allows them to keep the time coordinate real on both sides of the signature change surface. One could equally well leave the sign switch out of the metric (as in the unmodified Robertson-Walker form), in which case the change of signature would still take place when (according to Ellis, *et al*.'s proposed criterion) the cosmic dynamics caused da/dt to become imaginary. In this case, the signature change would manifest itself by a Wick rotation of the time coordinate from t to $\sqrt{-1}\,\tau$ rather than by a change of sign in g_{00}. It should be noted that in the physical (as opposed to coordinate artefact) signature change considered by Ellis, *et al*. and others, signature change occurs *either* by a change of sign of the metric *or* by a Wick rotation of the time coordinate, *but not both*. In Humphreys' coordinate-artefact-induced metric sign change, there is *both* a metric sign change *and* a Wick rotation of the time coordinate, and the two cancel each other, leaving the intrinsic signature of spacetime unchanged. The intrinsic signature change considered by Ellis, *et al*. is a coordinate-independent physical process which is caused by the dynamics of the cosmic expansion, while Humphreys' coordinate-artefact-induced sign change is not a physical process at all, but simply an artefact of the particular coordinate system he prefers to use, the Klein coordinate system.

35. Peebles, P.J.E., *Principles of Physical Cosmology*, Princeton University Press, pp. 312–313, 1993. This equation is strictly valid only for 'cold dust' cosmologies, but these are an excellent approximation to the actual universe throughout its observable ($Z < 1100$) history.

36. This transformation can also be derived by using the Ellis, *et al*. form of the metric to calculate the proper time interval elapsed on comoving clocks, in the same manner as is done for Humphreys' modified metric in note 37. This calculation shows that Ellis, *et al*.'s proposed criterion for classical metric signature change, imaginary expansion rate, is valid.

37. In fact, even Humphreys' proposed further generalization of the lapse function N to be a function of both t and η leads identically to the Robertson-Walker form of the metric. Humphreys' proposed generalization of the conventional Robertson-Walker metric is

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

(equation 14, p. 201, reference 3.). This is actually no generalization at all, as the following analysis shows. If we consider the trajectory of a comoving clock, $d\eta = d\theta = d\varphi = 0$, it follows that $ds^2_{\text{comoving}} = c^2 d\tau^2_{\text{comoving}} = c^2 N(\tau,\eta)d\tau^2$. This relation determines the mathematical form of the lapse function in terms of the comoving proper time interval dtcomoving and the coordinate time interval $d\tau$: $N(\tau,\eta) = d\tau^2_{\text{comoving}}/d\tau^2$. Substituting this formula for the lapse function $N(\tau,\eta)$ into Humphreys' modified metric immediately recovers the familiar Robertson-Walker form, which shows that the two equations are really the same.

38. Humphreys, D.R., *Starlight and Time: Solving the Puzzle of Distant Starlight in a Young Universe*, Master Books, Green Forest, Arkansas, pp. 10, 46, 1994, 1998.

Starlight and time: a response

D. Russell Humphreys

I thank Mr Conner and Dr Page for continuing to call attention to my little book on cosmology, *Starlight and Time*.[1] I often wonder if its persisting popularity is partly due to their determined attempts to discredit it. Of course, such a result would be far from what they desire, since their aim is to support Dr Hugh Ross's theistic evolutionary[2] version of the 'big bang' cosmology.

Another reason I am grateful for their critiques is that unsympathetic scrutiny, while not being particularly comfortable, either exposes flaws or, failing to do so, builds up confidence in the theory being scrutinized. I am happy to report that their latest attempt has had the latter effect, at least on me. That is because they have merely continued with Mr Conner's previous (1999) lines of attack,[3] without paying adequate attention to my responses[4] to those same arguments. Below I respond to these latest versions of their arguments, following the same order as in my 1999 reply.

They still have problems with a centre

In their 1998 critique,[5] Conner and Page argued that both bounded-matter and unbounded-matter universes would have the same gravitational forces, so that there would be no essential difference between my cosmology and theirs. Their first step was to try to show that an infinite (unbounded) Newtonian cosmos uniformly filled with matter would have the same forces as a finite (bounded-matter) one. Here I have reproduced Figure 2(d) of their 1998 article, showing their result. The arrows show the pattern of gravitational forces they derived.

In my 1998 reply,[6] I pointed out an alleged error in their derivation. In defence of their derivation, Conner and Page introduce several strained definitions. For example, they stretch out the meaning of the word 'centre' to include their idea of *'infinitely many'* non-unique centres. But they seem to have missed my main point: a uniform unbounded-matter cosmos **cannot have a unique centre**. They seem to acknowledge this inadvertently by saying that the various *D*s in equations (1) through (3) are distances from the *'adopted'* origin of coordinates. In Figure 2(d), they showed arrows of force converging upon a dot. The dot is the *'adopted origin of coordinates'* caused by their method of analysis. Let's call it 'point *C*'. Here is the crucial problem with their result: **their 'forces' depend on where they choose to put point *C*.**

Point *C* is an arbitrary artefact of their method of analysis, existing only in the mind of the analyst. Another analyst might place *C* in a different place. Yet the Newtonian cosmos they postulated is static, motionless on a

large scale. That means the forces they derive should be measurable, and therefore physically real. For example, we could measure the directions of the forces with a plumb line. So how could the derived forces be physically real if they are to point toward a purely mental location? Would the plumb line change its direction if we were to change our mental placement of the *'adopted origin of coordinates'?* The answer is, no — something is clearly wrong with their derivation. Whether that flaw is the use of Newton's 'hollow shell' theorem in a situation where it is not valid (as I alleged) is not the most relevant point. The most relevant point is that their **conclusion** is illogical. In writing my 1998 article, I had thought a quote from a cosmologist they respect would settle the issue:

> *'On the other hand, if matter were evenly dispersed through an **infinite** space, there would be **no center** to which it could fall.'*[6]

These are the words of Nobel Laureate Steven Weinberg[7] (the second emphasis is mine). He was talking about precisely the situation Conner and Page were analyzing, an infinite uniform-matter Newtonian universe. Weinberg confirms what was already clear to me: without boundaries or variations in density, we can define **no unique centre** toward which gravitational forces could make matter fall. But Conner and Page do not agree to that point. In fact, nowhere does their letter take notice of Weinberg's statement, though I quoted it in my 1998 paper and referred to it prominently in my 1999 reply. If Conner and Page cannot acknowledge such obvious features of a simple Newtonian theory, how can we have confidence in their pronouncements about much more subtle relativistic theories?

They still use circular reasoning about time

Referring to equation (20) of my 1998 article, the change in proper time τ measured by physical clocks at rest in the **centre** of a bounded-matter cosmos depends on the change in Schwarzschild (or coordinate) time t as follows:

$$d\tau^2 = \beta\ dt^2 \qquad (1)$$

where β is Klein's time dilation factor. In my 1998 article I pointed out that early in the expansion of the cosmos, β is negative, becoming positive only later. In the same article I offered reasoning that Schwarzschild time t is a *conceptual* coordinate, so that dt^2 remains positive throughout the expansion. Then the product $\beta\, dt^2$ would change sign during the expansion, being positive late in the expansion but negative early in the expansion. That would mean that $d\tau^2$ would be negative early in the expansion. The interval $d\tau$ would be imaginary (in the mathematical sense), or better, space like. As I pointed out, relativists interpret that as meaning that physical clocks would be stopped.

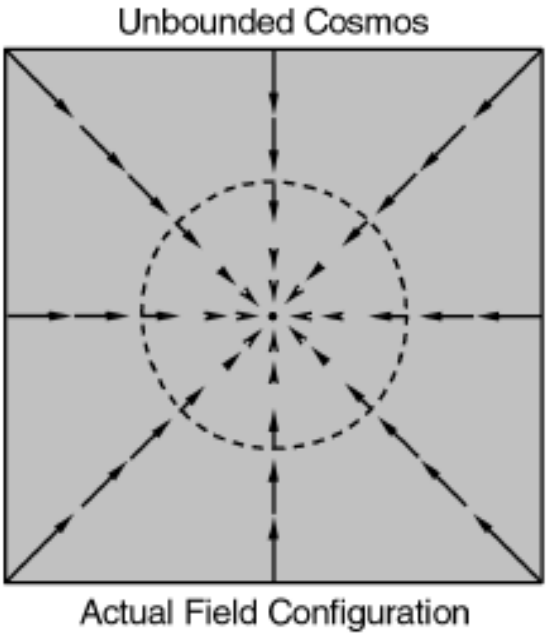

Figure 2(d) reproduced from 1998 critique by Conner and Page.[5]

My idea that the square of the Schwarzschild time interval dt^2 does not change sign is not new. It is the usual way relativists interpret the Schwarzschild metric in vacuum. Using my notation, that metric as applied to radial motions is

$$d\tau^2 = \beta\ dt^2 - \alpha\ dr^2 \qquad (2)$$

In this metric, $\beta = 1 - (r_s / r)$, $\alpha = (c^2\beta)^{-1}$, and r_s is the radius of the event horizon. Inside the event horizon both β and α are negative. Relativist theorists say this means that r for a particle inside the event horizon cannot be constant; otherwise dr^2 would be zero and the proper time interval $d\tau^2$ would become negative.[8] Now if the square of the Schwarzschild time interval dt^2 could become negative, then $d\tau^2$ could be positive even if the particle's r-coordinate were constant ($dr^2 = 0$). But relativists never seem to consider that option, perhaps because they interpret Schwarzschild time as a *conceptual coordinate*, at least unconsciously. This supports my reasoning that the square of the Schwarzschild time interval dt^2 remains positive through a signature change.

Conner and Page disagree. They are correct in saying that the time dilation factor β changes sign because (simplifying their notation a bit [9]) the factor $(\partial\tau / \partial t)^2$ in their equation (7) changes sign. But they claim that it does so because it is the Schwarzschild (or *'Klein'*) time interval dt which becomes imaginary, not the proper time interval $d\tau$. However, they provide no proof here for their claim. They merely refer (their ref. 22) to a derivation in Conner's 1999 letter.

My 1999 criticism of Conner's derivation was that he had based it on a questionable foundation. He assumed that his starting point, equation (1) in his 1999 letter, was valid in the timeless (Euclidean) zone. That is equivalent to assuming the point he wanted to prove; i.e. his reasoning was circular. But previously, in my 1998 article, I had questioned whether that very equation is valid in a Euclidean zone. In my 1999 reply, I emphasized those doubts. In their present letter, Conner and Page answer my criticism by using their conclusion to justify their starting point. **Circular reasoning** again! This leaves their case unproved.

My basic case for time dilation does not depend on the above point, the stopping of time in a Euclidean zone. As I asserted in my book and then pointed out on page 203 of my 1998 article, time dilation also occurs at the event horizon:

> *'Therefore physical clocks at the centre of a white hole must stop (relative to Schwarzschild time) when the event horizon arrives.'*

Contrary to an allegation by Hugh Ross,[10] this quote shows I never gave up on that first possibility, time dilation at the event horizon.

Last year I came across a **new paper** which **supports** my view above. It was published in the *Astrophysical Journal* in 1995, only a year after my book was published.[11] The author, Martin Harwit, asserts that physical clocks near an event horizon tick slower than physical clocks which are far away from it. He refers not to Schwarzschild time, but to **proper** time in co-moving reference frames, the same sort of time and frames Conner and Page prefer. This means that their arguments about the meaning of Schwarzschild time are irrelevant to the question of time dilation at the event horizon.

They still misunderstand my model

Conner and Page's reactions to some of the 'signature change' articles in secular relativity journals are useful to me; hitherto, most relativists have been fairly quiet about those developments. Here are my responses to the three comments in their sixth-from-last paragraph:

(1) *' ... the speculative' character of this literature ....'* 'Speculative' means different things to different people. For example, I think the currently popular string theories are highly speculative. But the basic observation by George Ellis — that Einstein's field equations do not exclude the possibility of signature change — is on rock-solid ground. It is not at all speculative to try to explore the new territory Ellis has opened up. (Conner and Page's parenthetical comment here merely repeats the conclusion of their circular reasoning, as I explained in section 2.)

(2) *' ... criterion for signature change ....'* I have already been considering, and will continue to consider carefully, whether gravitational potential energy can produce signature change. All writers have been rather unclear on precisely what would cause the changes, so I am not committed to any particular details of the picture I presented. We are indeed at the frontiers of human knowledge here, and I welcome knowledgeable instruction on these points.

(3) *' ... applies to unbounded as well as bounded ....'* I certainly was not trying to say that unbounded universes could not have signature change. I merely was pointing out that bounded-matter universes have an additional factor to consider, namely gravitational potential energy.

The next three paragraphs, including equations (8) and (9), are merely a belaboured attempt to show that the Robertson-Walker metric can allow a signature change, even if one does not include an explicit lapse function. Okay, I'll agree with that; I'm quite happy for them to now be allowing signature change. However if they had included a lapse function explicitly in their metric, they would have been more likely to see its effects in the equations. They did not do such.

In the second-to-last paragraph, Conner and Page assert that the cosmic microwave background radiation we see must have originated after any signature change. I agree. That is an implication of section 11 of my 1998 paper, and Figure 11 therein, in which the *'light ray'* includes light from such sources.

In their last paragraph, they assert that a signature change would have to be simultaneous throughout the cosmos. However, their supporting sentence for this, *'This simultaneity is imposed by the fact that ...',* turns out to rest on an assumption of the truth of the previous sentence — circular reasoning again! Their assertions about a 6,000 light-year particle horizon are built on the same inadequate logic. I exhort them to consider Figure 11 more carefully, especially on how it provides a counter example to their reasoning.

They still don't acknowledge confirming research

Note carefully: in all their comments on the literature, Conner and Page have **completely ignored** my pointed challenge to comment on a 1997 paper by Hellaby *et al.*,[12] which asserted that such a timeless zone could occur in a black-hole/white-hole situation:

> *'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 space.'*

Since that conclusion supports the main point of my 1998 paper, why do Conner and Page continue to remain silent about Hellaby's 1997 paper?

Conclusions

In summary, Conner and Page have ignored the essence of all my 1999 challenges to them. Section 1 shows they are still not acknowledging their problems with a **unique centre** of the cosmos, heeding neither me nor Stephen Weinberg. Section 2 shows that they did not break out of their **circular reasoning** about the interpretation of the various time coordinates. Section 3 shows they are still attacking only strawman versions of my model. Section 4 shows they are still not acknowledging the most important **supporting paper**, the 1997 article by Charles Hellaby *et al*.

Their continued silence about the Weinberg and Hellaby quotes is very significant. Because Conner and Page have not contested my interpretation of those two quotes, the reader would be justified in considering their silence to be indirect support for my points. I will be interested to see how Conner and Page respond to the **new support** I cited from the literature, the 1995 *Astrophysical Journal* article by Harwit.

In all of this, let me emphasize that I am not claiming to be omniscient or inerrant! For example, I do not know whether my interpretation of Schwarzschild time is correct. I merely know that Conner and Page have not proved their case, and that they are ignoring the most important issues. Furthermore, I suspect there are mysteries related to the interpretation of time which no human yet understands. In general, I regard my work as one incomplete example of a new **class** of theories; centric cosmologies with various types of time dilation. I urge gifted creationists, who have the advantage of knowing from both Scripture and science that the world is young, to become expert in general relativity. I call upon them to generate better cosmologies than mine, to the glory of God.

References

1. Humphreys, D.R., *Starlight and Time: Solving the Puzzle of Distant Starlight in a Young Universe*, Master Books, Green Forest, Arkansas, 1994; Sixth printing, March 2000.
2. By 'theistic evolutionism' I simply mean any attempt to reconcile **theism** with the events, sequence, and time scale alleged by naturalistic **evolutionism**, both physical and biological.
3. Conner, S.R., Vistas — one more, *CEN Tech. J.* **13**(1):56–58, 1999.
4. Humphreys, D.R., Russell Humphreys replies, *CEN Tech. J.* **13**(1):59–60, 1999.
5. Conner, S.R. and Page, D.N., *Starlight and Time* is the big bang, *CEN Tech. J.* **12**(2):174–194, 1998.
6. Humphreys, D.R., New vistas of space-time rebut the critics, *CEN Tech. J.* **12**(2):195–212, 1998.
7. Weinberg, S., *The First Three Minutes: A Modern View of the Origin of the Universe*, second paper edition, Basic Books (Harper-Collins), New York, p. 32, 1993.
8. Rindler, W., *Essential Relativity: Special, General, and Cosmological*, revised second edition, Springer-Verlag, New York, p.149, 1977.
9. Conner and Page change t to t_k and call it *'Klein'* time, but here I am dropping their subscript to keep the notation simple. Their notation contains some psychological subtleties. Notice that the factor $(\partial t_{Klein} / \partial \tau)^{-2}$ in their equation (7) is more complicated than necessary. They could have inverted the expression and dropped the cumbersome subscript, as I did in the text. Why didn't they clean up their notation? Probably because they want τ to be a dependent variable and τ to be an independent variable. The usual mathematical convention is to subscript a dependent variable and put it in the numerator. It is okay to use notation to emphasize a point one wishes to prove, but here it would have been good to note that explicitly, since it is the very point at issue.
10. Ross, H., Humphreys' new vistas of space, *CEN Tech. J.* **13**(1):49–50, 1999.
11. Harwit, M., Time and its evolution in an inhomogeneous universe, *Astrophysical Journal*, **447**:482–490, 1995. Not being interested specifically in time at the event horizon, Harwit does not state its behaviour explicitly in words. However, his equation (11) relates (A) the rate of a clock moving with the surface of an expanding (or contracting) dust cloud to (B) the rate of a clock co-moving with the inner surface of an expanding shell of dust much further away. In the equation, when the radius r_{vi} of the first clock becomes equal to the Schwarzschild radius r_s, the rate of the first clock becomes zero, as measured by the more distant second clock. This means that time dilation at the event horizon is a slowing of **proper** time as measured by **co-moving** physical clocks. It is not merely an alleged 'artefact' of using Schwarzschild time.
12. Hellaby, C., Sumeruk, A. and Ellis, G.F.R., Classical signature change in the black hole topology, *Int. J. Modern Physics*, **D6**(2):211–238, 1997.