# Order *versus* Chaos in a Steady-State Cosmology

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*It is shown that evidence claimed to reveal an irreversible universe can be explained in a steady-state universe. The age of rocks is local. The abundances of the elements is established in stars and novas. The cosmological red shift is a gravitational red shift, the value of the Hubble constant being thus derived. Olber's paradox is resolved by the cosmological red shift. The 2.7 K background is shown to be the cosmologically red shifted light from the farthest galaxies. The second law of thermodynamics is obeyed for local entropy reducing or ordering processes (such as life) by excess high entropy, or chaos, being radiated off into deep space as thermal radiation. The universe is then rejuvenated by the high entropy radiation, or chaos, in deep space being converted gravitationally back into low entropy gravitational potential energy, or order.*

## 1. Steady-state cosmology is testable

An expanding universe, a "big bang", or other irreversible cosmologies are not subject to serious scientific test; because there is no way of observing nor of knowing the distant past nor the distant future. Irreversible cosmologies are very convenient for their proponents; because they can never be proved wrong! It is always possible to contrive an appropriate hypothetical nonobservable past or future universe to counter any and all objections. In other words, irreversible cosmologies are not testable. They are thus not really scientific theories.

In contrast, a steady-state cosmology says that the universe in the large over space and time has always been and always will be precisely the same as observed today. It is not possible to escape into fantasy universes that were supposed to have once existed in the far past and or else are supposed to exist in the far future. Steady-state cosmology is a highly restricted mundane sort of theory. All conjectures about past and future universes, that must remain the same as the universe today, can be tested against observations of the universe today. Steady-state cosmology is not a convenient theory for its proponents; because it can be proven wrong. It is thus an actual scientific theory.

Many steady-state models of the universe have been proposed over the years by others, who have offered various explanations of the available evidence without having to assume an irreversible expanding universe. A few may be mentioned: Jaakkola (1991), Zwicky (1929), Kropotkin (1991), Rudnicki (1991), Marmet (1991), Van Flandern (1995), Huber (1994), Nernst (1909-1935), Shlenov (1991), Howusu (1996), Ferrari (1984), and others in the conference volume *Progress in New Cosmologies* (Arp *et al*. 1993). The author (Wesley 1988, 1995b) has also proposed a gravitational theory beyond Newton suitable for a steady-state universe (*cf*. Appendix).

## 2. The age of the oldest rocks

The age of the oldest rocks and minerals, as determined by a variety of methods, is about $4.5 \times 10^9$ years. It is often claimed that this is the age of the *universe*, which implies an irreversible cosmology. Obviously the rocks and minerals that we can lay our hands on need not be an appropriate sample of the rocks and minerals for the entire universe. Deducing the age of the universe from local rocks is like deducing the age of the universe as 4500 years from biblical evidence. One must, however, admit that our very small local corner of the universe must have condensed out of gas and dust into solids about $4.5 \times 10^9$ years ago. This age might be attributed to our local region of the Milky Way Galaxy. It might even be attributed to the age of our whole Galaxy; but it seems a bit presumptions to project this age out onto the whole universe with its endless numbers of galaxies.

This age of the oldest rocks in our immediate neighborhood of $4.5 \times 10^9$ years must be regarded as arising from a short-time local fluctuation in a steady-state universe. Thus, the constant uniform in space and time character of the universe for a steady-state cosmology can only be apparent for times averages much greater than $4.5 \times 10^9$ years and space averages over regions with millions of galaxies.

## 3. Cosmological red shift

The observed cosmological red shift of light with distance is frequently hypothesized to be due to an irreversible expansion of the universe. But in the absence of any other evidence for such an expansion, this expanding universe hypothesis must be regarded as simply *ad hoc*. A hypothesis or theory to explain one fact only is not acceptable; since the *one fact* all by itself is sufficient. The expanding universe hypothesis should be thus ignored. The cosmological red shift provides no evidence against a steady-state cosmology.

Many possible mechanism have been offered to explain the cosmological red shift in a steady-state universe. In particular, "tired light" mechanisms involving gravitation have been proposed by Kropotkin (1991), Zwicky (1929), Ferrari (1984), Van Flandern (1995), Howusu (1996) and Shlenov (1991). In Section 13 below, another gravitational mechanism is presented.

## 4. Abundances of the elements

It was originally hoped that an irreversible "big bang" origin for the universe could account for the observed abundances of the elements. But the abundances of the elements does not appear to be uniform throughout the universe. And nuclear processes in stars and super novas in a steady-state universe are better able to account for the details of the observed abundances of the elements.

## 5. The 2.7 K cosmic background

It has been claimed that the observed isotropic 2.7 K thermal cosmic background radiation, as a presumed remnant of the "big bang", is evidence for the "big bang". Since hydrodynamical fluctuations and instabilities would have to yield a highly anisotropic background today; the observed isotropy of the 2.7 K background is thus rather conclusive evidence against the "big bang". The numerous hypothetical fanciful unrealistic nonobservable conditions for the "big bang" make the "big bang" silly science fiction in any case. The thermal 2.7 K cosmic background was estimated long before the "big bang" was even proposed (*e.g.*, Guillaume 1896). See the excellent review by Assis and Neves (1995).

The 2.7 K cosmic background is effectively simply the cosmologically red shifted light from the most distant galaxies in a steady-state universe. Apart from local inhomogeneities, the radiant energy density in the universe is represented by the background light of the night sky. This radiant energy averaged out over all frequencies is the observed thermal background radiation. The radiant energy density of the universe is thus given by

$$u = aT^4 , \tag{1}$$

where $a = 7.56 \times 10^{-15}$ erg/cm$^3$ K$^4$ is a universal constant and $T = 2.7$ K.

As light passes through space a distance $\Delta r$ it loses energy $\Delta E$ according to the cosmological red shift given by

$$\frac{\Delta E}{E} = \frac{\Delta n}{n} = -\frac{\Delta l}{l} = \frac{H \Delta r}{c} , \tag{2}$$

where $n$ is the frequency, $l$ is the wavelength, and $H$ is Hubble's constant. Dividing Eq. (2) by the time interval $\Delta t = \Delta r/c$, the fractional loss of light energy per unit time in the universe due to the cosmological red shift equals the Hubble constant; thus.

$$H = \frac{\mathrm{d}E/\mathrm{d}t}{E} . \tag{3}$$

The rate of energy loss per unit volume of the thermal background is then given from Eqs. (3) and (1) by

$$uH = aT^4 H . \tag{4}$$

In a steady-state universe this energy loss, Eq. (4), must be replaced by the light radiated from galaxies into the universe. If the number density of galaxies is $r_n$ and the luminosity of each galaxy is $I$, then the rate light energy is supplied per unit volume is $r_n I$ Equating this energy source to the energy loss given by Eq. (4), the equilibrium temperature of the background radiation is given by

$$T = \left( \frac{r_n I}{aH} \right)^{1/4} . \tag{5}$$

If it is estimated that the number density of galaxies in the universe is $10^{-74}$ cm$^{-3}$, and if each galaxy has on the average a luminosity of $8 \times 10^{10}$ times the solar luminosity of $3.8 \times 10^{33}$ erg/sec, and if Hubble's constant is taken as $H = 100$ km/s Mpc $= 3 \times 10^{-18}$ sec$^{-1}$, Eq. (5) yields an estimate of the expected equilibrium temperature for the thermal background radiation of

$$T = 3.4 \text{ K}, \tag{6}$$

which may be compared with the observed temperature of 2.7 K. Since the value of the rate that light energy is radiated into the universe per unit volume, $r_n I$, is uncertain, as well as the value of Hubble's constant; no exact agreement can be expected here. Nevertheless, the agreement is sufficient to indicate that the source of the thermal back-ground radiation is light from galaxies. Since most galaxies are far distant; the thermal background is effectively the cosmologically red shifted light from the most distant galaxies in a steady-state universe.

## 6. Olber's paradox

If the galaxies are evenly distributed in the universe with a number density $r_n$, if each galaxy radiates energy at a rate $I$, and if radiation decreases as the inverse square of the distance from the source, then an observer should receive energy at an infinite rate. The energy flux $\mathrm{d}^2 J$ received from a shell of galaxies of thickness $\mathrm{d}r$ at a distance $r$ from the observer per unit solid angle is given by

$$\frac{\mathrm{d}^2 J}{\mathrm{d}\Omega} = \frac{r_n I r^2 \mathrm{d}r}{4pr^2} = \frac{r_n I \mathrm{d}r}{4p} . \tag{7}$$

The energy received per unit solid angle from all of the galaxies out to infinity is then infinite; thus,

$$\frac{\mathrm{d}J}{\mathrm{d}\Omega} = \frac{r_n I}{4p} \int_0^\infty \mathrm{d}r \to \infty . \tag{8}$$

But the night sky is dark: thus the paradox.

If the cosmological red shift is taken into account, the fractional loss in radiant energy per unit distance is given by Eq. (2), or

$$\frac{\mathrm{d}J/\mathrm{d}r}{J} = \frac{H}{c} . \tag{9}$$

Integrating Eq. (9), the radiant flux falls off exponentially with distance; thus,

$$J = J_o \exp\left( -\frac{Hr}{c} \right) . \tag{10}$$

where $J_o$ is the flux at $r = 0$. Instead of Eqs.(7) and (8), an observer receives a flux per unit solid angle given by

$$\frac{\mathrm{d}J}{\mathrm{d}\Omega} = \frac{r_n I}{4p} \int_0^\infty \exp\left( -\frac{Hr}{c} \right) \mathrm{d}r = \frac{c r_n I}{4pH} , \tag{11}$$

which is no longer infinite.

But the radiant flux of the night sky is known. It is given by the 2.7 K cosmic background. From Eq. (1) the radiant flux per unit solid angle observed is

$$\frac{\mathrm{d}J}{\mathrm{d}\Omega} = \frac{cu}{4p} = \left( \frac{ca}{4p} \right) T^4 . \tag{12}$$

Equating Eqs. (12) and (11) the condition (5) is again obtained. Thus Olber's paradox is also resolved in a steady-state universe when the cosmological red shift is taken into account. The 2.7 K cosmic background is again seen to be the cosmologically red shifted light from the most distant galaxies.

## 7. Second law of thermodynamics

According to the second law of thermodynamics it would appear that the universe must proceed irreversibly from a state of order and low entropy toward a state of disorder and high entropy. Eventually when the universe has reached a state of maximum entropy or maximum statistical probability the universe should be a uniform gas with a uniform constant temperature. All processes should then cease and the eternal "heat death" should prevail. A steady-state cosmology must offer some explanation as to why the universe escapes this fate.

It would appear that the universe today is very far from thermodynamic equilibrium. Time appears to run irreversibly from a unique past to another unique future. Life and other ordering or entropy-reducing processes are able to continue. High utility energy sources are still available to create and maintain thermodynamic order. How can a steady-state cosmology provide a universe that never seems to run down, a universe that is able to continue to escape an apparently inevitable thermodynamic equilibrium?

Nernst (1909-1935) attempted to resolve the "heat death" problem by introducing an *ad hoc* "ether" with drastic physical properties. It must absorb and hold vast quantities of energy per unit volume and also yield material particles on rare occasion by some unspecified mechanism. Although his drastic proposal creates energy of high utility (matter) from thermal energy of low utility, it does not resolve the "heat death" problem. In an equilibrium universe, the "rare" processes are also reversible, so his materialization of matter from his ether also permits the conversion of matter back into his ether, thereby leading to the ultimate "heat death."

A rather mundane and *necessary* process that circumvents the second law with its "heat death" is suggested here in Sections 11 through 14 below. First, the universe is continuously rejuvenated by converting thermal energy of the lowest utility directly into gravitational energy of 100% utility when light is cosmologically red shifted. Second, local *fluctuations* away from equilibrium can be long-lived, of the order of $6\times 10^9$ years. The universe that we observe involves such *fluctuations*.

## 8. Primary law for ordering processes in nature

For a steady-state cosmology it is important to recognize the state of the universe as it exists today. Ordering processes do occur in the universe, but only in localized regions. Local order is created at the expense of global disorder of deep space.

One of the most important laws of nature that governs all statistical thermodynamic processes observed in the universe is *the primary law for ordering processes in nature* (Wesley 1989, 1991), which states:

> *Statistical thermodynamic systems open to deep space with temperatures greater than 2.7 K proceed toward states of lower entropy.*

Since all planets, all gas clouds, stars, and galaxies, that can be seen, are statistical thermodynamic systems with temperatures greater than 2.7 K open to deep space; according to the *primary law* all observable portions of the universe are thus proceeding toward states of greater thermodynamic order, lower entropy, or less chaos.

It might seem that the *primary law* violates the second law of thermodynamics; but statistical thermodynamic processes in nature cannot and do not violate the second law of thermodynamics. If a statistical thermodynamic system in nature is observed to decrease in entropy, then a *larger* increase in entropy must be produced somewhere else in the universe. In particular, the net rate of increase of the entropy of the universe, according to the second law, must be greater than zero; thus,

$$\dot S_{Universe} = \dot S_{System} + \dot S_{in} - \dot S_{out} > 0\ . \qquad (13)$$

where $\dot S_{in}$ is the entropy flow into the system and $\dot S_{out}$ is the entropy flow out of the system. This means that the rate that order is created in a system is less than the entropy production; thus,

$$\left[-\dot S_{System}\right] < \dot S_{out} - \dot S_{in} = \dot S_{production}\ . \qquad (14)$$

A system in nature is driven toward states of lower entropy by the entropy production available. The entropy production is a measure of the potential for order to be created in a system.

The flux of low entropy into a system in nature $\dot S_{in}$ is generally proportional to the rate at which energy is available at some effective temperature $T_{in}$; thus,

$$\dot S_{in} = \frac{\dot Q}{T_{in}}\ . \qquad (14)$$

And the flux of high entropy out $\dot S_{out}$ is generally proportional to the rate that heat $Q$ is radiated off into the environment at some temperature $T_{out}$; thus

$$\dot S_{out} = \frac{\dot Q}{T_{out}}\ . \qquad (16)$$

Since the energy in and out generally remains the same the entropy production is given by

$$\dot S_{production} = \dot Q\left(\frac{1}{T_{out}} - \frac{1}{T_{in}}\right). \qquad (17)$$

In order for ordering processes to occur in a system in nature there has to be an entropy production; and the effective temperature out, $T_{out}$, must be less than the effective temperature in, $T_{in}$.

## 9. Ordering of the Earth driven by sunlight

An example of the application of the *primary law* is the ordering of the Earth's surface driven by sunlight (Wesley 1966, 1967, 1974, 1989, 1991). The ordering is effected primarily by photosynthesis. Energy $dQ$ from the Sun arrives at the Earth with the effective temperature of the Sun's surface of $T = 5800$ K. Since the Earth remains in thermal equilibrium; this energy $dQ$ is eventually reradiated off into deep space with the effective temperature of the Earth's surface of about $T_e = 290$ K. The entropy production $dS$ available to create order on the Earth's surface is then

$$d\,S_{production} = d\,Q\left(\frac{1}{T_e} - \frac{1}{T_s}\right). \qquad (18)$$

The reduction of the entropy of the Earth's surface, being so small, is neglected in this expression (18).

In the $4.5\times 10^9$ year history of the Earth with the present rate of solar irradiation the total entropy production from Eq. (18) is estimated as

$$S_{T_e} = 4.9\times 10^{38}\ \text{erg/K}. \qquad (19)$$

This is a measure of the total potential for thermodynamic order to have been created on the Earth's surface.

The initial ordering step on the Earth is due to photosynthetic life today, which converts gaseous carbon dioxide and liquid water to solid carbohydrates and gaseous oxygen; thus,

$$n\mathrm{CO_2} + m\mathrm{H_2O} \rightarrow \mathrm{C}_n(\mathrm{H_2O})_m + n\mathrm{O_2}, \qquad (20)$$

where $m$ and $n$ are integers. Considering the inverse process of oxidation of carbohydrates, the process is essentially the oxidation of carbon with the release of $3.33\times 10^{11}$ erg/gm of carbon. Assuming this energy is made available at the environmental temperature of $T = 293$ K, the photosynthetic fixation of a gram of carbon represents an entropy reduction of

$$-\frac{\Delta S}{\Delta M} = \frac{\Delta Q}{\Delta M\, T} = 1.14 \times 10^{8} \text{ erg/gm K.} \tag{21}$$

The Earth's atmosphere today consists of 20% oxygen or $1.1 \times 10^{21}$ gm of oxygen. This oxygen may be regarded as the detritus left over from photosynthesis that converted the $4.0 \times 10^{20}$ gm of carbon in $CO_2$ on the primordial Earth to the carbon in solids today, such as in limestone, coal, oil, tar, oil shale, and living biomass. From Eq. (21) this constitutes a net entropy reduction of the Earth's surface by the amount

$$S(\text{fixation of C from } CO_2) = -4.6 \times 10^{29} \text{ erg/ K,} \tag{22}$$

which is small compared with the entropy production, Eq. (19). Today the $CO_2$ in the atmosphere is essentially zero, being only 0.00033 parts by mass of the atmosphere. Its role today is limited to that of a catalyst for entropy reduction, the carbon being continually recycled.

The Earth's surface has also become thermodynamically ordered in other ways (Wesley 1989). Large ore deposits of simple compounds have separated out from the primordial uniform mixture of the elements. Small crystals of complex minerals have become large crystals of simple minerals. And the Earth's biomass, consisting of a pool of low entropy organic compounds, has increased over evolutionary times.

## 10. The birth of a star

An important example is the application of the *primary law* to the formation of a low entropy star from a high entropy gas cloud (Wesley 1966, 1967, 1974, 1991). The condensation of stars out of gas and dust is a natural inevitable process. Even a uniform distribution of gas molecules of constant uniform temperature would eventually yield by random fluctuations momentary localized concentrations of molecules. Such a concentration would gravitationally attract other molecules which would be accelerated toward the concentration. The attracted molecules would thereby convert some of their gravitational energy into kinetic energy. Some of these accelerated molecules would collide with other molecules; and part of their kinetic energy would be converted into electromagnetic thermal energy, which would then be radiated off into deep space. These molecules, having lost some of their kinetic energy would then be no longer able to climb back out of the gravitational potential well formed by the original concentration. These infalling molecules, becoming thereby trapped, would increase the size of the concentration and would thereby increase its gravitational strength. This process may be envisioned as proceeding indefinitely until mass concentrations and temperatures are attained that are large enough for hydrogen to be burned by nuclear fusion. When this happens a visible star is born.

Such a condensation from gas and dust to form a star represents a continual decrease in the entropy of the matter involved, as required by the *primary law for ordering processes in nature*. As a specific numerical example, a cloud of atomic hydrogen with a density of $r = 10^{-22}$ gm/cm$^3$ may be considered. The entropy per mole, $s$, of this tenuous gas cloud is given by the ideal gas formula,

$$s = c_v \ln T + R \ln V + s_o, \tag{23}$$

where $c_v = 3R/2$ is the heat capacity per mole at constant volume for a monatomic gas, $R = 2.0$ cal/mole is the ideal gas constant, $T$ is the absolute temperature, $V$ is the volume, and $s_o$ is an arbitrary reference. constant.

After the gas has condensed into a star it may still be approximated as an ideal gas. The net change in entropy per unit mass $\Delta S_m$ is then given by

$$\Delta S_m = \frac{3R}{2M_o} \ln\left(\frac{T_f}{T_i}\right) + \frac{R}{M_o} \ln\left(\frac{r_i}{r_f}\right), \tag{24}$$

where $M_o$ is the atomic weight of hydrogen, $r_i / r_f = V_f / V_i$, and where the subscript $i$ refers to the initial gas cloud and the subscript $f$ refers to the final star. If the initial gas cloud has a temperature of 15 K and the final density of the star is $r_f = 1.5$ gm/cm and its final temperature is $T_f = 10^7$ K, then from Eq. (24) the net entropy change per unit mass for this numerical example is

$$\Delta S = -62 \text{ cal/gm K.} \tag{25}$$

Assuming that stars do condense out of clouds of gas and dust, this result (25) indicates the truth of the *primary law*.

This numerical example may be seen to obey the second law of thermodynamics. The waste entropy, or entropy production, that is radiated off into deep space is given by the decrease in the gravitational energy, the infall energy, that had to be dissipated in order to form the star $\Delta U$ at some mean effective temperature $\overline{T}$, thus,

$$\Delta S_m(\text{of universe to form star}) = \frac{\Delta U}{M\overline{T}}, \tag{26}$$

where $M$ is the mass of the original cloud or the final star. The gravitational energy that must be dissipated to yield a spherical star of uniform density of radius $r$ and mass $M$ is

$$\Delta U = \frac{3GM^2}{5r}, \tag{27}$$

where $G = 6.67 \times 10^{-8}$ erg cm/gm is the universal gravitational constant. For a star of mass $M = 2 \times 10^{33}$ gm and radius $r = 6 \times 10^{10}$ cm, the entropy per unit mass dissipated as heat at the mean temperature of $T = 1000$ K to form the star from Eqs.(26) and (27) is then

$$\Delta S_m(\text{of universe to form star}) = 3 \times 10^{4} \text{ cal/gm K.} \tag{28}$$

It may be seen that this entropy production, Eq. (28), is two orders of magnitude greater than the entropy reduction, Eq. (25); so the second law of thermodynamics is not violated when a star condenses out from a gas cloud.

The availability of high utility gravitational energy, infall energy, with a utility of unity and the availability of a cold sink, deep space, with a temperature of 2.7 K into which waste thermal energy can be radiated causes or forces the formation of the star.

## 11. Gravitational red shift

When a photon is created in a potential well with a gravitational potential $f_1$ a mass $\Delta m_1$ is converted to photon energy such that $hn_1 = c^2 \Delta m_1$. After the photon is absorbed at a higher gravitational potential $f_2$, its energy $hn_2$ is converted to mass $\Delta m_2$ such that $hn_2 = c^2 \Delta m_2$. Conserving energy, including gravitational energy, gives

$$\Delta m_1 f_1 + c^2 \Delta m_1 = \Delta m_2 f_2 + c^2 \Delta m_2, \tag{29}$$

which then yields the frequency change or gravitational red shift as

$$\Delta n = n_2 - n_1 = \frac{n_1 f_1 - n_2 f_2}{c^2}. \tag{30}$$

In astronomy the final potential $f_2 = 0$ is the potential on the Earth's surface, which is at infinity relative to the surface of a star, where the potential is $f_1$ Dropping the subscript 1, the gravitational red shift observed in astronomy is then simply

$$\frac{\Delta n}{n} = \frac{f}{c^2}\,. \tag{31}$$

Since the gravitational potential $f$ is negative; $\Delta n$ is a decrease.

For the Mossbauer effect used by Pound and Rebka (1960) in the laboratory, the potential difference is $\Delta f = f_2 - f_1 = g\,\Delta z$, where $g$ is the acceleration of gravity and $\Delta z$ is the height between the position of the creation of the gamma ray photon and the position of the absorption of the gamma ray photon. Since $\Delta n f_1/c^2$ and $\Delta n \Delta f/c^2$ are negligible; the laboratory red shift is given by

$$\frac{\Delta n}{n} = -\frac{g\,\Delta z}{c^2}\,. \tag{32}$$

## 12. Gravitational red shift and entropy reduction

It is important to note that the gravitational red shift for thermal radiation constitutes a conversion of the most worthless energy of the lowest utility to the most valuable energy of the highest utility.

The amount of mechanical work $\mathrm{d}W$ that can be gained from a thermal source $\mathrm{d}Q$ at temperature $T$, when the coldest sink available is deep space at the temperature $T_o$ = 2.7 K, is given by an ideal Carnot engine; thus,

$$\mathrm{d}\,W = \mathrm{d}\,Q\left(1 - \frac{T_o}{T}\right). \tag{33}$$

The "utility" of such a thermal heat source may then be taken as the Carnot efficiency $h$, which is the fraction of the heat energy that can be converted to mechanical work; thus,

$$h = 1 - \frac{T_o}{T}\,. \tag{34}$$

It is possible to recover all of the energy that is available as gravitational potential energy as mechanical work; thus, the utility of gravitational potential energy is unity or 100%.

It should be noted that mechanical work constitutes energy that can be used to create the most thermodynamic order or to achieve the greatest entropy reduction in a system. Thus, "utility" of an energy source is appropriately defined as the fraction of the energy that can be converted to mechanical work. In particular, a source of mechanical energy functions like a heat source of infinite temperature. For an environmental temperature of $T_o$ the entropy decrease that can be created is then ($-\mathrm{d}W/T_o$).

The gravitational red shift, converting thermal energy of the lowest utility to gravitational potential energy of the greatest utility, is a rejuvenating process. Worthless thermal energy is converted directly to mechanical energy of the greatest value. In this way the high entropy of thermal energy is converted to low entropy of material systems. This process is opposite to the direction of entropy increase prescribed by the second law of thermodynamics. But the gravitational red shift is not an equilibrium process in a statistical thermodynamic system; thus, the second law of thermodynamics is not applicable; and it is not violated.

Another important feature of the process giving rise to the gravitational red shift is an accompanying effective expansion of mass density. Considering a spherical distribution of matter of constant density, the creation of a photon of frequency $n$ at $r_1$ means a decrease in mass $\Delta m = hn/c^2$ at $r_1$ and a decrease in the effective density of the sphere of radius $r_1$ by the amount

$$\Delta r_1 = -\frac{3\Delta m}{4 p r_1^3}\,. \tag{35}$$

When the photon is absorbed at $r_2$, the effective density of the sphere of radius $r_2$ is increased by the amount

$$\Delta r_2 = \frac{3\Delta m}{4 p r_2^3}\,, \tag{36}$$

neglecting the small red shift here. Roughly, the mean change in mass density following a gravitationally red shifted photon is the average of Eqs.(35) and (36); thus,

$$\Delta r = \frac{\Delta r_1 + \Delta r_2}{2} = -\frac{3\Delta m}{8p}\left(\frac{1}{r_1^3} - \frac{1}{r_2^3}\right). \tag{37}$$

The effective mass density is seen from Eq. (37) to decrease; or there is an effective mass expansion!

## 13. Cosmological red shift is a gravitational red shift

As has been shown in Section 6 above, the cosmological red shift resolves Olber's paradox. It is responsible for the darkness of the night sky. It permits deep space to remain a cold sink at 2.7 K. The existence of this cold sink permits thermodynamic ordering processes to occur as stated by the *primary law*. The cold sink permits the waste thermal energy to radiate off excess high entropy into deep space. The cosmological red shift keeps the universe young. It keeps the universe from the heat death predicted by the second law of thermodynamics. It keeps the universe from running down.

In order to have a steady-state cosmology it is only necessary to find a continuously available mechanism that accounts for the cosmological red shift. The mechanism proposed here is the gravitational red shift. The gravitational red shift permits the most worthless low utility thermal energy to be converted into the most valuable high utility gravitational potential energy.

On a cosmological scale thermodynamic ordering processes involve the condensation of uniform mass distributions into bodies such as stars with the radiation of high entropy waste into deep space. The gravitational red shift permits the reverse process to take place: Waste thermal energy is converted to high utility gravitational potential energy. And mass concentrations are expanded or evaporated back into uniform mass distributions

It is important to note that a universe with a distribution of bodies of condensed matter, such as a distribution of stars, is at a lower gravitational energy than a universe with the same mass uniformly distributed as gas and dust. Thermodynamic ordering processes in the universe, proceeding in the direction of the condensation of mass into objects such as stars, proceeds toward lower gravitational potential energy. The gravitational red shift drives the universe in the opposite direction toward a more uniform mass distribution with a greater gravitational potential energy.

If a finite Newtonian model of the universe is considered where the observer is at the radius $r$ from the "point at infinity", then the gravitational potential is

$$f = \frac{GM}{r} = \frac{4\pi G \rho r^2}{3}, \qquad (38)$$

where $\rho$ is the mass density of the universe and $r$ is the radius. A gravitational red shift then implies

$$\frac{\Delta \nu}{\nu} = \frac{\Delta f}{c^2} = \frac{8\pi G \rho r}{3c^2}\Delta r\ . \qquad (39)$$

In order for this gravitational red shift, Eq. (39), to be the cosmological red shift, as given by Eq. (2), the Hubble constant must be given by

$$H = \frac{8\pi G \rho r}{3c}\ . \qquad (40)$$

Assuming a mass density for the universe of $\rho = 10^{-29}$ gm/cm$^3$ and a radius $r = 8 \times 10^9$ light years = $7.6 \times 10^{27}$ cm, Eq. (40) yields

$$H = 1.42 \times 10^{-18}\ \text{sec}^{-1} = 43\ \text{km/sec Mpc}, \qquad (41)$$

which may be compared with the observed value usually estimated to be between 50 and 100 km/sec Mpc.

Considering the uncertainty of the value of the mass density of the universe $\rho$, the radius of the universe $r$, and the finite Newtonian model for the universe, this result is a satisfactory confirmation of the postulation that the cosmological red shift is a gravitational red shift.

## 14. Fluctuations away from equilibrium

If the process of conversion of thermal energy to gravitational energy were to be in equilibrium, then the reverse process would lead to thermal equilibrium and the ultimate "heat death." To escape the "heat death," not only must the universe be rejuvenated by conversion of energy of low utility to energy of high utility, but some sort of nonequilibrium must occur. In ordinary statistical mechanics such nonequilibrium states are allowed as fluctuations. Statistically temporary condensations of molecules can occur. The life-time of such condensations, or *fluctuations*, depends on the thermal velocities of the molecules and their mean free paths.

As described in the first paragraph of Section 10, a local gravitational condensation of matter, or fluctuation, can occur if the surrounding environment is transparent to thermal photons. The coupling between radiation and gravitation in this process depends upon the mean free paths of the photons. In particular, a photon loses half its energy gravitationally after travelling a distance $D$ given by the cosmological red shift; thus,

$$D = \frac{c\Delta \varepsilon}{H\varepsilon} = \frac{c}{2H}\ . \qquad (42)$$

With this distance as the mean free path of a photon, the life-time $\tau$ of a local *fluctuation* can then be of the order of magnitude

$$\tau = \frac{D}{c} = \frac{1}{2H} = 6.1 \times 10^9\ \text{years}, \qquad (43)$$

assuming a Hubble constant $H$ = 80 km/s Mpc. The age of our local region of the universe, as indicated by the oldest rocks, is about $4.5 \times 10^9$ years. Thus, the local nonequilibrium that we observe may, in fact, be interpreted as a *fluctuation* in the cosmological sense (as already mentioned in Section 2 above).

### Appendix

The author (Wesley 1988, 1991b) has proposed a gravitational theory with only *one* additional assumption beyond Newton: energy density equivalence of the gravitational field energy,

$$\rho' = -(\nabla\Phi)^2 / 8\pi^2 c^2 G\ , \qquad (A1)$$

Here $\Phi$ is the gravitational field, which is included as part of the source in Poisson's equation, thus,

$$\nabla^2\Phi = -4\pi G\rho + (\nabla\Phi)^2 / 2c^2\ , \qquad (A2)$$

where $\rho$ is the matter density. Letting

$$\Phi = -2c^2 \ln \Psi \qquad (A3)$$

yields a Helmholtz equation for $\Psi$

$$\nabla^2\Psi - (2\pi G\rho / c^2)\Psi = 0 \qquad (A4)$$

which may readily be solved for $\Psi$. The new potential $\Psi$ is well behaved, since

$$0 \le \Psi \le 1 \qquad (A5)$$

This rather *necessary* extension of Newtonian gravitation to include the mass-energy equivalence of the gravitational field energy itself has many nice features. It is a theory that is suitable for a steady-state universe. The gravitational force is always very slightly less than the Newtonian gravitational force. The asymptotic solution less than the Newtonian gravitational force. The asymptotic solution of Eq. (A4) within a universe of uniform matter density $\rho$ is

$$\Psi = \Psi_o \exp\left(-\sqrt{2\pi G\rho / c^2}\, r\right), \qquad (A6)$$

which yields a cosmological red shift with a Hubble constant given by

$$H = \sqrt{8\pi G\rho / c^2} = 100\ \ \text{km/s Mpc} \qquad (A7)$$

if the matter density $\rho = 10^{-29}$ gm/cm$^3$. This exponential factor, Eq. (A6), is a natural consequence of the theory. There is no need to introduce such an exponential factor *ad hoc* to resolve the "gravity paradox," as was done by Seeliger (1909), C. Neumann (see North 1965), Einstein (1917) and Friedman (1924).

In contrast to Newtonian gravitation and General Relativity, there is no Chandrasekhar limit to the size of a gravitating body. Thus, black holes are admissible simply as very massive bodies.

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