the radiation dominated epoch, the matter dominated epoch and the so called "dark matter" epoch when there was accelerated expansion. The calculation did not incorporate an "inflation" phase. Inflation is an *ad hoc* assumption necessitated when the universe is presumed to start from a singularity.

To keep track of the expansion since the universe was $\underline{\boldsymbol{\tau}}_u = 1$, we will be referencing as our standard of comparison the properties of a Planck sphere when $\underline{\boldsymbol{\tau}}_u = 1$. For example, the proper radius of the Planck sphere was Planck length l_p at that time and $\Gamma_u = 1$. The calculated value of $\Gamma_{uo} \approx 2.1 \times 10^{31}$ says that the proper radius of the Planck sphere today has increased by a factor of about 2.1×10^{31} times. Therefore, the proper volume of the Planck sphere has increased by a factor of about 10^{94} times (2.1×10^{31} cubed).

Γ_{uo} Calculation from Planck Temperature: One advantage of the proposed spacetime transformation model of the universe is that it describes the starting condition of the universe in

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[4] Five-Year Wilkinson Microwave Anisotropy Probe ∗ Observations: Cosmological Interpretation, E. Komatsu1 et.al. The Astrophysical Journal Supplement Series, 180:330–376, 2009 February

a way that we can make both predictions and plausibility calculations that check the model. The current characteristics of the universe have been experimentally measured. It is only the physical interpretation of these measurements that is being called into question. We can do simple calculations extrapolating from the proposed starting conditions to see if the model is reasonable. The first of these plausibility calculations determines the value of Γ_{uo} by comparing the temperature of Planck spacetime to the current temperature of the CMB. The ratio of these two temperatures should be equal to Γ_{uo}. The reasoning is that the temperature of the universe changed inversely with the scaling factor which means that the change in temperature also scaled inversely with the change in Γ_u. To express this relationship we will use the following new symbols

$\mathbb{T}_{ps}$ = temperature of Planck spacetime: $\mathbb{T}_{ps} = ½\, E_p/k_B = 7.08 \times 10^{31}$ °K
$\mathbb{T}_{uo}$ = current temperature of the universe (CMB temperature) $\mathbb{T}_{uo} = 2.725$ °K
Γ_{uo} = current value of the background gravitational gamma of the universe

$$\Gamma_{uo} = \frac{\mathbb{T}_{ps}}{\mathbb{T}_{uo}} = 7.08 \times 10^{31}\ °\text{K}/2.725\ °\text{K} \approx 2.6 \times 10^{31} \qquad \Gamma_{uo} \text{ from ratio of temperatures}$$

This is a fantastic result. From the ratio of temperatures we obtain $\Gamma_{uo} \approx 2.6 \times 10^{31}$ compared to $\Gamma_{uo} \approx 2.1 \times 10^{31}$ from the redshift calculation. This supports the assumption that the starting condition for the Big Bang was Planck spacetime and not a singularity or any other energy density in excess of Planck energy density.

Γ_{uo} Calculation from Total Energy Density: There is another way that we can calculate the value of Γ_{uo} using the energy density of Planck spacetime and comparing this to the total observable energy density of the universe today. The energy density of the universe today is commonly thought to be about 8.46×10^{-10} J/m^3 (equivalent to 9.4×10^{-27} kg/m^3). However, this is a calculated number based on the concept that the universe must maintain a critical density. Only about 27.9% of this energy density or 2.36×10^{-10} J/m^3 is "observable" mass/energy consisting of fermions and bosons (including dark matter). Dark matter is considered "observable" because the gravitational effects of dark matter are clearly observable. Only the observable 2.36×10^{-10} J/m^3 is traceable to Planck spacetime. The remaining approximately 72.1% of the "critical" energy density (8.46×10^{-10} J/m^3) is currently attributed to dark energy. Almost all this dark energy has supposedly been added to the universe since the universe was about 5 billion years old. It did not originate with Planck spacetime and therefore will be excluded from this calculation. Therefore, the current energy density of the universe that excludes dark energy is about 2.36×10^{-10} J/m^3. This will be called the "currently observable energy density of the universe" and designated with the symbol U_{obs}.

There is another way of calculating the value of Γ_{uo} using only U_{ps}, U_{obs} and z_{eq}. The reasoning is that the universe started with Planck spacetime with energy density of $U_{ps} \approx 5.53 \times 10^{112}$ J/m^3 and today the observable energy density is $U_{obs} \approx 2.36 \times 10^{-10}$ J/m^3. There are two reasons for

this change in energy density. First, the volume of each Planck sphere increased by a factor of Γ_{uo}^3 because the radius of the Planck sphere increased by a factor of Γ_{uo}. Secondly, the cosmic redshift reduced the energy in the Planck sphere during the radiation dominated epoch. This epoch started with $\Gamma_u = 1$ and ended roughly at the radiation/matter equality with a background gamma designated as Γ_{eq}. We do not experimentally know the value of Γ_{eq}, but we do experimentally know the redshift that has occurred since the radiation/matter equality. As previously stated, this redshift value has been measured by WMAP and found to be $z_{eq} = 3253 \pm 88$. The value of Γ_{uo} is $\Gamma_{uo} = \Gamma_{eq} z_{eq}$ therefore $\Gamma_{eq} = \Gamma_{uo}/z_{eq}$. The initial energy density of Planck spacetime was reduced both because of expansion (a factor of Γ_{uo}^3) and because of cosmic redshift (a factor of Γ_{eq}). We can now calculate the value of Γ_{uo} using this knowledge.

$U_{ps}/U_{obs} = \Gamma_{uo}^3 \times \Gamma_{eq}$ set $\Gamma_{eq} = \Gamma_{uo}/z_{eq}$
$U_{ps}/U_{obs} = \Gamma_{uo}^4/z_{eq}$
$\Gamma_{uo} = (U_{ps} z_{eq}/U_{obs})^{1/4}$
set $U_{ps} = 5.53 \times 10^{112}$ J/m^3 $U_{obs} = 2.36 \times 10^{-10}$ J/m^3 $z_{eq} = 3253$
$\Gamma_{uo} = 2.95 \times 10^{31}$ Γ_{uo} calculated from U_{ps}, U_{obs} and z_{eq}

This is another successful plausibility calculation that supports the model that the universe started as Planck spacetime because this value of Γ_{uo} generally agrees with the previous two values of Γ_{uo}.

Calculation from Energy Density of the CMB: The CMB currently has energy density equal to the energy density of 2.725 °K black body radiation: $U_{CMB} \approx 4.2 \times 10^{-14}$ J/m^3. Through the entire lifetime of the universe, the energy density in radiation has scaled proportional to $1/a^4$. Therefore if we only track the energy density of radiation we have an extremely simplified model of the universe. This assumption ignores all the fermions and other bosons which have about 5,000 times greater energy density than the energy density of photons in the CMB. Therefore, this greatly simplified assumption represents a rough <u>upper limit</u> estimate of Γ_{uo}. We assume that the universe started as Planck spacetime with energy density of $U_{ps} \approx 5.53 \times 10^{112}$ J/m^3 and through expansion achieved the current energy density of just the U_{CMB}. The cosmological redshift plus increased volume resulted in a $1/a^4$ scaling of energy density.

$\Gamma_{uo} \approx (U_{ps}/U_{CMB})^{1/4} \approx (5.53 \times 10^{112}/4.2 \times 10^{-14})^{1/4} \approx 3.4 \times 10^{31}$

I find it surprising that this simplified estimate that includes only radiation achieves a relatively close value for Γ_{uo}. The reason is that the greatest expansion factor occurred when the universe was radiation dominated therefore most of the energy loss in fact scaled as $1/a^4$. This Γ_{uo} value would more closely approach the previous three values if we included the relativistic energy of particles in the early universe which are similar to radiation because they also exhibit a relativistic "redshift".

Calculation from Spin: There is one last calculation that I find amazing. It is based on the assumption that quantized spin should be approximately conserved. The term "quantized spin" is best defined with an example. Two gamma ray photons, each with ħ spin, can interact to form an electron and a positron. These two fermions each have spin of $\frac{1}{2}\hbar$. The concept of quantized spin ignores spin direction and makes no distinction between ħ spin and $\frac{1}{2}\hbar$ spin. To determine the total number of quantized spin units we merely add together the number of bosons and fermions ($\hbar$ and $\frac{1}{2}\hbar$ units of spin are treated the same).

We know the density of quantized spin units in Planck spacetime and we know the density of photons and fermions in the universe today (except for dark matter). The spacetime based model of the universe does not require the exchange of virtual particles to transmit forces so no quantized spin is allotted to virtual particles. However, the assumption that there is large scale preservation of quantized spin is questionable. For example, two photons can be absorbed and reemitted as a single photon. However, with black body radiation there is large scale preservation of the total number of photons because the numerous absorptions and reemissions average out. For this calculation to be accurate we will make the questionable assumption that quantized spin has a similar averaging. If the answer is reasonable, then this will support the accuracy of this assumption.

Planck spacetime had $\hbar$ spin in each Planck sphere with initial volume of $(4\pi/3)l_p^3 = 1.77 \times 10^{-104}$ m^3 or a quantized spin density of 5.65×10^{103} spin units/m^3. Today matter dominates the universe but the quantized spin units contained in observable matter is small compared to the quantized spin in the CMB. Ordinary matter is 4.6% of the "critical density" of the universe. Therefore the density of ordinary matter has a density of about 4.3×10^{-28} kg/m^3. This is equivalent to about ¼ hydrogen atom per cubic meter. Since a hydrogen atom has 3 quarks and one electron, ¼ hydrogen atom per cubic meter is equivalent to about 1 quantized spin unit per cubic meter.

Recall that the spacetime based model has no virtual photons, gravitons or gluons. If there really are gravitons, etc. then this calculation should be wrong by many orders of magnitude. The quantized spin in the photons of the CMB dominate baryonic matter because the 2.725°K blackbody CMB photon density is 4.2×10^8 photons/m^3 compared to about 1 fermion/m^3 for ordinary matter. The photon density of starlight is also considered insignificant because it has been estimated[6] that the density of starlight photons is less than 1% of the photon density of the CMB. We will also temporarily ignore the spin in neutrinos and dark matter. Therefore, with these exceptions the quantized spin of the CMB dominates the universe.

If each Planck sphere contained one unit of quantized spin in Planck spacetime and if there was preservation of quantized spin, then we would expect that the expanded Planck sphere would still on average contain one unit of quantized spin. The best estimate of the current proper radius

[6] Paul Davies, 1982 The Accidental Universe, Cambridge University Press ISBN 0-521-24212-6

of this Planck sphere is: $l_p\Gamma_{uo} \approx l_p \times 2.6 \times 10^{31} \approx 4.2 \times 10^{-4}$ m or a volume of about 3.1×10^{-10} m^3. This estimate uses the value of Γ_{uo} obtained from the ratio of temperatures ($\Gamma_{uo} \approx 2.6 \times 10^{31}$). This number represents the middle of the range of values and is obtained from the simplest calculation. Therefore, assuming spin preservation we would expect that the current density of quantized spin units would be 3.2×10^9/m^3. It appears as if the CMB photon density of 4.2×10^8 photons/m^3 is low by a factor of about 7.6. However this is actually very good agreement considering that the volume has expanded by a factor of about 10^{94} from: $\Gamma_{uo}{}^3 = (2.6 \times 10^{31})^3 \approx 10^{94}$. In fact, compared to 10^{94}, this small factor could be explained by not including a numerical factor near 1 such as 2π.

Dark Matter Calculation: Even though we should be satisfied with an agreement that is quite accurate considering that it covers a range of 10^{94}, we still have not accounted for neutrinos and dark matter. Suppose that we assume that statistically there is virtually prefect preservation of quantized spin. This assumption gives us the opportunity to estimate the energy of a dark matter particle (rotar). Using 4.2×10^8 photons/m^3 and an expanded Planck sphere volume of 3.1×10^{-10} m^3/sphere we have:

4.2×10^8 photons/m^3 $\times$ 3.1×10^{-10} m^3/sphere = 0.13 photons/sphere

Assuming spin preservation and $\Gamma_{uo} \approx 2.6 \times 10^{31}$, there should be 1 spin unit per sphere therefore we are missing 0.87 spin units/sphere. The average density of dark matter in the universe is about 2.2×10^{-27} kg/m^3 or an energy density of 1.9×10^{-10} J/m^3. The current volume of a Planck sphere is 3.1×10^{-10} m^3, therefore combining these we have:

1.9×10^{-10} J/m^3 $\times$ 3.1×10^{-10} m^3/spin unit $\times$ (1/0.87) = 6.8×10^{-20} J/spin unit

The implied energy per dark matter fundamental particle is 6.8×10^{-20} J $\approx$ 0.4 eV. Perhaps this is a coincidence, but out of the many orders of magnitude involved in this calculation, the answer of about 0.4 eV is in the energy range currently attributed to neutrinos and it is far removed from the $>10^{10}$ eV energy range assumed for the hypothetical WIMP dark matter particle model. For example, a photometric redshift survey[7] has set an upper limit of 0.28 eV/c^2 on the sum of the masses of the three types of neutrinos known to exist. An analysis of the Planck space probe data has set an upper limit (0.23 eV/c^2) on this mass sum[8]. Allowing for the speculative nature of this result, this surprising result warrants a new examination of dark matter candidates.

Can Neutrinos Be Dark Matter? Neutrinos have been discounted as possible explanations of dark matter because they are considered to be "hot dark matter" propagating at velocity in

[7] Thomas, S.A.; (2010). "Upper Bound of 0.28 eV on Neutrino Masses from the Largest Photometric Redshift Survey". *Physical Review Letters* **105** (3): 031301.arXiv:0911.5291

[8] Planck Collaboration, "Planck 2013 results. XVI. Cosmological parameters". *Astronomy & Astrophysics* **1303**: 5076.arXiv:1303.5076

excess of 0.1c. They have such low rest mass that even at a temperature of about 1° K, they would have a velocity much greater than the escape velocity of a galaxy. For example, the Milky Way galaxy has an escape velocity of roughly 600,000 km/s. Also, in the early universe a high density of ultra-relativistic neutrinos would excessively homogenize the CMB distribution. However, the leading candidate for dark matter (a WIMP) also has problems. For example, the hypothetical fundamental particle of a WIMP ($\sim 10^{10}$ to 10^{12} eV) must not exhibit any electromagnetic or strong interaction. Therefore these hypothetical particles would not experience collisions with baryonic matter except through the unlikely event of a weak interaction. Most important, the WIMPs cannot lose kinetic energy by EM radiation to form a stable gravitationally bound orbit.

Think about the required properties of a WIMP particle. It must have such a high probability of being formed that in the early universe, that over 80% of the energy that was destined to become a fermion would have had to go into the formation of these highly energetic particles. In all other respects, the lowest energy particles are the most stable and have the highest probability of surviving to today. If a WIMP is dark matter, then this trend should be reversed. A high energy island of stability would have to exist and over 80% of the rest mass in the universe would have to currently exist as WIMPs.

Now look at the ease with which neutrinos are produced. They are formed with the birth of almost every new particle. They are the lowest energy fermion known and they are known to have long term stability. Also, the low mass/energy of neutrinos more easily forms a mass distribution around a galaxy that is characteristic of the dark matter spherical "halo" provided that they can somehow be slowed to fit the definition of cold dark matter. However, a plausible method for them to lose kinetic energy and cool to less than about 0.01 °K must be suggested. Neutrinos at 2.7 °K would greatly exceed the escape velocity from galaxies. However, neutrinos at a temperature in the range of 0.01 °K would have the required properties.

Neutrinos have the following advantages: 1) They are known to exist, 2) They are known to be produced in large numbers in the early universe and 3) They are known to only interact with ordinary matter by the weak force. Using the known properties of neutrinos, the density of neutrinos has been estimated[9] at about $^3/_{11}$ of the CMB photon density per species. Therefore the 3 species of neutrinos would have a total density of about 82% of the photon density ($\sim 3.4 \times 10^8/\text{m}^3$ for 3 species). This is not quite the density required to satisfy the missing quantized spin (requires $\sim 2.8 \times 10^9/\text{m}^3$), but it is within an order of magnitude. Even though this is not enough, the known formation mechanisms make them the most abundant fermion in the universe.

A rotar model of a neutrino with internal energy of 5×10^{-20} J (about 0.3 eV) would have a quantum radius of $\lambda\!\!\!^{-}_c = \hbar c/E_i \approx 6.3 \times 10^{-7}$ m or a quantum volume of about 10^{-18} m^3. The energy

[9] J Rich; Fundamentals of Cosmology (second edition 2009); Springer, Heidelberg, New York

density of a 0.3 eV rotar would be about 10^{24} times smaller than the energy density of an electron. The enormous difference in energy density of neutrinos compared to any other fundamental particle suggests the possibility that perhaps neutrinos also possess other characteristics not observed with other fundamental particles.

Neutrino flavor oscillation has been well documented experimentally. However, it is difficult to explain how neutrinos can change their rest mass if they are visualized as propagating through an empty vacuum. The usual explanation invokes the neutrinos existing simultaneously in three states that differ slightly in mass/energy. These three states would have three slightly different de Broglie frequencies when they are moving relative to an observer. The three frequencies can then constructively and destructively interfere with each other producing what is a change in neutrino flavor (mass). However, this explanation has problems. It is difficult to devise an explanation which allows for a change in rest mass while maintaining both a conservation of energy and a conservation of momentum.

I would like to propose a new consideration which is best explained by an example. The so called "MSW effect" occurs when neutrinos pass through matter such as a star and achieve a resonance with electrons. This is analogous to introducing a different index of refraction for each of the 3 neutrino flavors and results in an increase in flavor oscillation frequency. The mystery of neutrinos changing their mass ceases if we postulate an interaction with other particles because conservation laws hold if other particles are introduced.

Suppose that we assume that there is some mechanism by which neutrinos can be cooled to a temperature less than 0.01 degrees K. Then neutrinos would exhibit the properties of dark matter. At the earth's distance from the galactic center, the energy density of dark matter is about $3x10^{14}$ eV/m^3. If we assume neutrinos to have energy of about 0.3 eV, then this works out to about 10^{15} neutrinos/m^3 at the earth. With this density, the experiments conducted on earth are not measuring the flavor oscillation rate in a total vacuum. Our best vacuum would still contain about 10^{15} neutrinos/m^3. The interesting point is that an interaction between neutrinos would produce acceleration and deceleration of fermions with rest mass. This would generate gravitational waves and cooling of neutrinos.

Perhaps this is an over simplification, but a flavor oscillation which involves an interaction between neutrinos with different energy resulting in a slight mass change would involve acceleration and deceleration of matter. This should produce a small gravitational wave. If this happens, it would represent a loss of kinetic energy relative to the cosmic microwave background (CMB) rest frame of reference. Neutrinos which originated at the Big Bang could possibly be cooled by gravitational wave emission to a temperature far below the temperature of the CMB photons. If this additional cooling occurs to an extent that neutrino temperature is lowered to less than about 0.01 degree K, then neutrinos would qualify as being cold dark matter.

Summary of the Γ_{uo} Calculations: We took a deviation in the discussion of dark matter. However, now we will return to the earlier discussion of the Γ_{uo} calculation. We have now

calculated the value of Γ_{uo} several different ways and they all give about the same answer. The closeness of the results obtained with very different approaches supports the model being used. We will use the value $\Gamma_{uo} \approx 2.6 \times 10^{31}$ as representative of the range of values calculated here for future calculations. Using this value, today each Planck sphere has expanded to a proper radius of $l_p \times \Gamma_{uo} \approx 0.42$ mm. However, measured in coordinate units which presume $\Gamma_u = 1$, the Planck sphere still has a radius of $\mathbb{R} = 1$. It also appears to still have on average 1 unit of quantized spin. The analysis of the spin per Planck sphere will be made in the next chapter.

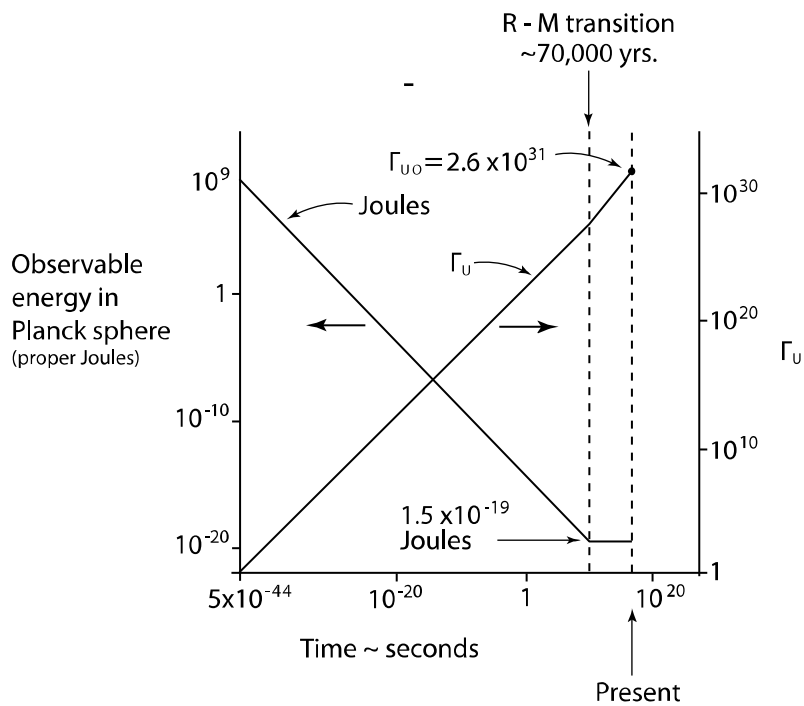

FIGURE 13-4 Left Scale: Plot of the observable energy in the Planck sphere over the age of the universe. Right Scale: Plot of the background gravitational gamma of the universe Γ_U over the age of the universe.

Graph Showing the Evolution of Γ_u and Observable Energy: Figure 13-4 shows two superimposed graphs that use the same time line but different Y axis scales. Note first that the X axis is a log scale of the age of the universe in seconds. The time scale extends from 5×10^{-44} s which is 1 unit of Planck time to 10^{20} seconds which is an age of about 3 trillion years. The present age of the universe is about 4.3×10^{17} seconds ($\sim 13.8 \times 10^{9}$ years) and is designated with an arrow and a vertical dashed line.

The graph line designated Γ_u is the value of the background gravitational gamma of the universe (Γ_u). This graph uses the right scale which is a log scale extending from $\Gamma_u = 1$ to about $\Gamma_u \approx 10^{32}$. It can be seen from this graph that $\Gamma_u = 1$ at a time of $\tau_u = 5 \times 10^{-44}$ seconds and ends with $\Gamma_u \approx 2.6 \times 10^{31}$ at the present ($\tau_u \approx 4.3 \times 10^{17}$ s). Note that there is a slight change in the slope of

this line as it crosses the vertical line designated R-M transition. This is the transition between a radiation dominated universe and a matter dominated universe that occurred about 70,000 years after the beginning of the universe (the Big Bang). There should also be another slope change at the transition between the matter dominated epoch and the dark energy dominated epoch. However, this slope change is so small that it does not show up on this log-log graph.

The other graph (designated "Joules") uses the left scale and is the observable energy in the Planck sphere (also a log scale). A sphere Planck length (l_p) in radius started with about 1 billion Joules when the universe was Planck spacetime for the first unit of Planck time. Over the age of the universe as Γ_u increased, the proper radius of this sphere increased and equaled $\Gamma_u l_p$. The proper energy of this imaginary Planck sphere decreased during the radiation dominated epoch by a factor of 6.4×10^{27} from about 10^9 J to about 1.5×10^{-19} J and then the proper energy generally has remained constant since the end of the radiation dominated epoch. Therefore, note the flat line from an age of about 70,000 years to the present. However, the energy on an absolute scale where $\Gamma_u = 1$ continues to decrease as Γ_u increases. For example, the decreasing rate of time makes it appear that the Compton frequency of fundamental particles is constant. However, if we timed the Compton frequency of an electron using the $\Gamma=1$ clock, we would find that on this absolute time scale, even the Compton frequency of an electron would be slowing down each second. It is not noticeable because our cosmic clock is slowing down at the same rate.