Starlight — time and again

Samuel Conner & Don Page

Dr Humphreys rejects our Newtonian illustration and relativistic demonstration[1,2] of the identical gravitational fields of bounded and unbounded universes on the basis of his claim that unbounded universes cannot possess the property of spherical symmetry.[3,4] Humphreys' claims are mistaken, and are based on a misunderstanding of the physical and mathematical meaning of spherical symmetry. An object is said to possess the property of spherical symmetry with respect to a particular point if it is unchanged by an arbitrary rotation about an arbitrary axis passing through that point. For objects which have a spherical boundary, there is only one such point of spherical symmetry,[5] and this point constitutes a unique centre to the object. Humphreys believes that objects which do not possess a spherical boundary, such as the unbounded universe models of 'big bang' cosmology, cannot possess spherical symmetry. However, such unbounded universes in fact are spherically symmetric about *every* point: an arbitrary rotation about an arbitrary axis through any point will leave the system unchanged. The spherical symmetry of the unbounded 'big bang' models is also obvious from the manifest spherical symmetry of the Robertson-Walker form of the metric,[6] which is commonly employed to describe their geometry.

Spherical symmetry with respect to a particular point is identical to the notion of *isotropy* about that point. Unbounded standard 'big bang' universes are isotropic with respect to every point in their interiors, which is to say that they are spherically symmetric from the point of view of every point. Such universes are not acentric, as claimed by Humphreys, but rather have infinitely many centres of spherical symmetry. The centres of spherical symmetry are not unique, but that does not mean that they do not exist at all. Humphreys' claim that the Copernican principle is incompatible with spherical symmetry[7] is another misunderstanding. The Copernican principle imposes spherical symmetry with respect to every point because it imposes the property of isotropy at every point. The spherical symmetry of standard unbounded 'big bang' models is discussed, using the language of isotropy, in every cosmology textbook. Readers interested in a thorough discussion are referred to the chapter which Weinberg devotes to his discussion of symmetric spaces[8] and especially to the conclusion of that chapter, which discusses the special case of 'Spherically Symmetric Homogeneous Spacetime' and derives the Robertson-Walker form of the metric solely from the symmetry properties of this geometry.[9]

We did not commit a 'big blunder,' as Humphreys charges,[10] in our appeal to the obvious symmetry properties of unbounded homogeneous and isotropic matter distributions. Our appeal to these properties is valid and the conclusions, we have drawn from these properties regarding the identity of the gravitational properties of Humphreys' bounded universe and the unbounded 'big bang' universe are correct.

Another demonstration of the identity of the gravitational properties of the bounded and unbounded universes is found in consideration of the manner in which each of these models decelerates as it expands. It is straightforward, using simple Newtonian arguments,[11] to show that the thin shell of matter at the boundary of Humphreys' bounded universe experiences a radial deceleration of

$$\frac{d^2 D_B(\tau)}{d\tau^2} = -D_B \frac{4}{3}\pi G \rho$$

(1)

Where ρ is the mass density of the bounded universe[12] at time τ, $D_B(\tau)$ is the distance from the centre of the matter sphere to the expanding boundary, and *t* is the time measured by an observer at rest at the centre of the matter sphere.[13] This calculation may also be employed to calculate the deceleration of any matter shell located at the physical distance *D* from the center: just substitute *D* for D_B in equation 1.

To compare the deceleration of the unbounded universe to that of the bounded universe, we will consider the deceleration of a comoving shell of matter located at the same physical distance from the adopted origin of coordinates as the boundary (or any other choice of matter shell) of the bounded matter sphere is from its unique centre. Denote the comoving radial coordinate of this matter shell by η_{shell} and the physical distance to the origin by $D_{shell,\ unbounded}(\tau)$. The metric tells us how to compute $D_{shell,\ unbounded}(\tau)$:

$$D_{shell,unbounded}(\tau) = a(\tau)\int_{\eta=0}^{\eta=\eta_{shell}} \frac{d\eta}{\sqrt{1-k\eta^2}} \qquad (2)$$

The deceleration of this shell is simply

$$\frac{d^2 D_{shell,unbounded}(\tau)}{d\tau^2} = \frac{d^2 a(\tau)}{d\tau^2}\int_{\eta=0}^{\eta=\eta_{shell}} \frac{d\eta}{\sqrt{1-k\eta^2}} = D_{shell,unbounded}(\tau)\frac{1}{a(\tau)}\frac{d^2 a(\tau)}{d\tau^2} \qquad (3)$$

The deceleration of $a(\tau)$ is given by the Friedman deceleration equation[14,15] which, for the cosmic matter content under consideration, is simply

$$\frac{1}{a(\tau)}\frac{d^2 a(\tau)}{d\tau^2} = -\frac{4}{3}\pi G \rho$$

(4)

This relation may be combined with equation 3 to give

$$\frac{d^2 D_{shell,unbounded}(\tau)}{d\tau^2} = -D_{shell,unbounded}(\tau)\frac{4}{3}\pi G\rho \tag{5}$$

This equation is obviously identical to the bounded case deceleration equation (equation 1). Matter shells located at the same distance from the adopted origin of coordinates experience the same deceleration, regardless of whether they are in a bounded or unbounded universe. This deceleration is manifestly gravitational in origin, since there are no forces other than gravity acting on the shells.[16] In Newtonian language, gravitational accelerations are due to the 'gravitational field.' Therefore, the gravitational fields in the interiors of the bounded and unbounded universes are identical.[17] This simple illustration overthrows the central claim of Humphreys' cosmological theorizing.

To understand the cause of the sign change in the Klein form of the metric, it is helpful to understand where the Klein metric components come from. Unlike the Robertson-Walker form of the metric, the Klein form of the metric is not derived from first principles using symmetry properties or the field equations of general relativity applied to a bounded matter distribution. Rather, the vacuum Schwarzschild coordinate system is extended inward from the surface of the matter and the resulting coordinate system (including the imaginary part of t_{Klein}) is used to transform the Robertson-Walker metric components[18] into the Klein coordinate system.[19] The transformation is given by the conventional tensor transformation relation.[20] Mak-

$$\beta(t,r) = g_{tt,Klein} = \left(g^{tt}_{Klein}\right)^{-1} = \left(g^{\tau\tau}_{RW}\left(\frac{\partial t_{Klein}}{\partial\tau}\right)^2 + g^{\eta\eta}_{RW}\left(\frac{c\partial t_{Klein}}{\partial\eta}\right)^2\right)^{-1} \tag{6}$$

It is a straightforward mathematical exercise to show that this equation, using the full complex form of $t_{Klein}(\tau,\eta)$, gives Klein's metric component $\beta\ (t,r)$. It is

$$\beta(t,r) = \left(\frac{\partial t_{Klein}}{\partial\tau}\right)^{-2}\left(\frac{1-\eta^2}{1-\frac{a_{max}}{a}\eta^2}\right) = \left(\frac{\partial t_{Klein}}{\partial\tau}\right)^{-2}\left(1-\eta^2\right)a(t,r) \tag{7}$$

where $a(t,r)$ is the Klein g_{rr} metric component. It is clear from equation 7 that $\beta\ (t,r)$ switches sign whenever $a\ (t,r)$ does. These sign changes are uninteresting, since the metric component signs have a Lorentzian appearance on both sides of such a sign change surface. The change which Humphreys considers interesting is when $\beta\ (t,r)$ switches sign but $\alpha\ (t,r)$ does not. It is clear from equation 7 that this type of change occurs if, and only if, $(\partial t_{Klein}/\partial t)^2$ changes sign;[21] that is, if, and only if, $(\partial t_{Klein}/\partial t)$ changes from real to imaginary or vice versa.

A number of consequences inescapably follow from this fact. First, the 'interesting' sign change in β is simply an artefact[22] of the change of the Klein time coordinate dt_{Klein} from real to imaginary. This is a trivial form of metric component sign change and it has no physical consequences.[23] Second, Humphreys' claim that the integral from which $t_{Klein}(t,\eta)$ is computed *'should only be evaluated for values of the variable which are real, not imaginary,'*[24,25] eliminates the sign change in $\beta\ (t,r)$, since the sign change is caused by the change from real dt_{Klein} to imaginary dt_{Klein}. Finally, we note that Humphreys' alleged restriction on t_{Klein} is not present in the published research literature on the Klein form of the metric.[26]

Finally, we offer the following observations on Humphreys' appeals to the research literature on classical signature change. First, Humphreys fails to note the speculative character of this literature. No one knows at present whether, and, if so, under what physical conditions classical signature change may occur.[27] This literature certainly does not establish Humphreys' claims (and, in any event, Humphreys' model does not undergo the signature change described in this literature; the sign change in Humphreys' model is the consequence of the imaginary character of the Klein time coordinate). Second, Humphreys misunderstands the criterion for signature change proposed by Ellis, *et al.*[28] This criterion relates to the local non-gravitational energy density of the universe. Ellis *et al*. propose that, if the details of this energy content are such that the dynamics of the universe would lead to da/dt imaginary, then signature change should take place to keep da/dt real.[29] Humphreys erroneously includes gravitational potential energy in the local energy budget,[30] when in fact the only contributions to da/dt are matter fields, spacetime curvature and the cosmological constant.[31] Third, Humphreys fails to note that much of the published literature on signature change[32] applies to unbounded as well as bounded matter distributions,[33] which shows that it is not necessary to posit a boundary for signature change to occur.

Finally, Humphreys erroneously claims (and uses this false claim as justification for his erroneous rejection of the Robertson-Walker form of the metric) that signature change of the type considered by Ellis *et al.* cannot take place in the spacetime described by the Robertson-Walker metric. In fact, signature change will take place in the Robertson-Walker metric if the Ellis, *et al.* criterion (assuming it to be valid) is satisfied.[34] This is easy to show by writing the Robertson-Walker metric with the a-dependence of the

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

(8)

The radius of curvature, a, of the universe is by definition a real number, so da is necessarily real. The signature of this metric will change from Lorentzian to Euclidean if the expansion rate of the universe, da/dt, changes from real to imaginary. The actual behaviour of the expansion rate is determined by the dynamics produced by the matter/energy content of the universe, an issue which is independent of the employment of the Robertson-Walker form of the metric (the R-W metric is valid for locally homogeneous and isotropic universes, regardless of the details of the expansion dynamics). For the Friedman-Lemaitre class of R-W cosmologies (pressureless dust with non-zero cosmological constant), which are an excellent description of the late-time behaviour of the real universe, the expansion rate is given by the Friedman equation[35] for the Hubble parameter:

$$\frac{da}{d\tau} = aH_0\left[\Omega\left(\frac{a_0}{a}\right)^3 + \left(1-\Omega-\Omega_\Lambda\right)\left(\frac{a_0}{a}\right)^2 + \Omega_\Lambda\right]^{1/2}$$

(9)

where a_0 is the present radius of curvature of the universe, H_0 is the present value of the Hubble parameter, about 75 km/s/Mpc, and Ω and Ω_L are, respectively, the present matter and vacuum energy densities, in units of the critical density. This expansion rate can, in principle, be imaginary in the past (that is, for $a < a_0$) if Ω_L is much larger than Ω ; in such a case, the Robertson-Walker metric can have Euclidean signature for a range of past *a*. This shows the falsity of Humphreys' claim that the Robertson-Walker metric is not general enough to include the possibility of signature change. In fact, contrary to Humphreys' claims, the Robertson-Walker metric is every bit as general as the modified version employed by Ellis, *et al.* Indeed, the two forms of the metric are transformed into each other by the simple coordinate transformation[36] $(cdt/da)^2 = N(t)$, $da = dt$. Just as the Klein form of the metric is simply a different coordinate representation of the same underlying geometry described by the Robertson-Walker form of the metric, so also is the modified metric employed by Ellis, *et al.* Humphreys' claim that the geometry described by Ellis, *et al*. is profoundly different from the geometry of the Robertson-Walker metric is mistaken: the two geometries are identical.[37]

Having shown that the Robertson-Walker form of the metric does, in principle, permit classical signature change, the question remains, 'has the universe actually experienced this in the past?'

The answer to this question is almost certainly 'not in the observable history of the universe (that is, not since the cosmic microwave background radiation decoupled from the matter of the universe)'. The reason for this is that the present equation of state of the matter content of the universe repels the universe from any Euclidean region which may exist: as the scale factor *a* approaches the transition to Euclidean signature, the expansion or contraction slows to a stop and reverses itself. This is what causes negative energy 'big bang' models to stop expanding and positive energy models with too large a value of Ω_L to 'bounce' in the past. The Euclidean region is a classically forbidden region of, essentially, negative cosmic kinetic energy (recall that the expansion rate *da*/*dt* is imaginary, so that $(da/dt)^2$ is negative). It is not known whether there may be other equations of state which would permit a transition from positive to negative $(da/dt)^2$. We know of no such proposals and the literature cited by Humphreys contains none.

It may be possible to invent unusual hypothetical equations of state which would allow a homogeneous and isotropic universe to undergo signature change. However, such unusual equations of state bear no resemblance to the actual equation of state of the known matter and energy content of the real universe. Further, if one were to adopt such an unusual description of the expansion dynamics and impose a hypothetical signature change surface at some point in the past, this still would not solve the light travel problem, for such a signature change would occur simultaneously (that is, at the same value of *a* and *t*) throughout the universe, so that there would be no differential ageing of different parts of the universe. This simultaneity is imposed by the fact that cosmic time is synchronous with the expansion in all locally homogeneous and isotropic universes, so that *da/dt* is the same function of *a* throughout the universe. Therefore, if *da/dt* changes from real to imaginary, this change will take place at the same value of *a* and the same cosmic time *t* throughout the universe. In addition, by reducing the proper time available for light propagation, such a scenario would reduce the distance to the particle horizon (the greatest distance light can travel since the beginning of the universe).

If the location of a hypothetical signature change surface were adjusted to provide only 6,000 years of proper time since the beginning of the universe, as proposed by Humphreys, the particle horizon would be only about 6,000 light years distant, making all objects more distant than this invisible to observers on Earth. In fact, the furthest visible objects have been measured to be on the order of 10 billion light years distant (measurements with which Humphreys concurs[38]). This indicates that, regardless of the number and 'duration' of past episodes of metric signature change, at least 10 billion years of proper time have elapsed since the beginning of the universe. As we have noted previously, the observed properties of the universe and the validity of General Relativity as a description of its behaviour over past time are incompatible with a recent origin. Humphreys' appeal to signature change cannot solve the light travel problem.

References

1. Conner, S.R. and Page, D.N., Starlight and time is the big bang, *CEN Tech. J.* **12**(2):177–179, 1998.
2. Conner, S.R. and Page, D.N., *The Big Bang Cosmology of Starlight and Time*, unpublished manuscript, ~ 200 pages, 1997. Readers interested in obtaining this document may contact Mr Conner by mail at 10 Elmwood Avenue, Vineland, N.J. 08360, USA or by email at CERS_corresp@hotmail.com.
3. Humphreys, D.R., New vistas of spacetime rebut the critics, *CEN Tech. J.* **12**(2):203–205, 1998.
4. Humphreys, D.R., Letter to the Editor, *CEN Tech. J.* **13**(1):59, 1999.
5. There is only one point of global spherical symmetry for a bounded

spherical object because there is only one point about which an arbitrary rotation will map the *surface* of the object into itself. If there is no surface, then it is possible for there to be many points about which the object has spherical symmetry.

6. The Robertson-Walker form of the metric may be written

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

The spherical symmetry of this formula is evident in that the angular part of the metric is simply the customary spherical line element $d\theta^2 + \sin^2 d\varphi^2$

7. Humphreys, Ref. 3, pp. 205–206.
8. Weinberg, S., *Gravitation and Cosmology*, John Wiley and Sons, chapter 13, 'Symmetric Spaces,' pp. 375–404, 1972.
9. Weinberg, Ref. 8, pp. 403–404.
10. Humphreys, Ref. 4, p. 59.
11. It should be noted that such Newtonian arguments are not strictly valid, but are only approximately valid in the limit of low particle velocities, weak gravitational fields and nearly flat spacetime geometry. The Newtonian result for cosmic deceleration, computed in this limit, matches the fully relativistic result derived from the Einstein field equations when the pressure contributions to the energy-momentum tensor are negligible compared with ρ *c2*.
12. We confine our attention to the 'cold dust' universe models considered by Humphreys. The Newtonian analysis may be extended to more general cases of non-zero pressure and non-zero cosmological constant, but the resulting identity of the deceleration of bounded and unbounded universes is not affected, so the present simple case suffices to illustrate that identity.
13. In Newtonian gravitation, there is no such thing as 'time dilation' and one need not employ the metric to compute physical (that is, 'proper') distances. In the Newtonian limit of GR, the spacetime metric approaches the metric of flat spacetime, so that (for appropriately chosen coordinates) there is little difference between coordinate and physical distances or between coordinate and proper time intervals for a stationary observer. One may do a fully relativistic analysis of the deceleration of a bounded matter sphere; the result is identical to that for the unbounded matter distribution, which is described below.
14. Peebles, P.J.E., *Principles of Physical Cosmology*, Princeton University Press, p. 312, 1993.
15. Weinberg, Ref. 8, p. 472.
16. There is no pressure in 'cold dust' models.
17. This point has been made previously, in Ref. 2 and in Conner, S.R. and Ross, H.N., *The Unraveling of Starlight and Time*, 1999, available from Reasons to Believe, <www.reasons.org>.
18. which, *contra* Humphreys, are indeed a valid metric description of the geometry of the bounded matter sphere (see Weinberg, Ref. 8, pp. 342–345.). If the Robertson-Walker metric were not valid as applied to the bounded matter sphere, then the Klein/Weinberg method of deriving the Klein metric, by transforming the Robertson-Walker metric into the Klein coordinate system, would fail and the resulting Klein metric would itself not be a valid description of the bounded matter sphere geometry.
19. Weinberg, Ref. 8, pp. 345–346.
20. $$g_{\alpha\beta,\text{Klein}} = g_{\mu\nu,\text{RW}} \frac{\partial x_{\alpha,\text{Klein}}}{\partial x_{\mu,\text{RW}}} \frac{\partial x_{\beta,\text{Klein}}}{\partial x_{\nu,\text{RW}}}$$

The simplest implementation of this relation, and that chosen in this letter, uses the contravariant coordinate transformation $\frac{\partial x^{\alpha}_{\text{Klein}}}{\partial x^{\mu}_{\text{RW}}}$ and the contravariant metric components $g^{mm} = (g_{\mu\mu})^{-1}$:

$$g_{\alpha\alpha,\text{Klein}} = \left(g^{\alpha\alpha}_{\text{Klein}}\right)^{-1} = \left(\left(g_{\mu\mu,\text{RW}}\right)^{-1}\left(\frac{\partial x^{\alpha\alpha}_{\text{Klein}}}{\partial x^{\mu\mu}_{\text{RW}}}\right)^2\right)^{-1}$$

21. The factor $(1 - \eta)^2$ is always greater than or equal to zero.
22. as noted in Conner, S.R., Letter to the Editor, *CEN Tech. J.*, **13**(1):56–58, 1999.
23. It is obvious that one can always switch the sign of *gtt* simply by changing the time coordinate from *dt* to $\sqrt{-1}$ *dt*, a coordinate transformation called 'Wick rotation'. Such a change has no physical significance.
24. Humphreys, Ref. 3, p. 209.
25. Humphreys, Ref. 4, p. 59.
26. Weinberg's discussion of the derivation of the Klein metric (Weinberg, Ref. 8, pp. 345–346.) is the most accessible English-language treatment. Weinberg's discussion makes it clear that imaginary dt_{Klein} is an inescapable consequence of the extension of the Schwarzschild coordinate system into the interior of the matter sphere. Humphreys' proposed restriction on Weinberg's integral expression for t_{Klein} is unjustified, for it destroys the resulting form of $\beta(r,\tau)$. To obtain Klein's form of $\beta(r,\tau)$, with its sign-switching behaviour, it is necessary to perform the full integral for t_{Klein}, with no restrictions.
27. An example of an unresolved problem in this research is the open question of what type of boundary and continuity conditions should be imposed across a signature change surface and the fact that the Einstein field equations are not obeyed on the surface. Another open question is the meaning of the discontinuities in physical properties (such as particle rest masses) which occur across a signature change surface. It should be noted that there is no such discontinuity in particle masses or the cosmic mass/energy density in the Klein metric, which shows that the coordinate-artefact-induced metric component sign change which occurs in the Klein metric is unrelated to the hypothetical processes considered in the literature cited by Humphreys.
28. Ellis, G., Sumeruk, A., Coule, D. and Hellaby, C, Change of signature in classical relativity, *Classical and Quantum Gravity*, **9**:1546–1548, 1992.
29. Ellis, *et al*., Ref. 28, p. 1548.
30. Humphreys, Ref. 3, p. 202. Humphreys claims that Ellis, *et al*.'s proposed signature change criterion is *'closely related to the gravitational potential of our spherical, bounded, distribution of matter'*, but in fact it is unrelated. The local character of the Ellis, *et al*. criterion is obvious from the fact that their signature change occurs at the same point in the cosmic expansion (at the same value of the cosmic scale parameter *a*), regardless of location in the universe, as expected for a locally homogeneous geometry, whether bounded or unbounded.
31. See, for example, the discussion in Peebles, Ref. 14, pp. 259–268, 280–313.
32. including the article by Ellis, *et al*., Ref. 28, which Humphreys cites extensively.
33. In particular, Ellis *et al*. study signature change in the context of conventional unbounded cosmology.
34. Humphreys is mistaken in claiming that one must explicitly incorporate a sign switch in the g_{00} metric component in order for signature change to be possible. Transformation from Lorentzian to Euclidean signature is a physical process which, if it is possible at all, will occur regardless of the coordinate representation used for the metric. Ellis, *et al.* make the signature transition explicit by incorporating the possibility of a sign switch into the metric. This is simply a notational convenience which

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 $ds^2_{comoving} = c^2 d\tau^2_{comoving} = c^2 N(\tau,\eta) d\tau^2$. This relation determines the mathematical form of the lapse function in terms of the comoving proper time interval *dt*comoving and the coordinate time interval $d\tau : N(\tau,\eta) = d\tau^2_{comoving}/d\tau^2$. 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