New Vistas of Space-Time Rebut the Critics

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ABSTRACT

In their critique of my book, Conner and Page fail to keep in mind that their own theory, the Big Bang, does not have a centre of mass. Thus they overlook an obvious contrast between the Big Bang and my cosmology, the existence of a centre of mass in my theory. The centre is crucial because it causes significant differences in gravitational potential energy between various places. During creation week, those energy differences were large enough to produce a region of space in which time ***did not*** *exist.*

This profoundly different zone of timelessness shows up in the mathematical cornerstone of my theory (the Klein metric) as a region of ***Euclidean signature,*** *wherein all four components of the metric are space-like. This zone, which should not be confused with the event horizon, makes the Universe young as measured by clocks on Earth.*

Only recently have relativists realised that some metrics can contain both Euclidean regions and normal space-time. This article is the first time anyone has pointed out such a feature in the Klein metric. Conner and Page relied on the Robertson-Walker metric, which is blind to the Euclidean zone and therefore ***inadequate*** *for the topology of my theory. Conner and Page should have used either the Klein metric or, according to a recent relativist article, a more general form of the Robertson-Walker metric. The Conner-Page criticisms, being based on an incorrect metric, are wrong.*

This paper is not merely a defence of my book. I have taken the opportunity to clarify and develop my theory a few steps further, opening up new and spectacular vistas of the space-time God created.

1. CONNER AND PAGE MISS THE CENTRAL ISSUE

In 1994 my book **Starlight and Time**[1] introduced a young-Universe creationist cosmology based on Einstein's general theory of relativity. It has disturbed theistic evolutionists[2] relying on the Big Bang theory, such as Hugh Ross.[3] In 1995 Ross commissioned two of his supporters, Samuel Conner and Don Page, to criticise my book.[4] The critique by Conner and Page in this issue[5] is the first opportunity they have given me to reply before a scientific audience, and I am delighted to do so.

Though much of my reply will be rather technical, the most important issue is simple: does the Universe have a **centre,** such as a centre of mass? My book says 'yes' and informed Big Bang theorists say 'no'. I say *'informed'* theorists because, as I will show in section 8.2, Conner and Page seem to have forgotten that the theory they are defending, the Big Bang, is **acentric.** The starting assumption of the Big Bang, the Copernican principle, forbids the existence of a centre within the three dimensions we can perceive. The public and even most scientists are often unaware of that fact. If you, the reader, have been unaware of that before now, the introduction to section 8 should be helpful. But as for Conner and Page, I am astonished that the acentricity of the Big Bang should somehow have escaped the notice of two theorists trained in cosmology — especially since I emphasised the point in the book they are criticising! Yet they say nothing about the issue.

A centre of mass is essential to my theory. The centre is gravitationally lower than the rest of the Universe, so gravitational forces point downward toward it. The resulting gravitational potential energy differences from place to place in the Universe affect space-time and clocks, as I explain in my book. I will show that in the early phases of the expansion of space, those differences were so great that they produced a spherical zone around the centre in which **time did not exist.** This zone was deep inside the event horizon and not connected to it. I demonstrate the existence of the timeless zone in sections 3 through 6 by analysing the mathematical foundation of my theory, a space-time metric published in 1961 by theoretical physicist Oskar Klein.[6] According to the Klein metric, as the expansion proceeded, the timeless zone shrank until it disappeared at the centre. As section 9 will make clear, objects at the centre (such as the Earth) emerged from the timeless zone last of all, thus becoming the youngest things in the Universe.

Conner and Page have not criticised the Klein metric. But apparently they have not tried to understand it deeply, since they show no awareness of the timeless zone. Instead they have relied upon a metric previous authors had applied to the situation of my cosmology, that of matter collapsing into a black hole and then expanding out of a white hole (the inverse of a black hole). Their equation, the Robertson-Walker metric, is also the foundation of the Big Bang theory. But the Robertson-Walker metric does not show the timeless zone at all, and I show in section 7 why it is incapable of doing so. Thus the Robertson-Walker metric is an **inappropriate** description of the space-time of my cosmology. Since Conner and Page base their reasoning heavily upon that metric, their resulting criticisms are wrong.

A 1997 article in the **International Journal of Modern Physics**[7] by general relativity theorists Charles Hellaby, Ariel Sumeruk and George Ellis, strongly supports the above conclusion. Hellaby *et al.* showed that a (classical, not quantum) timeless zone can indeed occur in the late stages of black hole collapse and in the early stages of white hole expansion. Since they used a different approach than the Klein metric, they have provided independent evidence for the existence of the timeless zone and the inadequacy of the metric Conner and Page used.

This paper is much more than a mere defence of my book. It unveils a **new discovery:** the above-mentioned zone of timelessness, already present in the Klein metric but unnoticed until now. The existence of this zone not only clarifies my cosmology, but also has important implications for black-hole theory. Thus I have devoted most of sections 3 through 6 to explaining this discovery, and parts of sections 9, 11 and 12 to exploring some of its implications. The rest of the paper grapples with the details of the Conner-Page critique. The next section deals with their main allegation.

2. THEIR MAIN CHARGE AND MY MAIN DEFENCE

The main criticism Conner and Page make is evident in their title, '**Starlight and Time** is the Big Bang'. In their **section 1** they amplify this claim, asserting that my cosmology is not fundamentally different from the Big Bang cosmology:

> *'The model of* ***Starlight and Time*** *is in fact a trivial variant of the standard Big Bang model.'*

The reason Conner and Page make this claim is that they implicitly assume one can use the foundational metric of Big Bang theory, the Robertson-Walker metric, to describe **completely** space and time within the type of bounded-matter cosmos I depict, a contracting or expanding cloud of matter surrounded by empty space.[8] This assumption leads them to assert that, like the unbounded Big Bang cosmologies, my bounded cosmology would have no time dilation:

> '. . . *physical clocks located on Earth and on distant galaxies behave identically in bounded and unbounded Universes ...*'[9]

According to them, in the space-time I picture there would be no stage of the expansion at which clocks would be stopped in one place and ticking in another. In that case, it would be hard to imagine a way to get light from distant galaxies to the Earth in a short time as measured by clocks here on Earth.

My answer to this charge is that the Conner-Page mathematical foundation, the Robertson-Walker metric, does **not** fully describe the space-time of a bounded-matter cosmos, as I shall show in sections 3 through 6 below. In particular, their metric gives no hint at all of a large region of space-time in which physical processes, including clocks, are **completely stopped** while the expansion proceeds. In this region, which is well inside the event horizon and unrelated to it, the **signature** (set of algebraic signs) of the metric tensor is different than in normal space-time, as I will explain in section 4. The existence of this timeless zone demonstrates:

(1) the inadequacy of the metric Conner and Page used,
(2) a major difference between my cosmology and the Big Bang theories, and
(3) that time dilation does exist in a bounded-matter cosmos.

These results refute the main Conner-Page criticisms.

In their application of the Robertson-Walker metric to the cosmos I envisage, Conner and Page failed to heed the warning I made in my book about that metric.[10] The warning should have helped them realise that their metric is incomplete in this situation. I will try to clarify the caveat in section 7.

I encourage less mathematically inclined readers to be patient. In section 7, I will show with simple verbal reasoning why the Robertson-Walker metric is fundamentally incapable of showing when time dilation might occur. The reasoning in sections 8 through 12 is largely verbal, with only a few equations. In the following sections, 3 through 6, I use equations in order to prove my answer to the main criticism. Yet even in these sections, more determined readers will find much verbal reasoning sandwiched in among the equations.

3. THE KLEIN METRIC IS THE KEY

Except for a brief comparison with the Robertson-Walker metric (their **section 3.2),** the Conner-Page critique takes little note of the mathematical cornerstone of my book, the Klein metric.[11] First published in 1961 by the Swedish theoretical physicist Oskar Klein (known for the Kaluza-Klein theory, the Klein-Gordon equation, and the Klein-Nishina formula), this metric[12] uses the Schwarzschild coordinates *t, r,* θ and ϕ (time, radial distance, colatitude and azimuth, respectively), whose definitions I clarify in my book.[13] Schwarzschild coordinates are **conceptual.** You can think of them as the times and distances which would be read out from clocks and rulers unaffected by gravity, velocity, acceleration, or any other feature of the space-time continuum. As such, I regard Schwarzschild coordinates as good navigational tools to help the theorist find his way amid the hills and valleys of space-time.

All metrics specify a quantity *ds*, the **space-time interval** between any two events which are near one another in space and time, as I explain in my book.[14] The most important feature of the space-time interval is that it should be the same in all coordinate systems. Therefore if two different metrics (such as the Robertson-Walker and Klein metrics) describe the same space-time, then they should always give the same value for *ds* for any given pair of events. The Klein metric specifies *ds* in an expanding or contracting cloud of 'dust-like' matter having negligible forces between 'particles', such as a cloud of stars or galaxies:

$$ds^2 = \beta c^2 dt^2 - \alpha dr^2 - r^2 d\theta^2 - r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 \quad (1)$$

Here dt, dr, $d\theta$ and $d\phi$ are the time, radial distance, and angle separations between the two events. The constant *c* is the speed of light and *r* is the Schwarzschild radial distance from the centre of the cloud. Equations (17) and (18) of my book, and equations (2) and (3) below, show the functions α and β Klein derived. They depend on the radius of curvature of space *a* and its maximum value a_m, the comoving radius $\eta = r/a$ and its value at the edge of matter η_e, the gravitational constant *G*, and the minimum mass density ρ_m, which occurs at maximum expansion:

$$\alpha = \frac{1}{1 - \frac{a_m}{a}\eta^2}, \text{ where } a_m \equiv \sqrt{\frac{3c^2}{8\pi G \rho_m}} \quad (2a,b)$$

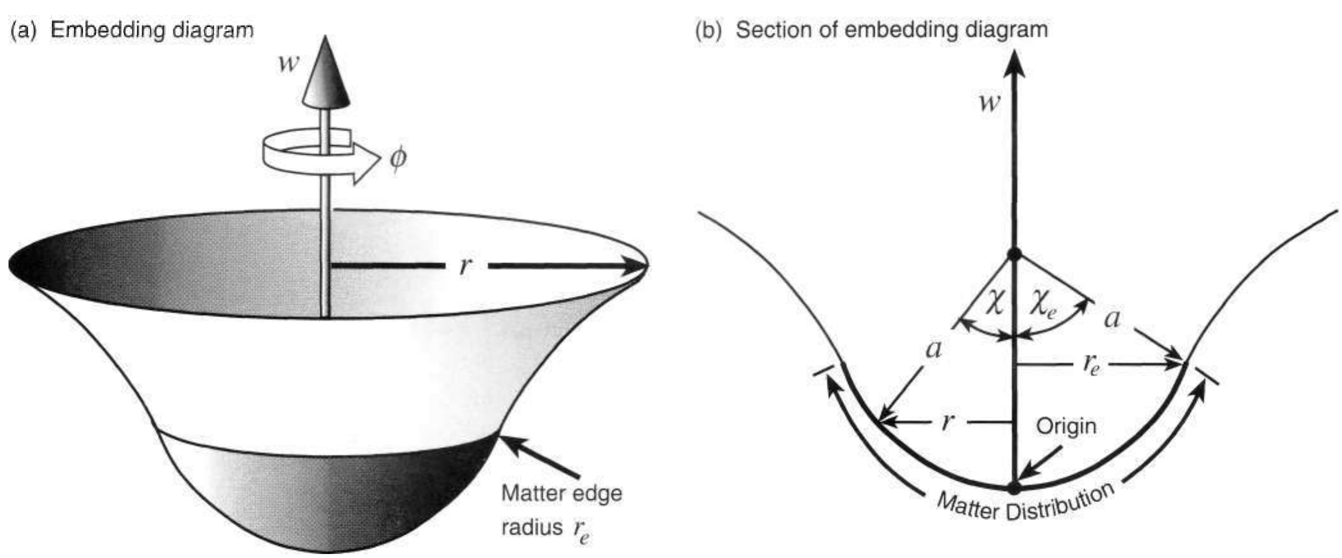


Figure 1. *(a) 'Embedding diagram' of Klein space-time, representing matter collapsing into a black hole or expanding out of a white hole. To understand the diagram, imagine flattening out the three-dimensional space you perceive into a flat rubber sheet. Then deform the sheet in the w-direction until it has the correct curvatures for a given instant of proper time τ. As time proceeds, the dent in the rubber membrane changes size to represent the contraction or expansion of space. The darker region is where the 'dust-like' matter is located. The radius r and angle ϕ are the Schwarzschild radius and azimuth, respectively. The colatitude Θ has been suppressed by the flattening. The circular boundary of matter in this diagram represents a sphere in the three dimensions we perceive.*

(b) Cross-section of the embedding diagram: Notice that there is a definite centre at the origin, r = 0. The matter segment is part of a sphere whose radius a either decreases or increases with time. The comoving angle χ shows the location of a particle moving with the contraction or expansion; χ is constant. The angle χ_e, which also is constant, shows the location of a particle at the edge of matter.

$$\beta=\alpha\frac{\left[1-\frac{a_m}{a}\left(1-\frac{\left(1-\eta_e^2\right)^{3/2}}{\left(1-\eta^2\right)^{1/2}}\right)\right]^2}{\left[1-\frac{a_m}{a}\left(1-\frac{\left(1-\eta_e^2\right)^{1/2}}{\left(1-\eta^2\right)^{1/2}}\right)\right]^3} \tag{3}$$

Above I have modified the nomenclature of my book (which used Klein's nomenclature) a bit to clarify the meanings. I have changed the maximum radius of curvature from a_o to a_m, the minimum density from ρ_o to ρ_m, and the comoving radius of the edge of matter from η_o to η_e Although the subscript 'm' means 'maximum' for the radius of curvature and 'minimum' for the density, there should be little confusion, since both of those values occur at the same time. My book describes these variables and functions in more detail. Figure l(a,b) is an 'embedding diagram' (adapted from a figure in my book[15]) which ties together all the geometric quantities. In the diagram, the comoving angle χ of a 'particle' (say a galaxy) remains constant as the expansion increases the radius of curvature a. The same is true of the comoving angle χ_e of a particle at the edge of matter. Since the comoving radius η is related to the comoving angle χ by η = sin χ, we can use the following trigonometric identities, plus a definition of a new variable x, the **expansion** fraction,

$$-\eta^2 \equiv \cos^2\chi, \quad 1-\eta_e^2 \equiv \cos^2\chi_e, \quad x\equiv\frac{a}{a_m} \qquad \text{(4a,b,c)}$$

to clarify the functions α and β in equations (2a) and (3) as follows:

$$\alpha=\frac{x}{x-\sin^2\chi}, \quad \beta=\alpha x\frac{\left(x-1+\frac{\cos^3\chi_e}{\cos\chi}\right)^2}{\left(x-1+\frac{\cos\chi_e}{\cos\chi}\right)^3} \qquad \text{(5a,b)}$$

Equations (5a,b) are simply a mathematical rephrasing of the metric Oskar Klein derived. As I mentioned before, nowhere do Conner and Page criticise the Klein metric. In fact, in their section 3.2, they appear to endorse it. They never disparage its standing as a valid solution of Einstein's field equations applied to this situation, a contracting or expanding cloud of 'dust' (galaxies or stars). It is well that they do not. Steven Weinberg, a Nobel laureate in physics, re-derives the Klein metric in his book, Gravitation **and** Cosmology.[16] Conner and Page may be disturbed by this metric's implications, which I will bring out below. If they decide to dispute Klein's metric, then before they argue with me, let them first fight it out with Weinberg!

4. THE KLEIN METRIC HAS A TIMELESS REGION

The **signature** of a metric is the set of + or - signs of its tensor components $g_{\mu\nu}$ after the metric has been transformed (at least locally) to a diagonal form. In classifying types of signatures, the order of the signs does not matter, but rather the number of occurrences of each sign. For the sign convention I use here and in my book, the signature of the normal space-time we live in is (+———), with the time part positive and the space parts negative. At any given point in space-time, the signature should be the same in all coordinate systems.[17] As some consideration of the Schwarzschild vacuum metric[18] will show, as we move into the event horizon of a black hole, the time and radial components switch signs, so that the signature within the horizon becomes (- + - -). Since the order does not matter in classification, both of these signatures are of the same type. They represent Lorentzian (or 'pseudo-Riemannian') metrics,[19] with one time dimension and three space dimensions.

Another possibility is that a metric could be **Euclidean**[2021] (or 'positive definite' or 'Riemannian'), having a signature of all one sign, for example (———-). Such a metric would have four space dimensions and **no** time **dimension.** As one relativist comments about such regions, *'there is no time there'.*[22]

I will show in the next section that the Klein metric **has just such a timeless Euclidean** region in the early stages of the expansion. Its signature changes from Euclidean to Lorentzian at a critical expansion factor x_c which depends on the comoving radial coordinate χ. As far as I know, this is the first time anyone has pointed out this unusual feature of the Klein metric.

Until recently, general relativists thought that classical solutions of Einstein's field equations could not change their signature. But in 1992 George Ellis (a leading relativist), along with several other authors, published an article in **Classical and Quantum** Gravity demonstrating the possibility of signature change and exploring the implications.[23] Ellis *et al.* responded to the previous consensus by pointing out:

> *'At first one's reaction is, certainly not, all solutions maintain the same signature. However this is true in the usual solutions not because it is demanded by the field equations, but rather because it is a condition we normally impose on the metric before we start looking for solutions.'*[24]

It appears that most relativists now agree with this assessment.[25,26] Ellis and his co-authors proceeded to show that the Robertson-Walker metric, on which Conner and Page rely heavily, is a metric with just such overly-restrictive conditions imposed upon it. Ellis *et al.* presented a more general version of the Robertson-Walker metric which is indeed a solution of Einstein's equations and yet changes its signature. I call this generalised Robertson-

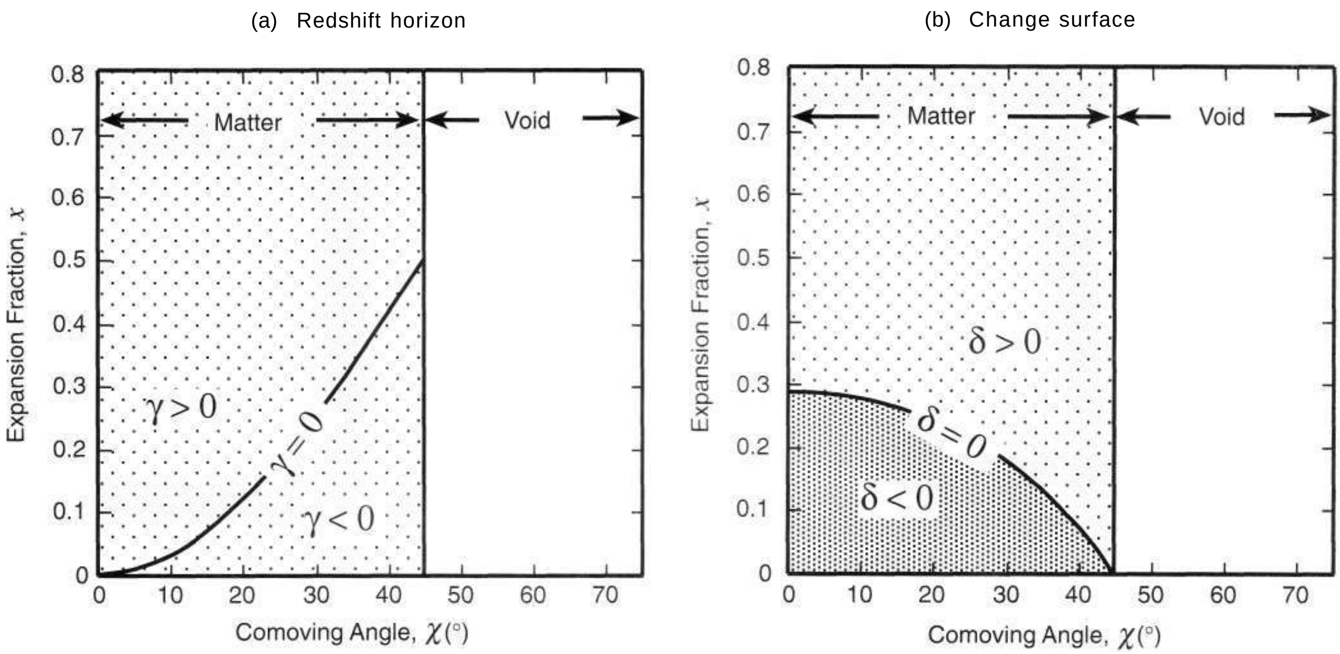


Figure 2. *(a) Redshift horizon in Klein space-time for the case $\chi_e = 45°$. See Figure 1 (b) and caption for explanation of comoving angle χ, and equation (6a) for definition of function γ. Notice that γ is positive to the left of the redshift horizon. The Klein metric extends as far as χ_e; beyond that the Schwarzschild vacuum metric applies,*
(b) Signature change surface. See equation (6b) for definition of function δ. Notice that δ is negative below the change surface.

Walker solution the **Ellis** metric, and I will discuss it further in section 6. Ellis and his co-authors also studied the geodesic paths of particles entering, traversing and leaving a Euclidean zone.

The main points I want to make here are that:

(1) signature changes are possible, and
(2) the Klein metric already contains them.

The next section shows this mathematically.

5. MAPPING THE KLEIN SPACE-TIME

In this section, I want to show how the various components of the Klein metric tensor change sign in different parts of space-time. To clarify the behaviour of the functions α and β in equation (5a,b), let us define three new functions γ, δ and ε as follows:

$$\gamma \equiv x - \sin^2\chi, \quad \delta \equiv x - 1 + \frac{\cos\chi_e}{\cos\chi}, \qquad \varepsilon \equiv x - 1 + \frac{\cos^3\chi_e}{\cos\chi} \qquad \text{(6a,b,c)}$$

Then, using these definitions and the usual notation for metrics $ds^2 = g_{\mu\nu}\, dx^\mu\, dx^\nu$, where $(x^0, x^1\, x^2, x^3) = (t, r, \theta, \phi)$, the four non-zero tensor components of the Klein metric, given in equations (1) and (5a,b), become:

$$g_{00} = \frac{x^2\varepsilon^2}{\gamma\delta^3}c^2, \; g_{11} = -\frac{x}{\gamma}, \; g_{22} = -r^2, \; g_{33} = -r^2\sin^2\theta$$

The last two components, g_{22} and g_{33}, are always negative, that is, space-like. The second component g_{11} switches sign at the (hyper)surface in space-time where $\gamma = 0$, that is, where $x = \sin^2\chi$. The first component g_m switches sign at two surfaces: the one above where $\gamma = 0$, and the second where $\delta = 0$. Figure 2(a,b) plots (for the case $\chi_e = 45°$) the two surfaces separately and shows the signs of γ and δ on each side of the surfaces. Also, g_{oo} becomes zero (but does not switch sign) on a third surface where $\varepsilon = 0$. Figure 3 plots the three surfaces together,

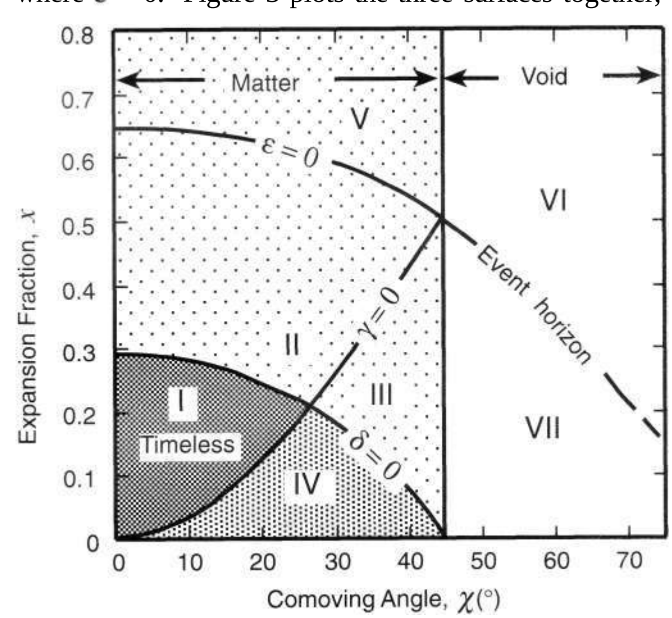


Figure 3. *The seven regions of Klein space-time. Region I is a **timeless** zone, where the Klein metric has a **Euclidean** signature (- - - -). In that region no physical processes take place, other than the contraction or expansion. Region IV has a 'Kleinlan' signature (+ + - -). In the other regions, the Klein metric has the Lorentzian signature of normal space-time (+ - - -).*

shows the void part (Schwarzschild vacuum metric) as well as the matter part, and labels the seven regions of space-time thus delineated.

The surfaces in Figure 3 have definite physical meanings. The $\gamma = 0$ surface represents the points for which the proper distance from the centre is increasing at the speed of light. We could call this surface the **redshift horizon** for observers at the centre of mass. Since it is observer-dependent, it is not likely to appear explicitly in comoving coordinate systems. The surface $\delta = 0$ delineates a more fundamental phenomenon, a change of signature; many authors call this the **signature change surface.** As I will discuss in the next section, this is the surface at which the gravitational potential energy reaches a critical value related to the curvature of space. The $\varepsilon = 0$ surface marks the location where the time dilation function β goes to zero, the well-known **event horizon** of black hole topologies. Though Conner and Page quibble about that name, when this surface emerges from the matter boundary, it becomes the Schwarzschild radius — which everybody calls the event horizon. Notice that the signature change surface is deep inside the event horizon.

REGION	MATTER	γ	δ	g_{00}	g_{11}	g_{22}	g_{33}	SIGNATURE	ROLES OF *t, r*
I	Yes	+	−	−	−	−	−	Euclidean	
II	Yes	+	+	+	−	−	−	Lorentzian	Normal
III	Yes	−	+	−	+	−	−	Lorentzian	Reversed
IV	Yes	−	−	+	+	−	−	Kleinian[27,28]	
V	Yes	+	+	+	−	−	−	Lorentzian	Normal
VI	No			+	−	−	−	Lorentzian	Normal
VII	No			−	+	−	−	Lorentzian	Reversed

Table 1. *The seven regions of Klein space-time.*

Table 1 shows the signs of γ, δ and $g_{\mu\nu}$ in each of the seven regions. It also points out which regions contain matter and which do not, the names assigned to each type of signature, and which of the Lorentzian regions have normal or reversed roles for time and radial distance.

Notice region one. It appears to have a Euclidean signature, with all its metric components $g_{\mu\nu}$ being negative. Let us just double-check the signs. In region one, we have $x > \sin^2\chi$, so according to equation (6a) γ is positive. Also, in that region the expansion fraction x is less than 1 - $(\cos\chi_e/\cos\chi)$, so by equation (6b) δ is negative. Using those signs in equations (7a) and (7b) makes both g_{00} and g_{11} negative. The signs of g_{22} and g_{33} being negative, this confirms that in region one **all four of the metric components are negative.**

To check this crucial conclusion even more thoroughly, let us go back to Klein's original equations, equations (1) through (3), and consider the signs of α and β at a particular sample point in region one, namely the centre. The fact that the comoving radius η is zero at the centre simplifies the equations. For that case, equation (2a) shows that α = 1. Referring to the metric in equation (1), we see that this makes the second term (the one with dr^2) negative, that is, space-like, just like the third and fourth terms (the ones with $d\theta^2$ and $d\phi^2$). Substituting $\alpha = 1$, $x = (a/a_m)$, and $\eta = 0$ into equation (3) gives us β at the centre:

$$\beta = \frac{\left[1 - \frac{1}{x}\left(1 - \left(1 - \eta_e^2\right)^{3/2}\right)\right]^2}{\left[1 - \frac{1}{x}\left(1 - \left(1 - \eta_e^2\right)^{1/2}\right)\right]^3} \qquad \textbf{(8)}$$

Since the numerator of this equation is squared, it will always be either zero or positive. Thus it is the denominator which determines the sign of β, and since the factor in the denominator is cubed, we have:

$$\text{sign}[\beta] = \text{sign}\left[1 - \frac{1}{x}\left(1 - \sqrt{1 - \eta_e^2}\right)\right] \qquad (9)$$

We can rewrite this equation as follows:

$$\text{sign}[\beta] = \text{sign}\left[1 - \frac{x_c(0)}{x}\right] \qquad (10)$$

where $x_c(0)$ is the critical value of the expansion fraction at $\eta = 0$:

$$x_c(0) = 1 - \sqrt{1 - \eta_e^2} \qquad (11)$$

I will show the significance of $x_c(0)$ here. The comoving radius, $\eta_e \equiv \sin\chi_e$, of the edge of matter is greater than zero, since we have a non-zero matter content, and the matter must occupy some finite comoving radius. Substituting $\eta_e > 0$ into equation (11) shows that $x_C(0) > 0$. Then for values of the expansion fraction less than the critical value $x_c(0)$, equation (10) says that the sign of β at the centre of mass will be negative:

$$\boxed{\beta < 0, \text{for } x < x_c \text{ and } \eta = 0} \qquad (12)$$

A negative value of β makes the first term (the one with *df)* in the metric equation (1) also negative, the same sign as the other three terms. Thus for this sample point in region one, the signature is (————) and ds^2 has to be space-like, not time-like. So this sample point in region one verifies that **the signature of region one is indeed Euclidean.**

Setting $\delta = 0$ in equation (6b) gives the critical value of the expansion fraction over the whole change surface; that is, it gives x_c in terms of the comoving coordinate χ:

$$x_c(\chi) = 1 - \frac{\cos\chi_e}{\cos\chi} \qquad (13)$$

This gives us the shape of the change surface in Figure 3. In the earliest phases of the expansion it appears at the comoving coordinate χ_e, thus enclosing all matter. As the expansion proceeds, the spherical change surface (containing the timeless Euclidean zone) shrinks in terms of the comoving coordinate χ, gradually allowing more and more matter to appear outside it. Physical clocks emerging from the change surface begin to tick. Clocks at the centre emerge and begin ticking last of all, when the expansion fraction reaches the value $1 - \cos\chi_e$. All clocks moving with the expansion which are ticking do so in lockstep with the expansion. That is, for a given value of x in the Lorentzian part of space-time, the change $d\tau$ in proper time for a given change dx in the expansion fraction would be the same regardless of location.

Please note, however, that for a given value of x, **not all clocks have the same reading.** That is because clocks at the edge start ticking earlier in the expansion than do the ones close to the centre. Thus, as section 9 shows in more detail, for any given value of x which is greater than $x_c(0)$, the total **proper** time elapsed, that is, the age, depends on location. The age increases with distance from the centre, so that **the centre is youngest** and the edge is oldest. This is precisely what Conner and Page claimed could not happen!

6. THE CONNER-PAGE METRIC IS INCOMPLETE

The existence of region one contradicts the Conner-Page claim of no time dilation in my cosmology, because, as I pointed out above, clocks are stopped in a Euclidean region. As I will clarify in section 7, the Klein metric tells us that early in the expansion for clocks at rest in the centre of the 'dust' cloud, the squared interval ds^2 marked off during a Schwarzschild time interval dt is negative — it is space-like rather than time-like. This means the physical clocks at the centre cannot tick at all. Yet the Robertson-Walker metric, on which Conner and Page depend, gives no hint of such a situation. Why? One reason is that their equation (3) should have been more general. According to recent articles,[29] it should have included a **lapse function** $N(\tau, \eta)$ in the time term, so that the metric would be:

$$ds^2 = N(\tau,\eta)c^2 d\tau^2 - a^2\left[\frac{d\eta^2}{1-k\eta^2} + \eta^2\left(d\theta^2 + \sin^2\theta d\phi^2\right)\right] \tag{14}$$

I call this the **Ellis** metric. Permitting the lapse function to change sign allows the metric to be Euclidean for some values of η and τ (or the space-like parameter corresponding to τ in the Euclidean zone). Conner and Page, in adopting their equation (3) from the Big Bang theory and applying it to this situation, unwittingly restricted their space-time to regions wherein $N = 1$, thus automatically excluding any Euclidean solutions. As George Ellis pointed out in the quote in section 4, that is an unwarranted restriction.

In their 1997 paper, Hellaby, Sumeruk and Ellis[7] show that it is very important to allow for the possibility of a classical Euclidean zone in a black-hole or white-hole topology:

> *'We have succeeded in demonstrating the possibility that a change in the signature of spacetime may occur in the late stages of black hole collapse, resulting in a Euclidean region which bounces and re-expands, passing through a second signature change to a new expanding Lorentzian spacetime.'*

I will say more in section 12.2 about the very interesting possibility that a black hole *'bounces and re-expands'* to become a white hole, a possibility which would aid my cosmology. But as for the Euclidean zone, Hellaby *el ah* used the Ellis metric, not the Klein metric, in their reasoning. Thus their conclusion above adds support to mine. It is independent evidence that the Robertson-Walker metric is inadequate for this situation.

Now let us consider why the lapse function is important in this situation of a bounded-mass cosmos. Ellis and his colleagues relate signature change to the matter in the universe and its potential energy. The criterion they derived for the change is:

> '. . . *when the matter content of spacetime is a scalar field...* [the signature change] *occurs when the spatial curvature of the universe is equal to the potential energy of the scalar field.'*[30]

Noting that the spatial curvature is $3k/a^2$ and calling the potential energy *V*, Ellis *et al.* expressed this signature change condition as follows:[31]

$$\frac{3k}{a^2} = \kappa V \tag{15}$$

where κ is the Einstein gravitational constant, $8\pi G/c^4$. Let us see what this means in our situation. From equation (2b) and the fact that the mass density ρ is inversely proportional to the cube of the expansion factor x, we get the following expression for a^2:

$$a^2 = \frac{3c^2}{8\pi G\rho x} \tag{16}$$

The condition of equation (15) applies at the change surface, where the expansion fraction x has the critical value x_c given in equation (13). Substituting that equation, the definition of κ, and $k = 1$ into equation (15) gives us a simple expression for the potential energy V at the change surface:

$$V = \rho c^2 x_c \tag{17}$$

Now we can use equation (13) to expand x_c in this expression. By using the geometric definitions of Figure 1(b), we can specify the cosines of equation (13) in terms of the radii of the edge of matter and of a field point at the time of maximum expansion:

$$\cos\chi_e = \sqrt{1 - \frac{2GM}{c^2 R_e}}, \quad \cos\chi = \sqrt{1 - \frac{2Gm(R)}{c^2 R}} \tag{18a,b}$$

Here R_e and R are the values of r_e and r at maximum expansion, M is the total mass of the 'dust' cloud, and $m(R)$ is the mass contained within radius R. Using equations (18a,b) in equation (17) gives us the potential energy at the change surface in terms of those parameters:

$$V = \rho c^2 \left(1 - \frac{\sqrt{1 - \dfrac{2GM}{c^2 R_e}}}{\sqrt{1 - \dfrac{2G\,m(R)}{c^2 R}}} \right) \tag{19}$$

By applying a relativistic textbook calculation[32] to a uniform static distribution of mass, one can show that V in equation (19) is exactly the energy (per unit volume) required to lift a mass of density ρ upward against the gravitational field from radius R in the distribution out to radius R_e at the edge of matter.

Thus the Ellis condition for signature change, equation (15), is closely related to the **gravitational potential energy** of our spherical, bounded, distribution of matter, as Figure 4 illustrates. If the conditions assumed for the Big Bang theory (unbounded, roughly uniform matter) were to apply, then there would be no centre of mass and no gravitational potential difference from point to point large enough to change the signature. In that case (the Big Bang after very early times[33]) one could assume the lapse function was always equal to one, and not worry about Euclidean signature. But if we have a centre of mass and large gravitational potentials, we no longer have that option.

In other words, Conner and Page must include the lapse function N and permit space-time to change signature if they wish to properly describe the space-time of my cosmology. They cannot use the restrictive Robertson-Walker metric; they must use the Ellis metric or the Klein metric. The Robertson-Walker metric fails to describe a large, very significant part of a black-hole or white-hole space-time. Thus the Robertson-Walker metric is a **less complete description** of this physical situation than the Klein metric is. The Euclidean character of region one demonstrates a large and crucial blind spot in the Conner-Page critique.

7. WHERE THE NEW PHYSICS COMES FROM

At this point you may be wondering how a simple change of coordinates, from those of the Robertson-Walker metric (τ, η) to those of the Klein metric (t, r), could suddenly reveal so much new physics. My first comment is that this is not the first time a change of coordinates has done so. In 1960, Kruskal[34] and Szekeres[35] introduced a new set of coordinates which revealed startling new regions of space-time in the vacuum around and within a black hole, regions which had lain concealed and unsuspected in the Schwarzschild vacuum metric. The new coordinates shed a great deal of light on the nature of the event horizon, opened up the possibility of white holes and worm-holes, and stimulated a great outpouring of research on black holes for the next three decades. Thus it should not be too surprising that a shift of coordinates has again revealed new black-hole physics, this time within the matter region.

My second comment is that the time coordinate t used in the Robertson-Walker metric is, by itself, fundamentally incapable of showing changes in the rates of physical clocks. That is because, as I commented in my book,[36] τ is the **proper time,** the reading of physical clocks riding along with each point in space as it expands. If those clocks should slow or stop, we need other types of clocks (which behave differently) to compare them with and to give us hints of possible time dilation.[37] Thus the conceptual Schwarzschild clocks, giving a different time t, are useful for the theorist in detecting changes in physical clocks. Without such a comparison, metrics based only on proper time, such as the Robertson-Walker metric, will be blind to any time dilation which might occur. For example, as Conner and Page acknowledge, the Robertson-Walker metric gives no hint of the location of the event horizon (at which location time dilation occurs) within a collapsing cloud of dust. Yet other coordinate systems reveal the location of the event horizon, as Figure 5 shows. For more detailed comments on this topic, see my letter in another journal.[38] The disappearance of the event horizon and its associated time dilation effects could have been a clue to Conner and Page that the Robertson-Walker metric might be concealing other time dilation phenomena, such as the Euclidean zone. Another clue they ignored was my warning in **Starlight and Time:**

> '. . . *inside the sphere* [of matter] *the metric is* ***almost*** *identical to the Robertson-Walker metric . . . However,*

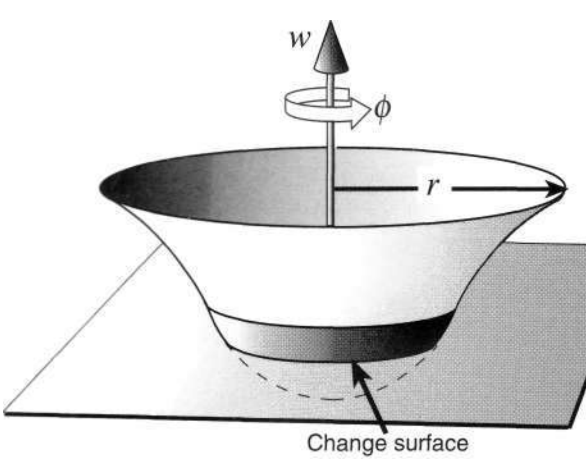


Figure 4. *The signature change surface formed by the intersection of the embedded membrane of Figure 1(a) with a plane representing the critical value of the gravitational potential energy given in equation (19). The circular boundary in this diagram represents a sphere, the change surface, in the three dimensions of our perceptions. As space expands, the membrane is stretched out and the 'dent' moves up with respect to the plane, shrinking the change surface.*

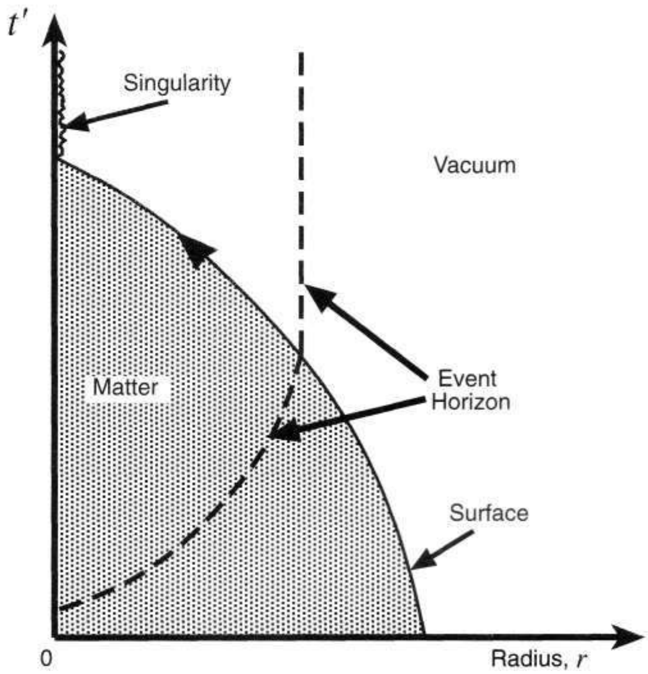


Figure 5. The event horizon inside and outside a collapsing sphere of matter, shown with the Schwarzschild radius r and the Eddington-Finkelstein time coordinate t', which is the sum of the Schwarzschild time t and a particular function of r. Adapted from Hawking and Ellis, Ref. 40, p. 309, Figure 57(1). This diagram represents the conventional opinion of the last few decades that the matter in a black hole does not 'bounce', but remains as a singularity forever. The new insight that the collapsing matter enters a Euclidean zone may change that opinion. See Figure 12.

there is one very important difference. Whereas for an unbounded Robertson-Walker cosmos, the origin of coordinates can be anywhere, here the origin of coordinates must be ***at the center*** *of the sphere and nowhere else.'* (Emphasis in original)[39]

Perhaps this difference is what Stephen Hawking and George Ellis had in mind when they wrote the following about a contracting dust cloud on its way to forming a black hole singularity:

'The metric inside the dust will be similar to that of part of a Robertson-Walker universe, while that outside will be the Schwarzschild metric.' (Emphasis mine)[40]

'Similar' is not the same as identical', the latter being what Conner and Page imply throughout their critique. The fixity of the Robertson-Walker-like coordinate system in this case should have been a clue to Conner and Page that perhaps there might be important but concealed physics related to the existence of a Centre of mass.

Conner and Page state correctly that clocks freely falling toward a black hole event horizon, or expanding out from a white hole event horizon, would not show time dilation effects at the horizon,[41] and so they are not very concerned about the location of the horizon. Yet they do not seem to appreciate the fact that if one is at rest **at the** centre of the 'dust' cloud, one is no longer falling inward or expanding outward — no longer necessarily in the 'comoving' system. Therefore, when the event horizon in a white hole reaches objects at rest in the centre, such as the Earth, time dilation effects could be significant. At the centre of the dust cloud, it is easy to use the Klein metric to compare proper time and Schwarzschild time. Using the equations $ds = c\,d\tau$,[42] $r = 0$, and $dr = 0$ in equation (1), we can directly relate the two types of clock:

$$d\tau^2 = \beta dt^2 \qquad \textbf{(20)}$$

According to equation (7a), $\beta = 0$ at the event horizon, where ε of equation (6c) is zero. Since Schwarzschild time is conceptual and unaffected by space-time, dt^2 is non-zero and positive. Therefore, physical clocks at the centre of a white hole must stop (relative to Schwarzschild time) when the event horizon arrives. The Robertson-Walker metric Conner and Page specify in their equation (3) could allow this by allowing $d\tau_c$ to be zero, but their metric gives no clue as to when and where such stopping might occur.

More important than the above, at yet earlier phases of the expansion and inside the change surface, β at the centre is negative, according to equation (12). Therefore according to equation (20), during the earlier part of the expansion, $d\tau^2$ at the centre must be **negative.** That is, $d\tau$ is space-like instead of time-like. The only way the Robertson-Walker metric could yield such a result is by allowing τ_c in Conner-Page equation (3) to be imaginary, which other authors have shown is equivalent to including the lapse function N and allowing it to be negative while keeping τ real.[43] As Hawking and others have shown, allowing imaginary time means allowing a Euclidean region wherein physical clocks are stopped,[33,44] a possibility Conner and Page appear never to have entertained.

8. CONNER AND PAGE MISUNDERSTAND THE COPERNICAN PRINCIPLE

In the previous sections, I introduced new understandings of the foundations of my cosmology in order to answer the main Conner-Page criticisms, summarised in their **section 1.** In this and the following sections I will grapple with the other allegations Conner and Page make. Here I will deal with their **section 2,** *'Misunderstandings about the significance of the Cosmological Principle'.* I hope to convince you that the biggest such misunderstandings are their own!

In the cosmos I have proposed, **matter is bounded.** That is, stars and galaxies would be contained within an expanding spherical boundary (a conceptual dividing surface), beyond which there would be a large region of empty space. It does not matter to my theory whether that space is ultimately bounded or not. Conner and Page contend it also does not matter if the mass is bounded, as they claim in this section:

'The imposition of a spherical boundary to the matter of the Universe has no effect on the gravitational and clock time-keeping properties in the interior of such a boundary.'

To check this claim, let us consider one obvious consequence of such a boundary, which is that the matter distribution would have a **centre.** As I will clarify below, that sort of cosmos is quite different from the unbounded matter of the Big Bang theory, which is **acentric.** It cannot have a centre within the three-dimensional space we can perceive. Some cosmologists explicitly acknowledge the acentricity of the Big Bang theory:

*'The universe is portrayed in illustrations as if it were a cloud expanding in space, and the impression is thus created that the universe is contained within space and has a **center** and an edge. **This is wrong. ..** **[It]** has **no center** and edge.'* (Emphases mine)[45]

As I emphasised in my book, this centrelessness is a logical consequence of the **Copernican principle,** the starting assumption of the Big Bang theory. This principle, formerly called the *'Cosmological Principle',* insists that all points in the cosmos must be essentially the same, that there can be no special or unique places. Most textbooks and teachers neglect to add that a centre would be such a unique place. Consequently, people who have not thought out the consequences of the Copernican principle have not realised that the Big Bang has no centre.

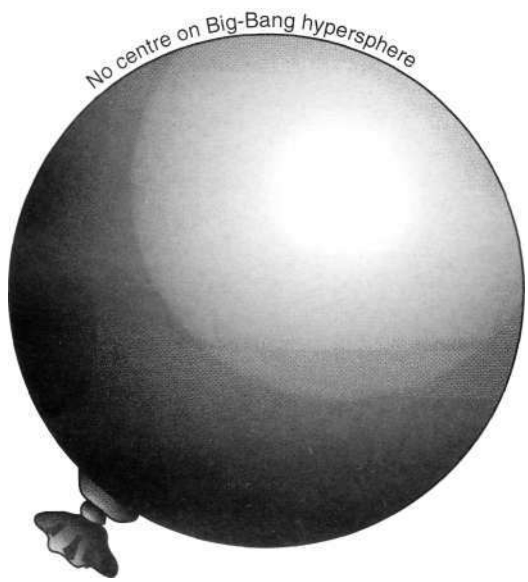


Figure 6. *'Balloon' representation of the closed-space version of the Big Bang theory, illustrating its lack of a perceivable centre. The **surface** of the balloon represents the three-dimensional space we perceive. The air inside and outside the balloon represents 'hyperspace', which the 'flatland' inhabitants of the surface cannot perceive. The centre of the balloon is in hyperspace; **no point on the surface is the centre.***

Even the 'closed' version of the Big Bang has no centre, as an illustration in my book shows.[45,46] I will repeat it here. Imagine the three-dimensional universe of your perceptions as being flattened out into a two-dimensional sheet, with ourselves becoming two-dimensional 'flatland' creatures confined to the surface of the sheet. Now wrap the sheet into a spherical shape so that it becomes the skin of a balloon. Glue uniformly-spaced sequins all over the surface of the balloon to represent galaxies. Except for the lack of one spatial dimension, the one you squashed, this picture is exactly analogous to the 'closed-space' version of the Big Bang theory. Time is yet another dimension, a fifth one, not pictured explicitly here. As time proceeds, the balloon expands.

The air inside and outside the balloon represents 'hyperspace', which is not accessible to or perceivable by the flatland creatures. Those creatures can find no centre in the realm of their perception, which is restricted to the skin of the balloon. The true centre is in 'hyperspace', which the flatlanders cannot perceive. In an exactly analogous way, the closed version of the Big Bang theory can have no favoured location within the space its inhabitants could perceive. It has no perceivable centre, as Figure 6 illustrates.

The other two varieties of the Big Bang theory, the 'flat' and 'open' versions, picture the cosmos as infinitely large, so they also have no centre. The acentricity of all three versions was a major theme of my book:

'There is no "center" to this proposed expansion, just as, on the surface of the balloon, there is no central point from which all other sequins are receding'[47]

'Homogeneity would mean that our three-dimensional universe [that is, within the three dimensions we can perceive] *would have **no edges and no center!**'*[48]

'But in the actual big-bang theory there is no center in [what we perceive as] *3-dimensional space for gravitational forces to point to."*[49]

I can find no place in the Conner-Page critique where they appear to have noticed these statements. It is as if they did not see them.

My book also pointed out that popularisers of the Big Bang theory have almost completely neglected to explain its lack of a centre to the public. Because of their failure in teaching, it is extremely difficult for most people to grasp the fact that the Big Bang is centreless. Surprisingly, I am finding that even some people with graduate training in cosmology have failed to get that point.

8.1 Opinions of Authorities

In their **subsection 2.1,** Conner and Page show that two cosmologists[50] failed to point out any significant differences between bounded and unbounded universes. But that is not a proof that such differences do not exist.

8.2 A Strange Conner-Page Mistake

In their **subsection 2.2,** Conner and Page try to show that gravity in a bounded-matter cosmos is the same as it would be in an unbounded cosmos. At the end of their subsection they lay great stress on this as being my major mistake:

> *'Identical interior space-time metric implies identical space-time geometry which implies identical interior gravitational properties. Humphreys' failure to recognise this fact lies at the heart of the errors of **Starlight and Time.**'*

As sections 2 through 6 show, the metrics are not identical. But putting aside this major flaw in their logic, let us follow the rest of their reasoning. First, Conner and Page picture a Newtonian unbounded-matter cosmos, one which has matter uniformly spread out *'without limit'* to infinity. Then they divide their cosmos into two parts, one part inside an arbitrary and conceptual sphere, the other part outside the sphere. They do not specify the size or location of the sphere. A few steps of logic result in their equation (2), which gives the acceleration of gravity $g(x)$ at location x (in their arbitrary coordinate system) in terms of an integral. Let us evaluate their integral. As many textbooks show,[51] we then get the following expression:

$$\boldsymbol{g}(\boldsymbol{x}) = -\frac{4}{3}\pi G\rho \boldsymbol{r}, \quad \text{where } \boldsymbol{r} \equiv \boldsymbol{x} - \boldsymbol{X} \qquad (21\text{ a,b})$$

Here, as Figure 7(a) shows, X is a vector specifying the location of the centre of their arbitrary sphere, and $\boldsymbol{r}$ is the vector from the centre out to point x. Notice that g is directed along $\boldsymbol{r}$ toward the centre of the sphere. This agrees with Conner-Page Figure 2(d), which I have reproduced here in my Figure 7(b). Labelled *'Unbounded cosmos'* at the top and *'Actual field configuration'* at the bottom, their figure shows their centre and arrows representing force converging on it. Thus their conclusion requires their infinite Newtonian cosmos to have a **centre.**

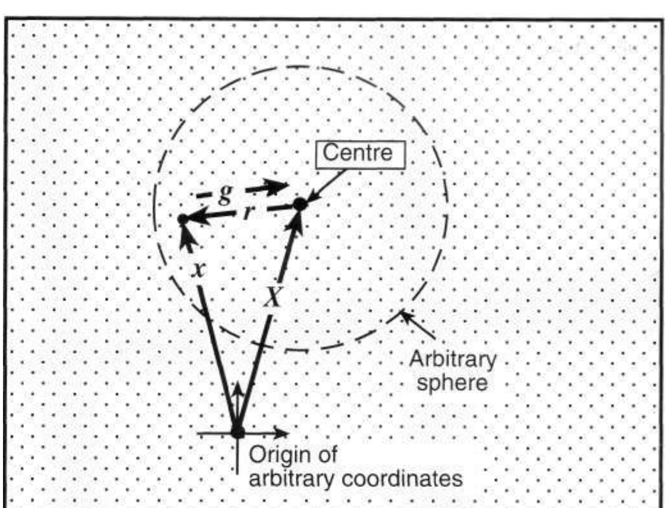
This Conner-Page conclusion is very strange. It violates the very idea they are trying to work with, **the Copernican principle!** The Conner-Page centre would be a **unique** place in the cosmos, unlike any other place. As I mentioned above, the Copernican principle desires that all places in the cosmos be essentially the same, that there can be no special places, such as a centre.[52]

I am astonished that both Conner and Page failed to notice this fundamental contradiction. How could they have started with an unbounded cosmos conforming to the Copernican principle, and yet wind up with one which does not? Somewhere in the derivation, we would think, they must have made a step which contradicts that principle. In fact they did so. The misstep occurs between their equations (1) and (2), where to get their result $g_{ext} = 0$, they cite a well-known theorem which dates back to Isaac Newton:[53]

> *'The gravitational field in the empty interior of a hollow spherically symmetric matter distribution vanishes.'* [Emphasis mine][54]

Spherical symmetry violates the Copernican principle. But unless there is spherical symmetry in the mass around the cavity, their unnumbered equation $g_{ext}(x) = 0$, between their equations (1) and (2), would not be correct. For example, while the Earth's mass would produce zero gravitational force in a spherical cavity exactly at the Earth's centre, the force in a spherical cavity anywhere else would not be zero. Thus their derivation requires a

(a) Conner-Page vectors



(b) Conner-Page alleged center

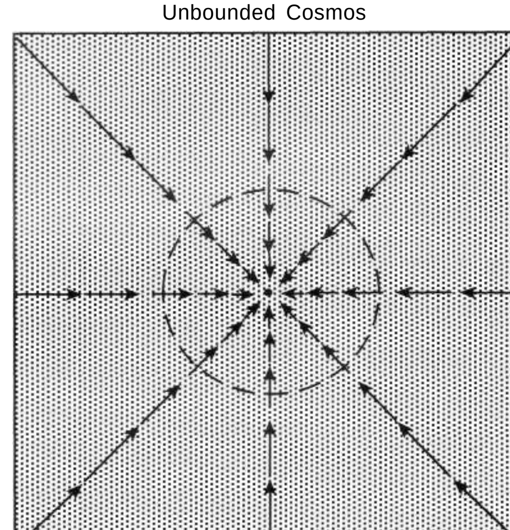


Figure 7(a). *Vectors used in Conner-Page equation (2) and my equations (21 a,b). A faulty analysis by Conner and Page has caused a spurious centre of mass to appear at the centre of the arbitrarily-located sphere they put into their unbounded cosmos.*

Figure 7(b). *Conner-Page Figure 2(d), reproduced here, **mistakenly** shows a centre in their infinite unbounded cosmos. Their alleged centre is the dot toward which all the alleged lines of gravitational force (the arrows) are pointing. Their error consists of the facts that (1) an unbounded cosmos can have no centre, and (2) a centre contradicts the Copernican principle, which they are trying to uphold. The astonishing mistake epitomised in this figure leads to the unravelling of the whole Conner-Page critique (see section 12.1).*

spherical cosmos. Conner and Page were indeed thinking of a spherical cosmos as they made their derivation, as the following phrases show:

> '. . . *the external spherical matter distribution* . . . *the external spherically symmetric matter distribution* .. .' [Emphases mine][55]

Thus Conner and Page saw no problem with having a centre or spherical symmetry around it. However, to be spherically symmetric, their mass distribution would have to extend radially an **equal** distance in all directions from the centre of their sphere. They say that their Newtonian cosmos extends *'without limit'*, that is, the distance is infinite. But if it is infinite, there is no way to claim the distance is equal in all directions. Infinity is not a large number; it is **beyond** number. An infinite cosmos would have no centre! If Conner and Page have a problem seeing that, perhaps this comment from cosmologist Stephen Weinberg, a Nobel laureate in physics, will be helpful:

> *'On the other hand, if matter were evenly dispersed through an infinite space, there would be no center to which it could fall.'* [Second emphasis mine][56]

8.3 A Central Issue

We have seen that Conner and Page mistakenly thought their unbounded Newtonian cosmos would have a centre. Did they also think the same about their unbounded Big Bang cosmos? Their use of Birkhoff's theorem (which has the same *'spherically symmetric'* restriction) to extend their Newtonian reasoning to a relativistic Big Bang cosmos supports that conjecture. That would explain why they cannot see a major difference between my theory and the Big Bang theory. It would mean they have failed to keep in mind a key feature of their own theory: its lack of a centre.

The unconcern by Conner and Page at having a centre in their unbounded cosmos means they have somehow missed one of the main implications of the Copernican (or 'Cosmological') principle — **no boundaries means no centre!** This makes their subsection title, *'Misunderstandings about the significance of the Cosmological Principle'*, rather ironic. It is they who misunderstand!

I am not just quibbling about some minor mistake here. Conner and Page themselves attached great importance to this issue, claiming that it *'lies at the heart'* of my alleged errors. Though wrong about who erred, they were right about the importance of the issue. Turning their phrase around, their failure to recognise the implications of the Copernican principle lies at the heart of **their** errors. They were trying to show that gravitational forces ought to be the same in both a bounded-matter cosmos and the Big Bang theories. But their attempt failed, because the forces are different.

This issue of centres is crucial. The lack of a centre in the Big Bang theory means that differences of gravitational potential energy from place to place would be too small to cause large differences in clock rates. The presence of a centre in my theory causes large differences in gravitational potential energy, which in turn produce the timeless Euclidean zone. The next section deals with the major consequence of that zone's existence, time dilation.

9. CONNER AND PAGE MISUNDERSTAND TIME

The main thrust of Conner-Page **section 3** is to disparage the usefulness of Schwarzschild time t and to promote proper time τ as a panacea to the plague of time dilation. Very well: in this section I will use **proper** time to prove time dilation!

At the very beginning of their section 3, Conner and Page exhibit in their equation (3) the basis of all their reasoning, the Robertson-Walker metric. As I have pointed out in section 6, the Robertson-Walker metric is an **incomplete description** of the space-time of my cosmology, and therefore it obscures their understanding of how time behaves in it. In the Lorentzian region of that space-time, proper time τ is indeed tied to the expansion of space, and in that region one can use the radius of curvature of space as a kind of clock to which we can compare the proper time, as Conner and Page correctly point out. That is, for a given value of the expansion fraction x in the Lorentzian region, $d\tau/dx$ has the same value everywhere. In that sense, clocks in the Lorentzian region tick *'at the same rate everywhere'*.

But what Conner and Page did not know is that those clocks do not all start ticking at the same value of x. The outer ones start ticking earlier in the expansion, the inner ones, later. Thus, as I will show below, for a constant value of x in the Lorentzian region, the **proper** time elapsed **increases with distance from the centre.** In other words, the age of a bounded-matter cosmos — as measured by real, physical clocks — depends on location. At any given stage of expansion, the centre is younger and the edge is older.

Conner-Page subsection 3.1 is a tutorial — right out of the textbooks — showing that proper time is what physical clocks on various trajectories read. I agree; that is what I said in my book.[57] The significance they assign to this well-known fact is that it makes them feel suspicious: *'there is something fishy about Humphreys' appeal to a different coordinate system'*. But as I pointed out at the beginning of section 7, we have historical examples wherein a change of coordinates has revealed new physics previously concealed by the old coordinates. Are Conner and Page suspicious of new physics?

In their **subsection 3.2,** Conner and Page labour diligently to transform Schwarzschild coordinates into the coordinates of the Robertson-Walker metric. Their object is to try to show — again — that there is no time dilation in my cosmology: *'the elapsed time is equal to the cosmic time and is the same, regardless of the location of the clock* *inside the matter sphere.'* Their equation (8) epitomises their mistake. There they integrate their equation (7), which is correct only in the Lorentzian section of space-time, *'from the beginning of the expansion of the Universe',* that is, from a = 0 (or x = 0), to try to show that all clocks at a given value of a (or x) have the same reading. But since according to the Klein metric, my cosmology starts the expansion in a Euclidean region, their integration is wrong. They should start the integration at the critical value of a, a_c ($a \equiv x_c a_m$), which as equation (13) shows, depends on the comoving radius η (or χ).

Let us correct their mistake by using my book's equation (19a,b) giving the proper time τ as a function of the radius of curvature a,[58] an equation which can be easily derived from Conner-Page equation (20). My equation defined time zero as being at the peak of the expansion, so for convenience here I will make the transformation $\tau \rightarrow \tau + \tau_m$, where τ_m ($\tau_m \equiv \tau_o \equiv a_m/c$) is the half-period of the expansion, the proper time (as measured at the edge) necessary for the expansion to go from zero to maximum radius. That redefines time zero as occurring at the 'big crunch', when a = 0. Then using my new terminology ($a_o \rightarrow a_m$ and $\tau_o \rightarrow \tau_m$), the expansion fraction $x \equiv (a/a_m)$, and the negative sign option of my book's equation (19a) to represent the expansion phase, we get the following expression:

$$\tau(\chi_e) = \tau_m - \frac{\tau_m}{\pi}\left[\mathrm{Arccos}(2x-1) + 2\sqrt{x-x^2}\right] \quad \textbf{(22)}$$

Here I have written the proper time as $\tau(\chi_e)$ to emphasise the fact that only clocks at the edge of matter, where the comoving angle coordinate is χ_e, would start ticking at the beginning of the expansion, x = 0. Being comoving (and indestructible), they of course register proper time. Clocks in other locations would start ticking at later stages of the expansion, as Figure 8 illustrates. Let

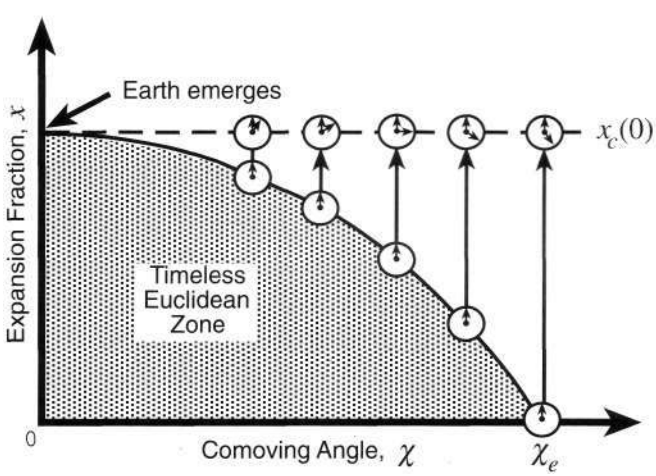


Figure 8. *Clocks in different places start ticking at different stages of the expansion, thus showing different proper times elapsed when the Earth emerges from the change surface. As measured in proper time at our present stage of expansion, the centre of the cosmos is young and the edge is old.*

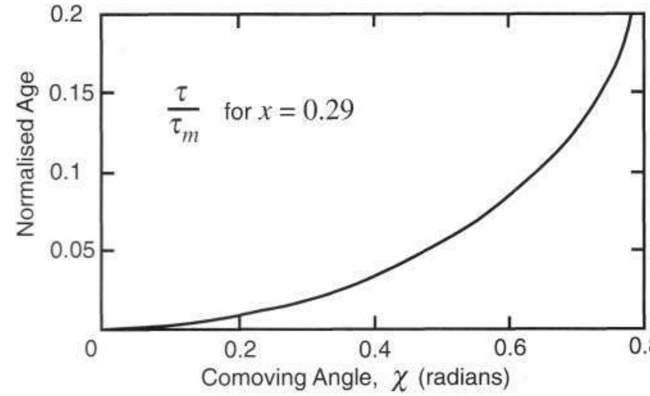


Figure 9. Age in proper time (normalised to the half-period of the expansion) increases with increasing comoving distance from the centre. Here as an example I have assumed χ_e = 45°, with a corresponding expansion factor of 0.29 when the Earth emerges from the signature change surface. The shape and size of the curve would change for negative spatial curvature, non-zero cosmological constant, or inflationary changes in the vacuum.

us define $T(\chi)$ as the proper time elapsed at location χ from the moment of emergence out of the Euclidean zone, when $x = x_c(\chi)$, until the Earth later emerges from the Euclidean zone at the end of the fourth day of creation, when x reaches $x_c(0)$. Since, as Conner and Page would agree, comoving clocks throughout a Lorentzian region are synchronous (same rate, not same starting time) with the expansion, $T(\chi)$ is equal to the proper time elapsed at the edge between those two values of x:

$$T(\chi) \equiv \left[\tau(\chi_e)\right]_{x_c(0)} - \left[\tau(\chi_e)\right]_{x_c(\chi)} \quad \textbf{(23)}$$

In other words, $T(\chi)$ is the **age,** measured in proper time with real clocks, of things at location χ at the end of the fourth day of creation. Using equation (13) to give us the values of $x_c(\chi)$ and $x_c(0)$, substituting those into equation (22), and substituting the result into equation (23) gives us an equation showing how the age depends on location:

$$T(\chi) = \frac{\tau_m}{\pi}\Big[\mathrm{Arccos}(1-2z) - \mathrm{Arccos}(1-2z_e) + 2\sqrt{z-z^2} - 2\sqrt{z_e - z_e^2}\Big] \quad \textbf{(24)}$$

$$\text{where } z \equiv \frac{\cos\chi_e}{\cos\chi} \quad \text{and} \quad z_e \equiv \cos\chi_e \quad \text{(25 a,b)}$$

The parameter z is such that $0 < z_e \leq z \leq 1$. Figure 9 plots the age (normalized by τ_m) versus comoving radial distance from the centre. Figure 10 plots the age versus proper distance λ ($\lambda \equiv a\chi$) for an arbitrary choice of parameters. The age increases from zero at the centre to billions of years at the edge of matter. Although this figure is similar to Figure 11 in my book,[59] please notice that the age in this one is given in **proper** time, not Schwarzschild time. That invalidates the conclusion of Conner-Page subsection 3.1, which they repeat throughout their critique.

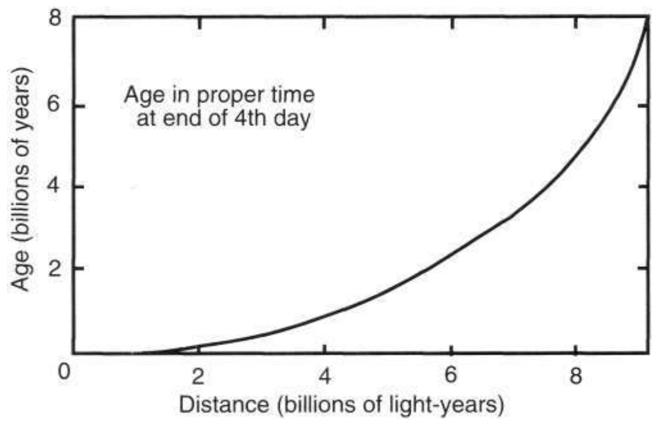


Figure 10. *Age (as measured with real clocks) at the stage of expansion when the Earth ended its fourth ordinary day after creation. For this example I have assumed the parameters of Figure 9 and* a_m *= 40 billion light-years. As mentioned in the caption for Figure 9, the shape of this curve depends on the parameters chosen. These ages are* ***not*** *the ages we would see in telescopes, which are affected by 'look-back' time.*

If this one figure, Figure 10, is even crudely correct — that is, different than a horizontal line — their whole critique is wrong.

Also note that the age in Figure 10 is **not** the age of objects as we see them in telescopes. Figure 10 plots age at a particular stage of expansion, the end of the fourth day. Except for the negligible 6,000 years that have since elapsed, Figure 10 shows the age of distant objects as they are right **now,** that is, for the value of the expansion fraction *x* we have here and now. The light we see in telescopes has already travelled billions of light-years and had begun its journey at an **earlier** stage of expansion, when those objects had not aged as much, although they were still many millions of years old then in terms of their clocks. In astronomers' terms, my cosmology has a **look-back time** to reckon with, just as the conventional cosmologies do.

In their equations (12) through (15) in the same subsection, Conner and Page briefly examine the Klein metric in order to transform Schwarzschild time into proper time. Interestingly, they overlooked the signature-changing properties of the Klein metric I have pointed out. But in their equation (12) they did correct two minor errors I made in transcribing Klein's result for the total Schwarzschild time elapsed. I am grateful for the correction; in fact, I regard it as the major positive contribution of the Conner-Page critique. But the corrections make no significant difference to my results.

In their **subsection 3.3,** Conner and Page enter into a detailed examination of Schwarzschild time. Their conclusion, near the end of their **subsection 3.3.1,** is that in some regions of space-time, *'Schwarzschild clocks are consequently physically impossible'.* I agree; I implied that in my book.[60] That does not diminish the value of Schwarzschild time as a conceptual guide to the theorist. The last paragraph of the same subsection criticises a statement of mine which is (a) not particularly relevant to the main issues, and (b) not in my book. In their **subsection** 3.3.2, they conclude *'the introduction of a boundary does not reduce the Earth proper time required for the Universe to expand to its present size'.* In this they again show unawareness of the Euclidean timeless zone and its effects. In their concluding **section 3.4,** they merely reiterate that unawareness.

10. CONNER AND PAGE ATTACK THE WRONG HORIZON

In their **section 4,** Conner and Page try to show that there is no time dilation at the event horizon. Yet their efforts here are entirely misdirected, because it is **in the Euclidean zone,** not at the event horizon, that the time dilation with which I am mainly concerned takes place. But it is I who am responsible — inadvertently — for misleading them.

The misleading happened because I myself did not understand the meaning of the Euclidean zone when I published my book in 1994. At that time I knew nothing of the newly-generated literature on classical signature change. I was aware of the time-stopping effects at the centre, as in equation (12), but I wrongly attributed that to the arrival of the event horizon and the fact that the Earth was not comoving with the expansion. As I remarked on page 119 of my book, one reason for thinking so was the

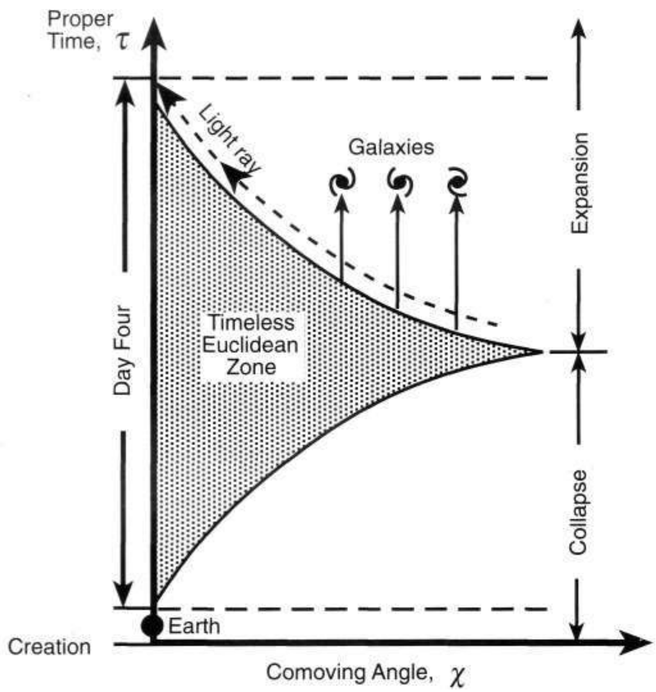


Figure 11. *Trajectory (dotted line) followed by light arriving at the Earth on the fourth day The light travels for billions of years, during which space expands greatly, but the Earth is in the timeless Euclidean zone during most of that expansion. Here I have shown the fourth day as encompassing both the collapse and the subsequent 'bounce' into expansion. See Figure 12.*

similarity of the cusps in Figure 10 of the book (p. 118) to the cusp in Figure 7 of the book (p. 112), which showed the effect on Schwarzschild time *t* for an astronaut crossing the event horizon. In plotting Figure 10 of the book, I misinterpreted an important clue I had noticed and which the referee of my ICC paper,[61] a theoretical physicist trained in general relativity, had asked me about. I wrote:

> *'Inside the event horizon, the Schwarzschild time also has a relatively small but non-zero imaginary component. The interpretation of an imaginary interval in section 3 (as spacelike) suggests that this imaginary part contributes to the stretching of space inside the event horizon.'*[62]

I now know that the location in question is not the event horizon, but rather the **change surface,** and that the imaginary component comes from a signature change in the Klein metric. Consequently the integration[63] which Klein performed to get his equation for *t* (equation [20] in my book, Conner-Page equation [12]) should only be evaluated for values of the variable which are real, not imaginary. In turn, that means the lines to the left of the cusps in Figure 10 (page 118) of my book should not be in the figure at all. (Also, removing the errors in my transcription of the equation shifts the location of the cusps.) Such a correction would have highlighted the cessation of time in the Euclidean zone.

11. CONNER AND PAGE ATTACK THE WRONG MODEL

In their **section 5,** Conner and Page seek to show that *'no amount of development can fix this model's problems* [with observations]/ But the model they are attacking is **not** the one I have proposed. They seek to show that *'rapid expansion'* would make the Hubble parameter much larger than what we observe. But *'rapid'* by **whose** clocks? As seen from the edge of matter, the expansion would take billions of years. Only as measured by clocks on Earth, which were stopped during most of that time, would the expansion seem rapid, perhaps even instantaneous.

What, then, would my model say the Hubble parameter should be? To a first approximation (beyond which we need a more developed model), just what is observed. Let me clarify my ideas as they now stand — and keep in mind that they are still being refined. The Klein metric and equation (23) for the elapsed proper time are based on three assumptions :-

(1) the curvature of space is positive, that is, $k = 1$,
(2) the 'cosmological constant' Λ has always been zero, and
(3) there has been no 'inflationary' change in the vacuum equation of state.

(Some would say that the third item is the same as the second.) I think it likely that at least one, and perhaps all, of these assumptions are not true. I suggest that God controlled (probably by adjusting vacuum inflation) the rate of expansion $\partial x/\partial \tau$ such that the rate of contraction of the signature change surface (x_c, χ_c) was slightly less than the local speed of light:

$$a_c \frac{\partial \chi_c}{\partial \tau} = x_c a_m \frac{\partial \chi_c}{\partial x} \frac{\partial x}{\partial \tau} \le c \qquad (26)$$

The result would be that an observer just outside the change surface would see it as a sphere[64] shrinking toward the centre at just under the speed of light. When the sphere reaches the centre, it disappears, revealing the Earth with its clocks showing **only four ordinary days** having elapsed from the beginning of creation.[65] Light from distant galaxies reaching the Earth at that moment would have travelled for billions of years, **as measured by clocks at the edge of matter,** and thus would have travelled a distance of billions of light-years. Figure 11 illustrates the trajectories. During the billions of years, space would have expanded by the same factor as suggested by conventional cosmologies, so the amount of redshift would be the same as in such cosmologies. The travel distance and redshift being the same, the Hubble constant would then be the same. The major difference between my book's explanation and this one is that here I have clarified the nature of the time dilation in more detail. This answers Conner-Page **subsection 5.1.**

Conner-Page **subsection 5.2** claims *'the Earth time elapsed'* gives a firm upper bound to the light travel distances. Not if Earth time had not been elapsing!

Their **subsection 5.2.1** is another tutorial from the textbooks. Yet it does cite a handy relation between redshift and light travel time, their equation (43). This rule of thumb is useful even in my cosmology, provided one keeps in mind that their $\Delta\tau_c$ would translate into the light travel time as measured by clocks **at the edge** of matter. Since in my cosmology the distances travelled are the same as in the conventional cosmologies, the observed angular diameters with which this section is much exercised should be the same. As for their concluding **subsection 5.3,** I simply point out that throughout their section 5, Conner and Page have completely ignored the mechanics of time dilation, thinking they had already refuted it.

12. CONCLUSION: BLINDNESS AND NEW VISIONS

12.1 A Large Blind Spot

By now it should be clear to unbiased readers, and I hope even to highly-committed theistic evolutionists also, that the Conner-Page critique suffers throughout from a fatal defect — unawareness of the timeless Euclidean zone. The existence of that zone shows that my cosmology is different from the Big Bang theory, and especially that time dilation does indeed occur in mine. It also shows that the restrictive Robertson-Walker metric Conner and Page depended on is not adequate for the black-hole and white-hole topology of my cosmology. Instead, they should have used the Ellis or Klein metrics.

It is important to keep in mind the recent developments[66] in relativity journals which give strong support to my points above, independently of whether my reasoning about the Klein metric is correct or not. These articles support:

(a) the feasibility of Euclidean zones and particle geodesics traversing them,
(b) the likelihood that Euclidean zones occur naturally in black holes and white holes, and
(c) the resulting conclusion that the Robertson-Walker metric Conner and Page used is too restrictive for the analysis of this situation.

The peculiar Conner-Page mistake I pointed out in section 8.2 shows they failed to keep in mind that their unbounded Big Bang cosmos is acentric. Being familiar with the basic equations and with the Copernican principle, they should have understood that before I pointed it out. Nevertheless, they failed to understand it even after I belaboured the point in my book. Their silence on the issue of centres implies that they were blind to it.

This intellectual blind spot has led them into a series of mistakes. First, it made them overlook a major difference between my theory and theirs, the presence of a centre in mine. That made them miscalculate the effects of gravity,[67] which caused them to neglect black-hole physics. In turn, that caused them to depend on an inadequate metric and ignore a good one. Thus they failed to notice the existence of the timeless zone. That helped them misunderstand my model and instead attack a wrong one, as sections 10 and 11 show. When we correct their mistakes, nothing remains of their critique.

I have gone through a major attitude change toward critics such as Conner and Page. At this point, for several reasons, I am grateful for their critique. First, I appreciate their having presented it in this journal, thus allowing me to answer them before a scientific audience. Second, it has confirmed that my book, now into its fourth printing, is having an effect. Though **Starlight and Time** makes little mention of evolutionism, it cuts to the roots of the evolutionary view of physical origins, the long time-scale of the Big Bang theory. If there had been no protest from evolutionists, I would have regarded my book as a failure. The loud and sometimes irrational complaints of theistic evolutionists,[68] particularly the Ross camp,[69] makes me feel that my labour has not been in vain.

A third reason I am grateful for the critique is that it has increased my confidence in the basics of my theory. These two highly-motivated and well-trained critics have been working diligently for several years, and yet they have failed to come up with anything more substantial than what they have said here. I hope most readers also have greater confidence in my theory now. Last, the questions have helped me clarify my answers, and this critique has opened a forum in which to present my new results. I have used this opportunity to present a better-defined version of my theory than in 1994, pointing out new and exciting vistas of space-time.

12.2 New Visions for Research

For creationists considering cosmological research along the lines I have presented here, I want to point out several possibilities. First, as I implied in section 9, there is an alternative form of the Klein metric (easily derivable from Klein's paper) which applies to negative spatial curvature ($k = -1$) rather than positive curvature ($k = 1$). Such a form may be more applicable to the real cosmos, which (unless the elusive 'dark matter' materialises) appears to have considerably less matter than the critical density. It is beginning to look to me as if this cosmology automatically solves one of the major problems plaguing the Big Bang theory: the great disagreement between

(1) the observed average mass density of the cosmos, and
(2) the Big Bang predictions.[70]

Second, the Euclidean zone opens up the possibility of a black-hole to white-hole 'bounce' occurring naturally, as Figures 11 and 12 illustrate. That is, the previous thinking that black holes cannot bounce, as typified in Figure 5, may not be correct in this new light. Third, since it seems that no physical processes, such as heating or nucleosynthesis, can occur in the Euclidean zone, we need to rethink how a collapse, 'big crunch', and subsequent expansion might fit into the Genesis account. Would the contraction into and expansion out of the Euclidean zone occur entirely on the fourth day? And since high temperatures right before and right after the Euclidean zone would only occur at great distances from the centre, how would that affect the cosmic background radiation? We now have a great many more possibilities than before.

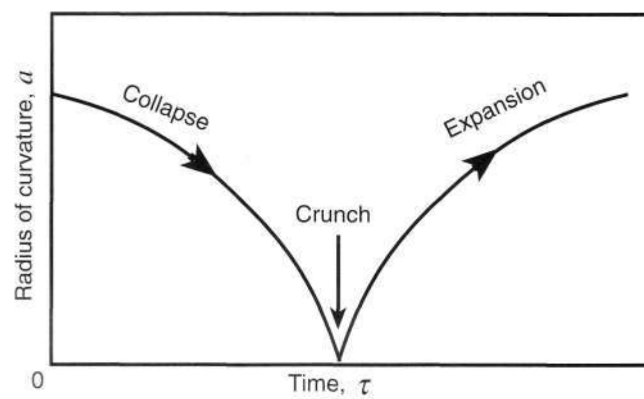


Figure 12. *The existence of the Euclidean zone may allow a black hole to 'bounce' and become a white hole, as implied in Figure 11.*

Finally, I want to emphasise the reliability of our Biblical foundations. Reading the Bible straightforwardly provides very clear evidence in many passages[71] that the Universe is young, as measured by clocks here. Therefore, those of us who know the Bible is scientifically reliable when taken at face value can remain assured that, regardless of how valid or invalid my particular theory may turn out to be, a correct young-world cosmology exists. Let us seek it out with diligence and courage!

REFERENCES

1. Humphreys, D. R., 1994. **Starlight and Time: Solving the Puzzle** of **Distant Starlight in a Young Universe,** Master Books, Green Forest, Arkansas.
2. I define 'theistic evolutionism' as any view that seeks to combine some kind of theism with naturalistic evolutionism — including that theory's **events** (Big Bang, molecules to man), **order of events** (light before Earth, fish before trees, death before Adam), and time-scale (billions of years). This includes the 'progressive creationism' of Hugh Ross. Theistic evolutionists object to my definition, disliking the opprobrium which has come upon the name 'evolution' in Christian circles. They claim that since they have their god 'creating' all the evolutionary events, they are really creationists. But since their process is completely different than the Biblical account, I say it is misleading to apply a Biblical name, such as 'creation', to it.
3. My book does not mention Dr Ross at all, but Ross seems to regard it as a major threat to his apologetics work. I think that is because my book demonstrates that the Big Bang theory is not the only possible cosmology which can flow from the experimentally well-established general theory of relativity. Ross has staked his teachings so heavily on the Big Bang that his work stands or falls with that theory, so he rightly sees any young-Universe cosmology as a threat.
4. Ross, H. N., 1995. Critique of **Starlight and Time** now available. **Facts and Faith,** 9(3):13. Also see: Ross, H. N., 1995. A fairer treatment of Humphreys' work. **Facts and Faith, 9(2):11. Facts and Faith** is the quarterly newsletter of Dr Ross' 'Reasons To Believe' organisation in California. The 'four physicists' Ross asked to write a critique have apparently diminished to one physicist, Dr Page, and one graduate student, Mr Conner. Finally, in a 'Reasons To Believe' general letter to supporters, dated July 1995, Dr Ross commends Mr Conner for his great zeal in supporting Ross' ministry both financially, and by research and writing.
5. Conner, S. R. and Page, D., 1998. **Starlight and Time** is the Big Bang. **CEN Tech. J., 12(2):** 174-194.
6. Klein, O., 1961. Einige Probleme der allgemeinen Relativitatstheorie. *In:* **Werner Heisenberg und die Physik unserer Zeit,** F. Bopp (ed.), Vieweg and Sohn, Braunschweig, Germany, pp. 58-72. Partial translation, Several problems of the theory of general relativity, 13 pages, available from D. R. Humphreys by sending a self-addressed envelope and US$2.00 to the address at the end of this paper.
7. Hellaby, C, Sumeruk, A. and Ellis, G. F. R., 1997. Classical signature change in the black hole topology. **International Journal of Modern Physics, D6(2):21**1-238 (p. 235).
8. Conner and Page, Ref. 5, section 3, equation (3). Throughout their paper, Conner and Page assume without question that the Robertson-Walker metric is fully applicable to this situation.
9. Conner and Page, Ref. 5, section 1.
10. Humphreys, Ref. 1, p. 114.
11. Humphreys, Ref. 1, pp. 115-116, equations (16) through (18).
12. Klein, Ref. 6, equations (68), (69) and (81). Klein uses the opposite sign convention for the metric than I do. That is, in the Lorentzian region, Klein has the time component negative and the three space components positive; in the Euclidean region all four components are positive.
13. Humphreys, Ref. 1, pp. 92, 102, 106.
14. Humphreys, Ref. 1, p. 89.
15. Humphreys, Ref. 1, p. 116, Figure 8.
16. Weinberg, S., 1972. **Gravitation and Cosmology,** John Wiley and Sons, New York, pp. 342-346, equations (11.9.31) through (11.9.36). Weinberg uses somewhat different nomenclature, but when the conversion is made, the metric is exactly the same as that of Klein, whom Weinberg references on pp. 342, 353.
17. Rindler, W., 1977. **Essential Relativity,** revised second edition, Springer-Verlag, New York, p. 113.
18. Humphreys, Ref. 1, p. 106, equation (13).
19. Wald, R. M., 1984. **General Relativity,** University of Chicago Press, Chicago, p. 23.
20. Hawking, S. W., 1988. **A Brief History of Time,** Bantam Books, New York, p. 134.
21. Ellis, G. F. R., Sumeruk, A., Coule, D. and Hellaby, C, 1992. Change of signature in classical relativity. **Classical Quantum Gravity, 9:** 1535-1554 (p. 1537).
22. Ellis *et al.,* Ref. 21, p. 1549.
23. Ellis *et al.,* Ref. 21, p. 1535.
24. Ellis *et al.,* Ref. 21, p. 1535. For clarity, I have added a comma in the first sentence.
25. Carlini, A. and Greensite, J., 1994. Why is spacetime Lorentzian? **Physical Review, D49(2):866-879.**
26. Kriele, M., 1994. Why are we living in a Lorentzian universe? **Classical Quantum Gravity,** 11:1325-1330.
27. Alty, L. J., 1994. Kleinian signature change. **Classical Quantum Gravity,** 11:2523-2536. Alty does not say explicitly why he called a (++ —) signature *'Kleinian',* but since he was examining the behaviour of the Klein-Gordon wave equation in such a region, he may have taken the name from that equation. There is no indication that Alty was considering the Klein metric.
28. Hellaby *et al.,* Ref. 7, section 3, p. 216.
29. Ellis *et al.,* Ref. 21, p. 1537, equation (2). Hellaby *et al.,* Ref. 7. Notice that while these authors considered the lapse function as depending only on time τ, I have also included the radial coordinate η for generality, because of what the Klein metric says.
30. Ellis *et al.,* Ref. 21, p. 1537. Their criterion also contains the qualifier *'essentially',* which I think refers to the fact that their verbal statement would agree with their equation [my equation (15)] only in a system of units wherein the Einstein gravitational constant κ would equal 1.
31. Ellis *et al.,* Ref. 21, p. 1547, equations (40) and (41).
32. Rindler, Ref. 17, p. 165, equations (8.98) through (8.100).
33. Big Bang theorists are weighing the possibility that in the very early stages of their expansion, quantum (or vacuum) field strengths could be high enough to cause the signature of the metric to be Euclidean. In that case, the scalar field φ and its potential energy V considered by Ellis would not be the mass density and the gravitational potential energy, but rather some other field, say a field causing vacuum inflation to occur, and its potential. See: Guth, Ref. 70. The current interest in signature changes has been driven by that possibility ever since Hartle and Hawking called attention to it over a decade ago. See: Hartle, J. B. and Hawking, S. W., 1983. Wave function of the universe. **Physical Review, D28(l**2):2960-2975. The *'imaginary time'* Hawking discusses in his popular book (Ref. 20) occurs in just such a Euclidean region he is considering.
34. Kruskal, M. D., 1960. Maximal extension of Schwarzschild metric. **Physical Review,** 119:1743-1745.
35. Szekeres, G., 1960. On the singularities of a Riemannian manifold. **Publ. Mat. Debrecen.,** 7:285-301.
36. Humphreys, Ref. 1, pp. 89, 92.
37. The second type of clock can indeed be the radius of curvature of space, *a,* as Conner and Page propose in their section 3. However, that type of clock is not sufficiently independent of proper time to show time dilation explicitly. See my comments at the beginning of section 9, second and third paragraphs.
38. Humphreys, D. R., 1997. It's just a matter of time. **Creation Research Society Quarterly,** 34(l):32-34. This is a response to Dr John Byl's critique, on time dilation in cosmology, on pp. 26-32 in the same issue.
39. Humphreys, Ref. 1, p. 114.
40. Hawking, S. W. and Ellis, G. F. R., 1973. **The Large Scale Structure of Space-Time,** Cambridge University Press, Cambridge, p. 360.
41. Conner, S. R. and Page, D. N., 1995. Light-travel time in **Starlight and Time. Bible-Science News, 33(7):** 12-16. In this paper, Conner and Page criticise (correctly though quibblingly) a phrase in Humphreys, Ref. 1, p. 109, saying that an astronaut **'falling'** towards a black hole event horizon that would experience time dilation effects. To make my phrase correct, simply replace the word *'falling'* with *'using retrojets to approach slowly'* the event horizon. That makes the astronaut's experience more compatible with the situation I had in

mind, that of an observer at rest in the centre of a white hole as the event horizon reaches him. Also see my response in the same issue: Humphreys, D. R., 1995. How we can see a young universe: a reply to Conner and Page. **Bible-Science** News, 33(7): 12, 16-19.

42. Humphreys, Ref. 1, p. 89, equation (1).
43. Barbero, G. J. F., 1996. From Euclidean to Lorentzian in general relativity: the real way. **Physical Review, D54(2):** 1492-1499.
44. Hawking, Ref. 20, p. 134.
45. Harrison, E. R., 1981. **Cosmology: The Science of the Universe,** Cambridge University Press, Cambridge, p. 107. My theory pictures the cosmos as just such a cloud expanding in (but also with) space. Thus Harrison would recognise that my theory is quite different from the Big Bang. It is ironic that Conner and Page do not make such a recognition. Another irony is that the picture the public incorrectly identifies with the Big Bang is actually quite appropriate for my theory!
46. Humphreys, Ref. 1, pp. 14-18, 93-99.
47. Humphreys, Ref. 1, p. 17.
48. Humphreys, Ref. 1, p. 88.
49. Humphreys, Ref. 1, p. 97.
50. That one of the two was Oskar Klein does not disturb me, since my view of science does not insist that academics be infallible, not even in the peer-reviewed publications. As for Klein's having published the idea of a bounded-matter Universe in 1971 before me, I am glad of it. I had not been aware of his 1971 article until shortly after my book was published in 1994. If I had known of it beforehand, I would have been happy to give Klein the credit he deserves, and I am happy to do so now. However, as Conner and Page point out, Klein was apparently not aware of the profound differences between a bounded-matter cosmos and an unbounded-matter cosmos.
51. Marion, J. B., 1965. **Classical Dynamics,** Academic Press, New York, pp. 116-118.
52. Hawking and Ellis, Ref. 40, p. 134.
53. Newton, I., 1687. **Philosophiae Naturalis Principia Mathematica,** Royal Society, London, Book I, Section XII, Proposition LXX, Theorem XXX. A. Motte's 1729 translation revised by F. Cajori. *In:* Newton, I., 1962. **Principia,** University of California Press, Berkeley, Vol. **I, The Motion of Bodies,** p. 193. The theorem shows with simple geometry how the gravitation force is zero everywhere within a thin spherical shell of mass. One can then extend the theorem to concentric thin shells of various radii and mass, and thence to a spherically-symmetric thick hollow shell with an arbitrary radial density distribution.
54. Conner and Page, Ref. 5, section 2.2.
55. Conner and Page, Ref. 5, section 2.2, last sentence above equation (1) and first sentence below it.
56. Weinberg, S., 1993. **The First Three Minutes: A Modern View of the Origin of the Universe,** 2nd paper edition, Basic Books (Harper-Collins), New York, p. 32. It is ironic that in Conner and Page's citation (their Ref. 16) about Birkhoff's theorem, it is the same Steven Weinberg who says, '. . . *at the center of a spherically symmetric system, even if the system is infinite* . . .'. This shows that even Nobel laureates are not exempt from self-contradiction. In this second quote, it seems clear that Weinberg's words outran his good sense, a phenomenon which often occurs in cosmology. The quote also shows that this issue frequently confuses even the experts.
57. Humphreys, Ref. 1, pp. 89, 92.
58. Humphreys, Ref. 1, p. 117.
59. Humphreys, Ref. 1, p. 120.
60. Humphreys, Ref. 1, p. 102.
61. Humphreys, D. R., 1994. Progress toward a young-earth relativistic cosmology. *In:* **Proceedings of the Third International Conference on Creationism,** R. E. Walsh (ed.), Creation Science Fellowship, Pittsburgh, Pennsylvania, pp. 267-286. Reprinted in Humphreys, Ref. 1, Appendix C, pp. 83-133.
62. Humphreys, Ref. 1, p. 119.
63. Klein, Ref. 6, p. 71, equation (87). Page 12 in my translation. The integration variable which must remain real is z, defined in Klein's equation (86).
64. As best I can tell from the literature, the signature change surface would reflect some light and absorb other light, thus making it look like shiny black glass. Because of the recession, the reflected light would look reddened to the observer. Inside the change surface, no light waves can travel, so we could think of the interior of the Euclidean zone as being totally dark.
65. According to the scenario I presently imagine, a little over three ordinary days would have elapsed from the moment of creation to the beginning of the fourth day, when the Earth disappeared into the change surface, newly formed by the collapse of matter toward the 'big crunch'. The crunch would be followed by the 'bounce' into expansion I mention briefly in section 12.2.
66. Hellaby *et al.*, Ref. 7, and their list of references.
67. Humphreys, Ref. 1, pp. 100-103. The miscalculation is the one I pointed out in section 8.2, namely the reasoning which misled them into thinking that an unbounded cosmos would have the same gravitational forces as a bounded-matter cosmos. In addition, they ignored the possibility that global parameters such as gravitational potential might have significant effects. Although the metric of my book's equation (9) is an approximation, the fact that it explicitly contains the gravitational potential Φ should have been a warning flag to Conner and Page that global properties might not be negligible.
68. Phillips, P., 1997. D. Russell Humphreys' cosmology and the 'Timothy Test'. **CEN Tech. J.,** 11(2):189-194. Dr Phillips is a theistic evolutionist (see my definition of such in Ref. 2) who objects to my taking Scripture straightforwardly. The same journal issue contains rebuttals by Dr Jonathan Sarfati and myself.
69. Ross, H., 1995. Progress towards resolution of the creation-date controversy. **Facts and Faith,** 9(1): 12-13. I answered Ross' criticisms, pointing out their 'off-the-wall' nature, in a personal letter to him (faxed March 7, 1995, mailed March 26, 1995) and then publicly *in:* Humphreys, D. R., 1995. An open letter to Hugh Ross, **Bible-Science News,** 33(4):21-22. Even after responses from his readers prompted Ross to apologise for oversimplifying (Ref. 4, issue 2), Ross has continued to repeat similar criticisms verbally to audiences. He also neglects to tell them about the existence of my published answers.
70. Guth, A. H., 1981. Inflationary universe: a possible solution to the horizon and flatness problems. **Physical Review,** D23:347-356. The problem I referred to in the main text is called the *'flatness problem'.* It amounts to the following: after billions of years of expansion, the conventional Big Bang theory requires the average density of the cosmos to be very different from the critical density — either much greater or much less — not the several percent of critical density observed. This is one of the two problems Guth designed his 'inflationary' version of the theory to solve. But the inflationary scenario requires the present density of the cosmos to be almost exactly equal to the critical density — again not what is observed. Thus the observed density lies annoyingly (for Big Bangers) far away from the predictions of both the conventional and the inflationary theories. The intense search for 'dark matter' over the past decade has been motivated for some mainly by a desire to support the inflationary theory and thus patch up a major problem. For others, it is a way to observationally test both versions.
71. For example, Genesis 1:1-2:4, Genesis 6:13-8:19, Exodus 20:11, Exodus 31:17, Psalm 33:6-9, Matthew 19:4, Mark 10:6, Luke 11:50, John 8:44, Romans 1:30, II Peter 3:6,1 John 3:8. Some of these verses directly say the world is young; the others strongly imply it.

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