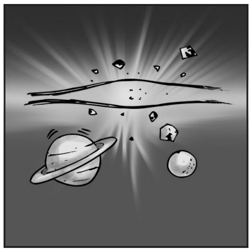


Reply to Gentry on Cosmological Energy Conservation and Cosmic Expansion

J. Brian Pitts

While by now Gentry is acquainted with the claim that the energy lost by photons is gained by the gravitational field, he mistakenly believes that this claim needs independent testing and that it could be refuted independently from the rest of Einstein's theory of gravity.

In reply to my recent criticism of his work, Robert Gentry has composed a long and energetic reply. Unfortunately he maintains the key erroneous claims that Big Bang cosmology violates energy conservation and that it relies on a confused notion of cosmic expansion. He also raises some additional matters, a few of which I will address. In particular, the issue of cosmology and young earth views will be discussed briefly.

Energy Conservation

While by now Gentry is acquainted with the claim that the energy lost by photons is gained by the gravitational field, he mistakenly believes that this claim needs independent testing and that it could be refuted independently from the rest of Einstein's theory of gravity. The fact that Gentry appeals to experiments in deciding whether a solution of the Einstein-Maxwell equations conserves energy indicates a failure to understand classical field theories such as Einstein's and Maxwell's. On the contrary, local energy conservation follows with *mathematical necessity* from the Einstein-Maxwell equations, for *every* solution of those equations. Experiments help to decide whether the Einstein-Maxwell equations describe the world accurately, but they do not decide whether a given solution of those equations also conserves energy. Gentry is confused in taking gravitational redshift experiments to have any relevance to energy conservation, and yet confidently relying on the Einstein-Maxwell equations as he appears to do.

To dispel these errors, it is necessary to review some classical field theory. Previously I observed that Gentry not only neglected to account for gravitational energy, but also neglected to address the literature on the subject. In that literature, one finds a wide variety of mathematical treatments of gravitational energy. When these treatments are applied to the issue of energy conservation for gravitation and electromagnetism combined, the result is that the combined energy of the gravitational and electromagnetic fields is conserved, but neither is conserved separately.

Perhaps the simplest and most familiar method for deriving the conservation laws is by deriving the densitized stress-energy-momentum tensor $T^{\mu\nu}\sqrt{-g}\ (t, x^i)$ for electromagnetism and corresponding densitized pseudotensor $t^{\mu\nu}\sqrt{-g}\ (t, x^i)$ for gravitation, which together form the stress-energy-momentum complex

$$\mathfrak{T}^{\mu\nu}\ (t, x^i) = (T^{\mu\nu} + t^{\mu\nu})\ \sqrt{-g}.$$ [1]

(Each of these quantities forms symmetric 4x4 matrix of numbers at every point in space and moment of time. The indices μ and ν each take on all the values of 0, 1, 2, 3, where 0 represents time and 1, 2, 3 represent space. The coordinate x^0 is the time t.) Using the techniques of classical field theory, which have had a recognizably modern form for more than eighty years, there is a mathematical recipe for constructing tensors (with respect at least to Lorentz boosts and rigid translations) that represents the energy and momentum densities and flux densities. Making the standard assumptions that the laws of physics are the same everywhere and always,[2] and that these laws can be derived from a Lagrangian density function $\mathfrak{L}$, one can readily derive the form of the conserved quantities like energy and momentum using Noether's first theorem.[3] The sameness of physical laws at every moment implies that the Lagrangian density $\mathfrak{L}$ is independent of time and leads to conservation of energy. The sameness of physical laws in every place implies that the Lagrangian density is independent of location and leads to conservation of momentum. The resulting energy and momentum are locally conserved as a consequence of the dynamical equations—in this case, the combined equations of Einstein's gravity and Maxwell's electromagnetism—for *every* solution of those equations, including the Robertson-Walker cosmological models used in Big Bang cosmology. One can write the local conservation of energy and momentum as $\partial\mathfrak{T}^{\mu\nu}/\partial x^\mu = \partial\mathfrak{T}^{0\nu}/\partial t + \partial\mathfrak{T}^{i\nu}/\partial x^i = 0$. Setting $\nu = 0$ gives the equation for local energy conservation alone:

$$\partial\mathfrak{T}^{00}/\partial t + \partial\mathfrak{T}^{i0}/\partial x^i = 0.$$

Gentry casts his energy nonconservation objection in terms of global rather than local conservation laws, so let us consider the relationship between the two. Global conservation laws say that the total amount of some physical quantity—energy, momentum, charge, or the like—collected over the entire volume of space, is constant over time. While such global laws are more familiar than local laws, modern relativistic field theory takes local laws to be more fundamental. A local conservation relation takes the form

$$\partial\rho/\partial t + \partial J^i/\partial x^i = 0,$$

where $\rho(t, x^i)$ and $J^i(t, x^i)$ are the density (amount per unit volume) and current density (amount flowing out through the boundaries of a small directed surface surrounding the little volume in question), respectively, for the energy, momentum, charge, or the like. This equation is called the continuity equation, and implies that energy (or momentum or charge) can disappear from a small region of space only by passing out through the surrounding imaginary walls. The local conservation of energy equation above takes the form of the continuity equation once one makes the identifications $\mathfrak{T}^{00} = \rho$, $\mathfrak{T}^{i0} = J^i$. The requirement of local conservation of energy is stricter than global conservation, which by itself would permit energy to disappear in Indiana and to reappear immediately in Georgia.[4] Furthermore, local conservation laws always make sense, whereas global conservations sometimes are meaningless, as will now appear.

One can try to add up all the energy (or momentum or charge) in the world by integrating the continuity equation over all space to get the rate of change of the conserved energy (or other conserved quantity) $E = \int dx \int dy \int dz\ \rho$. Using the divergence theorem, and letting the boundary surface be removed far outside the matter distribution gives

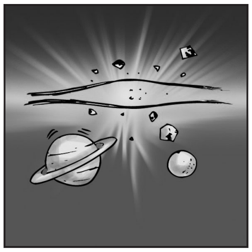
$$dE/dt + \int dS_i\, J^i = dE/dt = 0,$$

which shows that energy is conserved globally, if the matter distribution is bounded and the manipulations involving interchanges of mathematical limits hidden in the above expressions permit. However, in the standard cosmological models, matter is present everywhere, so the various limits might behave badly. Thus the integral E tends to diverge if there is nonzero energy density ρ everywhere throughout infinite space, as occurs in some of the cosmological cases at hand. Relevant work was done in the literature that my previous paper cited. Applying these lessons to cosmology, we find that Big Bang cosmologies satisfy global energy conservation insofar as it is meaningful—that is, as long as the mathematical limits behave suitably. If global conservation is not meaningful, then Gentry's objection is meaningless. In no case does there exist for Big Bang cosmology a meaningful notion of energy conservation, local or global, that is violated. Should Gentry venture to reject Einstein's equations, his claim would still be false, because any reasonable alternative theory will also be derivable from a time-independent Lagrangian density and so, like general relativity, it will have a local energy conservation law that holds for every solution of the field equations. The lack of novelty in my first paper refuting Gentry's claims is because the relevant results implicitly refuting them are already present in the specialist literature and disseminated in standard textbooks.

Although Gentry's energy nonconservation claim is demonstrably incorrect, the question of finite or infinite energy remains unsettled. One difficulty is that the energy-momentum complex $\mathfrak{T}^{\mu\nu}$ is not uniquely defined, in addition to worries about mathematical limits discussed above. More specifically, the energy-momentum complex suffers ambiguities from "superpotentials" or generalized curls, which are quantities that by themselves automatically satisfy the continuity equation.[5] One can therefore alter the distribution of energy and momentum in space and time without altering the total amounts of energy and momentum. This is a mathematical generalization of the vector calculus result that the divergence of a curl is zero, so specifying the divergence of a vector field leaves its curl unspecified. This ambiguity explains why it is unclear whether the energy for infinite-volume Big Bang solutions is infinite or zero. With this fact in mind, one can consider Gentry's reply to my refutation of his objection.[6] He writes of my previous paper:

> On one hand, he cites several GR authorities whose results support the concept of the universe's total energy being infinite. Then he cites other authorities in support of the total energy being zero. He admits not knowing which is true and is apparently not troubled by the possibility that this infinite difference may suggest a tremendous flaw in the underlying paradigm he uses to arrive at these results.[7]

On this point Gentry is correct: I am not worried about the status of classical field theory, Noether's first theorem, or tensor calculus. The only way that energy conservation could be threatened in a classical field theory is if the laws



of physics changed over time, but nothing of the sort holds for the Einstein-Maxwell field equations or any other plausible theory. The fact remains that, whether the energy is 0 and stays constant, or is infinite and remains infinite, Gentry's claim of violation of energy conservation is not true. In the first case, the claim is false; in the second case, it is meaningless.

Whether the energy is 0 and stays constant, or is infinite and remains infinite, Gentry's claim of violation of energy conservation is not true. In the first case, the claim is false; in the second case, it is meaningless.

Gentry comments:

> I do not think these alternatives require much comment from me except to say that his proposed solutions are quite imaginative and beyond the scope of modern science to realistically test them.[8]

It is disappointing that Gentry fails to notice when his position suffers a mortal wound. Be that as it may, my imagination plays little role in the argument. Rather, the relevant well-publicized mathematics, which Gentry persistently ignores, does all the work. Literature contrary to Gentry's claims continues to appear. Another paper that calculates the energy of some Big Bang models has recently appeared, with the conclusion that four different pseudotensor calculations give zero total energy.[9] Also a careful treatment of the Hamiltonian formalism for Big Bang spacetimes more realistic than the typical homogeneous toy models has been provided, according to which at least in some cases the energy is zero.[10]

Gentry cites four texts in defense of his claim of energy nonconservation in Big Bang cosmology,[11] but closer inspection shows that none of them provides a serious argument for such a claim. The case of Peebles' cosmology text was addressed in my earlier paper. The cited pages 423–5 of Silk's book say nothing about energy conservation, but when Silk discusses energy conservation on pages 100, 101 (albeit in a simplified way), he *affirms* it.[12] While Alpher and Herman do seem to assert that energy is not conserved in relevant cosmological models, this assertion is quite devoid of relevant argumentation, which would have to consider and refute the possibility that a gravitational contribution restores conservation.[13] Finally, Gentry cites Edward Harrison's generally admirable undergraduate cosmology text,[14] which indeed does assert that energy conservation is violated in cosmology.

Decisive justification for Harrison's claims must come from technical mathematics that accounts for possible gravitational energy contributions. But as we have seen, the detailed mathematics shows that energy conservation is satisfied in Big Bang cosmological models locally and, insofar as global conservation is meaningful, globally as well. Disappointing as it is for a fine undergraduate cosmology text to contain such an error, nevertheless it hardly suffices for Gentry to depend on a weakly argued claim in an undergraduate text in the face of detailed mathematical refutation in many journal articles and implicit refutation in standard graduate texts. Such a move is a bit like ignoring an atomic clock in favor of data from the telephone number for the time and temperature in running NASA's space program. Continued reliance on Harrison's authority would make sense if he were divinely inspired, if he were giving eyewitness testimony, or if he were blowing the lid on some conspiracy to which he was a party. But on this issue that is publicly understood in terms of rather technical mathematics, it does not make sense. Perhaps one problem is Harrison's effort to make thermodynamic arguments without including gravitational thermodynamics, a subject which has approached a mature form only in the last few years.[15]

The work of Vera in no way refutes the account given above of energy conservation.[16] Vera considers nonlocal situations with macroscopic rods and clocks of finite size. But the Noether field theoretic derivation of local energy and momentum conservation discussed above is more exact and fundamental: Noether's theorem is purely local (involving infinitesimal coordinate distances only), and uses an exact microscopic description in terms of classical field theory, not an approximate macroscopic description using rods and clocks which ought somehow to be built out of fields. (To be truly exact, one should of course use quantum rather than classical field theory, but that is beyond the call of duty.) Should any conflict arise between Vera's work and Noether's first theorem applied to classical field theory, the nonfundamental nature of the former implies that it, not the Noether field theoretic account, would have to give way.

Cosmic Expansion

Gentry's claim that the cosmic redshift is an arbitrary postulate is incorrect, because in fact the cosmic redshift (like energy conservation) is a consequence of the gravitational and electromagnetic field equations, in much the way that the Schwarzschild solution's terrestrial gravitational redshift follows.[17] Therefore the cosmic redshift also neither needs nor admits experimental testing in isolation from the rest of the theory and the assumed matter distribution.

Gentry makes various obscure claims regarding the Big Bang's cosmic expansion. For example, he claims that the cosmic expansion factor $\mathfrak{R}(t)$ is never measurable, and concludes that the equation involving the expansion factor and the wavelength of photons has no predictive value. Though the expansion factor is defined only up to an arbitrary multiplicative constant, the equation relating the expansion factor to photon wavelengths involves the *ratio* of the expansion factor at two different times. The overall multiplicative constant cancels out, so there is no difficulty in getting a prediction for the influence on wavelengths. Gentry's mysterious claim that I disagree with Misner, Thorne, and Wheeler's text regarding photon redshifting seems to be the result of his conjoining a statement of mine with an error of his own.

While it is difficult to uncover which of Gentry's errors are foundational and which are derived, I will attempt to do so. His older work makes a bogus distinction between two descriptions of what are in fact the same process:

> Was Einstein correct in postulating that different gravitational potentials at source and observer meant that clocks at these locations should run at intrinsically different rates, and hence that this was the origin of the gravitational redshift? Or did the measured redshift instead have its origin in photons experiencing an in-flight energy exchange with gravity as they moved in a changing gravitational potential in their transit from a star to the Earth?[18]

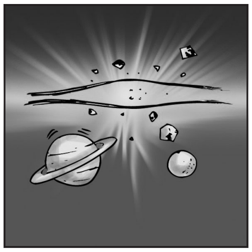
To Gentry, this distinction is an important physical question. In reality he is setting at opposition two standard alternative descriptions used for conservative forces in sophomore vector calculus and mechanics, transposed into a new context. For conservative forces, one can describe a process either in terms of what happens during the process, or in terms of the states before and after the process. Having erected this bogus distinction, Gentry deploys it so as to consider the possibility that these are two distinct processes, both of which conceivably might operate so as to give two gravitational redshifts. He writes in his recent reply to me: "(1) The Pound-Snider results show there is only one gravitational redshift between two points at different potentials … and (2) this redshift does not originate with photons exchanging energy with gravity during transit through a potential gradient, but instead originates …"[19] in effects dependent upon the potentials at the endpoints. Gentry's bogus opposition between equivalent descriptions of the same process encourages his misplaced emphasis on the significance of what goes on during photon emission and absorption processes.

To discuss the effect of the cosmic expansion on localized objects, one would consider a solution of Einstein's field equations that is a standard Big Bang solution on large scales, but with one or more local inhomogeneities. Objects such as stars, planets, and human bodies naturally violate homogeneity to some degree. One might use numerical approximations to get realistic approximate solutions, perturbation theory to get somewhat realistic and mathematically cleaner solutions, or exact but rather idealized solutions of Einstein's equations. The standard idealized model matches a Schwarzschild (uncharged, nonrotating) interior to a Big Bang exterior solution, while requiring the two solutions to match suitably at the boundary. Works discussing this question and its generalizations appeared in the 1930s and have continued to the present day, in some cases discussing the (generally nonexistent or negligible) influence of cosmic expansion on local systems.[20] Gentry cites the Noerdlinger-Petrosian paper, which is a good point of entry to the earlier literature, but rejects its relevance because "a close reading shows it is ambiguous in addressing the question of galactic expansion."[21] Presumably this ambiguity that Gentry finds is between redshifts as being due to expansion or to Doppler velocity effects. But as my previous paper discussed, this difference is merely conventional and linguistic, not physical, so Gentry's dismissal is unwarranted.

As it happens, this issue has been reconsidered by those using correct methods, and it has appeared that some of the earlier results are not as generally applicable as had been believed.[22] Some recent work found that there is an expansion effect on all scales—even stars and planets and trees—but it becomes negligible on small scales,[23] much as Noerdlinger and Petrosian found some time ago. Bonnor has considered a more general spherical scenario and found that cosmic expansion has no effect,[24] as well as a model atom for which the effect is negligible.[25] Mars and others have shown that spherical symmetry is indeed important in getting results along these lines, because they do not generalize to nonspherical exact solutions.[26] As Mars notes, a satisfactory treatment involving nonspherical systems embedded in the cosmic expansion will likely require techniques besides exact solutions. When proper techniques are applied to Gentry's question, it turns out that the issue is less resolved than was once believed. But many partial results, old and new, indicate that cosmic expansion has little or no effect on small distance scales and so support the conventional view, whereas Gentry provides no good reasons to doubt it.

Dialogue II: Big Bang Cosmology

Reply to Gentry on Cosmological Energy Conservation and Cosmic Expansion



Despite the tension between time scales, there seems to be no compelling reason for young-earth advocates to reject the bulk of Big Bang cosmology, stellar evolution, and the like. Instead it would be preferable to make minor modifications to the orthodox astrophysical theory to achieve consistency with the interpretation of Scripture.

Should There Be a Distinctive Young-Universe Cosmology?

In his introduction, Gentry reveals some important features of his theologically influenced philosophy of science. But even granting Gentry's literal six-day creation premise, the existence of scientific flaws in Big Bang cosmology as an evolutionary paradigm does not follow. Given that literal six-day creation should be manifest somehow or other, why should it be through *scientific* flaws in Big Bang cosmology? For example, Big Bang cosmology might be empirically adequate and internally consistent, but just false as a history of the universe, as demonstrated by comparison with the true literal six-day story in Scripture. For Gentry to demand that the falsehood of Big Bang cosmology be manifest by ordinary scientific standards appears to be a form of scientism. He neglects various philosophical issues, such as the scientific realist *vs*. antirealist controversy and the question of presuppositionalist *vs*. evidentialist apologetics, and so is forced to find nonexistent scientific flaws in Big Bang cosmology.

Despite the tension between time scales, there seems to be no compelling reason for young-earth advocates to reject the bulk of Big Bang cosmology, stellar evolution, and the like. Instead it would be preferable to make minor modifications to the orthodox astrophysical theory to achieve consistency with the interpretation of Scripture. In his philosophically sophisticated defense of a young-earth view,[27] John Byl concludes that young-earth cosmologies must include some notion of mature creation, though such might involve process rather than or in addition to instantaneous *fiat*. Young-earth advocates more given to scientific than philosophical defenses are increasingly coming to take orthodox astrophysics seriously,[28] at least in intent if not always execution.[29] The respectful attitude of Faulkner and DeYoung toward stellar evolution is noteworthy in comparison to attitudes of a previous generation.[30] But what better alternative theory to stellar evolution could a young-earth advocate find than stellar evolution itself?

Probably the best bet for young-earth advocates is to allow for an old universe with the help of miraculous time dilation on and near the earth, while the distant heavenly bodies behave much as standard cosmology asserts. This move combines types 3 and 5 in John Hartnett's taxonomy for addressing the problem of seeing distant stars on a young earth.[31] In that case, unlike stories of light created in transit, the story about the past given by the cosmological model is largely *true*, not merely empirically adequate. Such a view would largely demilitarize the field of astronomy, as far as issues of Genesis chronology are concerned, to the benefit of both Christianity and science.

Appendix

Returning to the case of electromagnetic and gravitational fields, for some purposes it might be useful to distinguish (somewhat artificially) among pure gravitational energy, an interaction term between gravitation and electromagnetism, and pure electromagnetic energy. The pure gravitational energy does not depend explicitly on the electromagnetic four-vector potential A_μ, and is represented in the pseudotensor $t^{\mu\nu}\sqrt{-g}$. The gravitational-electromagnetic interaction energy and the pure electromagnetic energy are both represented in $T^{\mu\nu}\sqrt{-g}$. One could separate them using an auxiliary background metric $\eta_{\mu\nu}$, so that the purely electromagnetic piece depends on $\eta_{\mu\nu}$ and A_μ but not the dynamical curved metric $g_{\mu\nu}$, whereas the interaction term depends on $g_{\mu\nu}$, $\eta_{\mu\nu}$ and A_μ. (It has been argued that proper treatment of conservation laws requires a background metric.[32]) In this way the gravitational-electromagnetic system looks more like traditional systems with an explicit interaction term between the fields. Thus a Newtonian limit, giving photons kinetic and potential energies, such as Silk uses, is facilitated. Moreover, a useful distinction between the Schwarzschild and cosmological redshift cases might be drawn to nuance the statement that lost photon energy is transferred to the gravitational field. In the Schwarzschild case for the redshifting of light in the gravity of a localized body, one expects the purely gravitational energy in $t^{\mu\nu}\sqrt{-g}$ not to change over time (there being a timelike Killing vector field); then there should be only conversion between the purely electromagnetic and the interaction energies within $T^{\mu\nu}\sqrt{-g}$. By contrast, one expects even the purely gravitational energy in $t^{\mu\nu}\sqrt{-g}$ to change over time in the cosmological case. ◈

Acknowledgments

I thank Ashby L. Camp for calling to my attention the work by John Hartnett. Shane and Laura Hollister, Dan Kim, Kyler Kuehn and Jan Pitts provided valuable comments that improved the manuscript.

Notes

[1]James L. Anderson, *Principles of Relativity Physics* (New York: Academic, 1967); and Hans Stephani, *General Relativity*, second edition (Cambridge: Cambridge University, 1990).

[2]Naturally Christians will wish to make exceptions for divine miracles, such as the creation of the world and the incarnation and resurrection of Christ, but these exceptions are not relevant for the purpose at hand.

[3]Michio Kaku, *Quantum Field Theory: A Modern Introduction* (New York: Oxford University, 1993); and James L. Anderson, *Principles of Relativity Physics.*

[4]David G. Griffiths, *Introduction to Electrodynamics,* 2d ed. (Englewood Cliffs, NJ: Prentice Hall, 1989), 4.

[5]James L. Anderson, *Principles of Relativity Physics*; and Michio Kaku, *Quantum Field Theory.*

[6]J. Brian Pitts, "Has Robert Gentry Refuted Big Bang Cosmology? On Energy Conservation and Cosmic Expansion," *Perspectives on Science and Christian Faith* 56, no. 4 (2004): 260–5.

[7]Robert V. Gentry, "Collapse of Big Bang Cosmology and the Emergence of the New Cosmic Center Model of the Universe, *Perspectives on Science and Christian Faith* 56, no. 4 (2004): 271.

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[9]M. Sharif, "Energy and Momentum in General Relativity," *Nuovo Cimento B* 118 (2003): 669; http://arXiv.org/abs/gr-qc/0404001.

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[11]Robert V. Gentry and David W. Gentry, "The Genuine Cosmic Rosetta," http://www.arxiv.org/abs/gr-qc/9806061.

[12]Joseph Silk, *The Big Bang: Revised and Updated Edition* (New York: W. H. Freeman, 1989).

[13]Ralph A. Alpher and Robert W. Herman, "Early Work on 'Big Bang' Cosmology and the Cosmic Blackbody Radiation," in B. Bertotti, R. Balbinot, S. Bergia, A. Messina, *Modern Cosmology in Retrospect* (Cambridge: Cambridge University, 1990), 151–2.

[14]Edward Harrison, *Cosmology: The Science of the Universe* (Cambridge: Cambridge University, 1981), 275, 276; 2d ed. (Cambridge: Cambridge University, 2000), 348, 349.

[15]Jonathan Oppenheim, "Thermodynamics with Long-range Interactions: From Ising Models to Black-holes," *Physical Review E* 68 (2003): 016108; http://arxiv.org/abs/gr-qc/0406041 v3.

[16]Rafael A. Vera, "A Dilemma in the Physics of Gravitational Fields," *International Journal of Theoretical Physics* 20 (1981): 19. The fact that this article has never been cited by journals indexed in the ISI Web of Science database tends to confirm that Vera has not made a strong case against any important part of standard physical theory.

[17]Robert M. Wald, *General Relativity* (Chicago: University of Chicago, 1984), sections 5.3, 6.3.

[18]Gentry and Gentry, "The Genuine Cosmic Rosetta."

[19]Gentry, "Collapse of Big Bang Cosmology."

[20]George C. McVittie, "The Mass-particle in an Expanding Universe," *Monthly Notices of the Royal Astronomical Society* 93 (1933): 325; further relevant works by McVittie can be found using the Electronic Research Archive for Mathematics based on the *Jahrbuch über die Fortschritte der Mathematik;* Gustaf Järnefelt, "On the One-Body Problem in the Expanding Universe," in *Den 10. Skandinaviske Matematiker Kongres i København 26–30 August 1946* (Copenhagen: Jul. Gjellerups, 1947), which also cites two German papers by the same author; "Note on the Mass-Particle in an Expanding Universe," *Arkiv för Matematik, Astronomi och Fysik* 27A no. 15 (1940–1); Hermann Bondi, "Spherically Symmetrical Models in General Relativity," *Monthly Notices of the Royal Astronomical Society* 107 (1947): 410; reprinted in *General Relativity and Gravitation* (1999): 1777; Engelbert Schucking, "*Das Schwarzschildsche Linienelement und die Expansion des Weltalls,*" *Zeitschrift für Physik* 137 (1954): 595; Ron Kantowski, "Corrections in the Luminosity-Redshift Relations of the Homogeneous Friedmann Models," *Astrophysical Journal* 155 (1969): 89; at http://adsabs.harvard.edu/abstract_service.html; Peter D. Noerdlinger, Vahé Petrosian, "The Effect of Cosmological Expansion on Self-Gravitating Ensembles of Particles," *Astrophysical Journal* 168 (1971): 1; at http://adsabs.harvard.edu/abstract_service.html; Michael E. Cahill and George C. McVittie, "Spherical Symmetry and Mass-energy in General Relativity II: Particular Cases," *Journal of Mathematical Physics* 11 (1970): 1392; K. Lake; "Local Inhomogeneities in a Robertson-Walker Background. I. General Framework," *Astrophysical Journal* 240 (1980), 744; "Local Inhomogeneities in a Robertson-Walker Background. II. Flux Conditions at Boundary Surfaces," *Astrophysical Journal* 242 (1980): 1238; at http://adsabs.harvard.edu/abstract_service.html; C. Bona and J. Stela, "'Swiss Cheese' Models with Pressure," *Physical Review D* 36 (1987): 2915; A. Chamorro, "A Kerr Cavity with a Small Rotation Parameter Embedded in Friedmann Universes," *General Relativity and Gravitation* 20 (1988): 1309; Andrzej Krasiñski, "Early Inhomogeneous Cosmological Models in Einstein's Theory," in B. Bertotti, R. Balbinot, S. Bergia and A. Messina, *Modern Cosmology in Retrospect* (Cambridge: Cambridge University, 1990), 118–9. When one compares his comments on the McVittie paper cited above with the paper itself (p. 337), it seems not unlikely that the results that Krasiñski claims to exist are mere coordinate rather than physical effects; Martin Harwit, "Time and Its Evolution in an Inhomogeneous Universe," *Astrophysical Journal* 447 (1995): 482; at http://adsabs.harvard.edu/abstract_service. html; James L. Anderson, "Multiparticle Dynamics in an Expanding Universe," *Physical Review Letters* 75 (1995): 3602; Hiroshi Kozaki and Ken-ichi Nakao, "Volume Expansion of Swiss-Cheese Universe," *Physical Review D* 66 (2002): 104008; http://arxiv.org/abs/gr-qc/0208091; and Chang Jun Gao and Shuang Nan Zhang, "Reissner- Nordström Metric in the Friedman [sic]-Robertson-Walker Universe," *Physics Letters B* 595 (2004): 28; http://arXiv.org/abs/ gr-qc/0407045

[21]Robert V. Gentry, "Flaws in the Big Bang Point to GENESIS, a New Millennium Model of the Cosmos: Part 3: Galaxies Point to Flaws in Big Bang's Expanding-Balloon Illustration and to Smoking Gun Signatures of GENESIS," http://orionfdn.org/papers/arxiv-3.htm (28 Feb 2001).

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[24]William B. Bonnor, "A Generalization of the Einstein-Straus Vacuole," *Classical and Quantum Gravity* 17 (2000): 2739.

[25]William B. Bonnor, "Size of a Hydrogen Atom in the Expanding Universe," *Classical and Quantum Gravity* 16 (1999): 1313.

[26]Marc Mars, "On the Uniqueness of the Einstein-Straus Model," *Classical and Quantum Gravity* 18 (2001): 3645; ——, "Axially Symmetric Einstein-Straus Models," *Physical Review D* 57 (1998): 3389; http://arxiv.org/abs/gr-qc/0202087; and Filipe C. Mena, Reza Tavakol, and Raul Vera, "Generalisations of the Einstein-Straus Model to Cylindrically Symmetric Settings," http://arxiv.org/abs/gr-qc/0405043

[27]John Byl, *God and Cosmos: A Christian View of Time, Space, and the Universe* (Edinburgh: Banner of Truth, 2001).

[28]D. Russell Humphreys, *Starlight and Time: Solving the Puzzle of Distant Starlight in a Young Universe* (Colorado Springs: Master, 1994); Danny R. Faulkner, "The Current State of Creation Astronomy," Fourth International Conference on Creationism, Pittsburgh, PA (August 3–8, 1998); Creation Science Fellowship, Pittsburgh (1998); www.icr.org/research/df/; and Danny R. Faulker and Donald B. DeYoung, "Toward a Creationist Astronomy," *Creation Research Society Quarterly* 28, no. 3 (1991); www.creationresearch.org/crsq/articles/28/28_3/starevol.html

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[31]John G. Hartnett, "A New Cosmology: Solution to the Starlight Travel Time Problem," [*Creation Ex Nihilo*] *Technical Journal* 17, no. 2 (2003): 98; www.answersingenesis.org/home/area/magazines/tj/docs/v17n2_cosmology.pdf

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