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Qualms Concerning the Inflationary Scenario

by B. H. Lavenda and J. Dunning-Davies

Introduction by Miles Mathis: I was recently given permission to reprint this paper by Jeremy Dunning-Davies. It was first published by *Foundations of Physics Letters* in 1992. Since it finds fault with a mainstream idea, it has been suppressed and ignored. This despite the fact that Dr. Dunning-Davies was a respected senior lecturer in physics at the University of Hull from 1966 to 2008 and is considered one of the top experts on thermodynamics in the UK. Although the Dunning-Davies page at en.Wikipedia is hidden and truncated, the page of Dr. Lavenda is not. It is both glowing and extensive, and I recommend you visit it before they take it down (they already have the telltale warnings at the top). Bernard Lavenda, a professor of physical chemistry at the University of Camerino since 1980, is also an acknowledged expert on thermodynamics. He worked with Prigogine in his early years and has since published over 130 papers worldwide—many of them critical of the mainstream.

The inattention to this paper is just more proof that all critics of the standard models are being ignored, and that there is really very little dialog left in physics. It doesn't matter if you are a high-level academic or an amateur: if you question any part of current dogma, you are marginalized and called a fringe scientist, if not worse. You are not answered, you are simply slandered. Those at the top of physics don't even feel the need to respond to learned criticisms anymore. Their theories are not promoted because the ideas or equations are good, their theories are promoted because. . . well, no one *knows* why they are promoted. We assume it is because they lead to the most expensive research. Some of the research dollars are then fed back into promotion, and the circle is closed. The top theories are then on top *because* they are promoted. As in all other fields, money determines everything.

Since the paper reprinted below includes a study of what Dr. Dunning-Davies calls the Robertson-Walker metric, some of you may be interested to continue your reading after this by consulting my analysis of that metric—also known in the US as the Friedmann metric. In two papers I show how this metric is borrowed from the first equations of Special Relativity, and how it is compromised by the same mistakes that compromise the foundational math of SR and GR.

Preface by Jeremy Dunning-Davies: In the article discussing qualms surrounding the inflationary scenario which is reproduced below, it is worth noting from the outset that the arguments concerned are thermodynamic in origin. Basic macroscopic thermodynamics is essentially a practical subject based on the operation of heat engines and is founded on a number of laws, the First and Second of which are the most important and of relevance here. The First Law is really a statement of the law of conservation of energy but in a form which acknowledges that heat is a form of energy. The law is represented in the equation

$dQ = dU + dW$

where dQ represents a change in heat, dU a change in internal energy and dW a change in the work done. The Second Law in either of its traditional forms states that (due to Kelvin), *it is impossible to transform an amount of heat completely into work in a cyclic process in the absence of other effects*; or (due to Clausius), *it is impossible for heat to be transferred by a cyclic process from a body to one warmer than itself without producing changes at the same time.*

This Second Law is then used to show that a quantity usually denoted by S and called the entropy is such that any change dS in it is given by

$TdS = dQ$

where T represents absolute temperature. Precisely what entropy in thermodynamics is physically is still an open question but it should not be immediately equated with the quantity called entropy in other branches of physics and information theory.

An adiabatic process is then one in which there is no change of heat; that is $dQ = 0$. From the last equation, this also implies that $dS = 0$ for any adiabatic process.

In his original article on the inflationary theory, Alan Guth restricted his attention to a mathematical space in which the distance ds between neighbouring points was given by the Robertson-Walker metric as given in equation (3) below where r, θ and φ represent the usual polar coordinates and R(t) is the so-called scale factor. Guth shows that the Einstein equations (1) and (2), where R represents the radius of curvature, result. What is shown in the first part of the paper below is that these two Einstein equation imply $dS = 0$ and hence imply, from what was said above, that all changes must be adiabatic. It follows that, if these equations are used, non-adiabatic processes cannot be considered; **but that is precisely what Guth did.**

Often the two equations above which represent mathematical forms of the First and Second Laws of Thermodynamics are combined into the form

$TdS = dU + dW$

But this equation obviously represents a combination of the First and Second Laws. It is pointed out in the second part of the paper below that this is another point not always recognized by people working in the general area of cosmology. Specifically it is shown that, when dissipative processes are taken into consideration, the vanishing of the mathematical quantity referred to as the divergence of the mass-energy tensor actually represents a combination of the First and Second Laws rather than being a relativistic analogue of just the First Law. Differences such as this may seem small but can have huge consequences.

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It is shown that the release of the condition of adiabaticity is incompatible with the Einstein equations that are derived from the Robertson-Walker metric. Once dissipative processes are considered, the vanishing of the divergence of the mass-energy tensor is a combination of the first and second laws rather than being the relativistic analogue of the first law. Dissipative processes destroy isotropy and hence cannot be described by any standard model based on Robertson-Walker models.

Key words: inflationary scenario, adiabatic Einstein equations, second law, entropy production, relativistic thermodynamics.

In order to resolve the "horizon" and "flatness" problems in the "standard model" of hot big-bang cosmology, Guth [1] released the adiabatic assumption. The resulting so-called "inflationary" scenario supposes the supercooling of the universe leads to a period of exponential growth when latent heat of the phase transition is released. This would have the effect of increasing the entropy of the universe.

The inflationary scenario has been criticized on account of the large inhomogeneities that it would produce that would be incompatible with observation [1]. Modifications were introduced into this model to overcome this difficulty [2,3]. Apart from these difficulties, there is a still far greater one in the inflationary scenario. Non-adiabaticity is incompatible with the Einstein equations resulting from the homogeneous and isotropic Robertson-Walker metric. The Einstein equations

$$\ddot{R} = -\frac{4\pi}{3}G(\varepsilon+3p)R \tag{1}$$

and

$$\left(\frac{\dot{R}}{R}\right)^2 + \frac{k}{R^2} = \frac{8\pi}{3}G\varepsilon \tag{2}$$

have been derived from the Robertson-Walker metric

$$ds^2 = dt^2 - R^2(t)\left[\frac{dr^2}{1-kr^2} + r^2(d\theta^2+\sin^2\theta\ d\phi^2)\right], \tag{3}$$

where $k = +1$, -1, or 0, depending upon whether the universe is closed, open, or flat, respectively. Differentiating the second of Einstein's equations (2) with respect to t and eliminating the second derivative, one finds

$$\frac{d}{dt}(\varepsilon R^3) + p\frac{d}{dt}(R^3) = 0, \tag{4}$$

where ε is the energy density and p is the pressure. A comparison of this equation with the thermodynamic relation

$$Td(sR^3) = d(\varepsilon R^3) + pd(R^3), \tag{5}$$

where s is the entropy density and sR^3 is the total entropy in a volume whose radius of curvature is R, shows that Einstein's equations implicitly imply the adiabatic condition

$$d(sR^3) = 0. \tag{6}$$

Hence no criterion for exponential non-adiabatic growth can be obtained from Einstein's equations. Guth's [1] error was to assume that 6 is an additional assumption not contained in (4).

The question is: How does one modify the standard model of an adiabatically expanding radiation-dominated universe that is described by a Robertson-Walker metric? Certainly, this touches on the role of the second law in general relativity. Tolman [4] considers the first and second laws separately. According to him, the relativistic analog of the first law is

$$\frac{\partial}{\partial x^k} T^{ik} = 0 \tag{7}$$

in a locally inertial coordinate system, where T^{ik} is the covariant mass-energy tensor, while the second law is

$$d(sR^3) \geq \frac{\delta Q}{T}, \tag{8}$$

where δQ is the proper heat that a local observer would measure at the proper temperature T in the volume element R^3. The only connection between the two laws is that imposed by the adiabatic condition of the first law (7), which reduces the second law (8) to

$$d(sR^3) \geq 0. \tag{9}$$

This is not a satisfactory approach since it leaves us no way of calculating the entropy and determining whether the process is reversible or not. Tolman makes the further distinction between classical and relativistic thermodynamics insofar as "reversible" processes can occur at a finite rate where an unenclosed fluid can expand without any form of dissipation. If this were the case, it would leave us without any criterion for determining what relativistic processes are reversible and whether they are adiabatic. We will now show that (7) is not the relativistic analogue of the first law but it is a combination of the first and second laws.

The mixed mass-energy tensor in the presence of a heat flux is

$$T_i^k = (\varepsilon + p)u_i u^k - p\delta_i^k + q_i u^k + q^k u_i, \tag{10}$$

where q^k are components of a heat flux-density 4-vector. They are related to the components of the entropy flux density in the following way:

$$s^k = su^k + \frac{q^k}{T}. \tag{11}$$

In a comoving set of coordinates $u = (1,0,0,0)$ all dissipative effects should vanish. This means that, in the proper frame, the component q^0 is zero since $u^\alpha = 0$, $\alpha = 1,2,3$, and hence in any frame

$$q^k u_k = 0, \tag{12}$$

so that the component s^0 of the entropy flux density 4-vector (11) in the proper frame is equal to the entropy density s. Introducing (11) into the mass-energy tensor (10), differentiating the resulting expression, and scalar multiplying by u^i lead to

$$u^i \frac{\partial}{\partial x^k} T_i^k = \frac{\partial}{\partial x^k}[(\varepsilon + p)u^k] - u^k \frac{\partial}{\partial x^k} p + \frac{\partial}{\partial x^k} q^k - q^i a_i, \tag{13}$$

where we have used $u_i u^i = 1$, $u^i \partial u_i / \partial x^k = 0$ and orthogonality condition (12). In (13) we have defined the 4-acceleration as

$$\alpha_i = u^k \frac{\partial}{\partial x^k} u_i. \tag{14}$$

Following Landau and Lifshitz [5], we make use of the continuity equation

$$\frac{\partial}{\partial x^k}(\rho u^k)=0, \tag{15}$$

where $\rho = 1/R^3$, to write (13) in the form

$$u^i\frac{\partial}{\partial x^k}T_i^k=\rho u^k\left\{\frac{\partial}{\partial x^k}\left(\frac{\varepsilon}{\rho}\right)+p\frac{\partial}{\partial x^k}\left(\frac{1}{\rho}\right)-T\frac{\partial}{\partial x^k}\left(\frac{s}{\rho}\right)\right\}$$

$$+q^k\left\{\frac{\partial}{\partial x^k}\ln T-\alpha_k\right\}+T\frac{\partial}{\partial x^k}s^k. \tag{16}$$

Noting that the terms within the curly brackets is precisely the thermodynamic relation (5), the condition for the vanishing of (16) is

$$\frac{\partial}{\partial x^k}s^k=-\frac{q^k}{T}\left\{\frac{\partial}{\partial x^k}\ln T-\alpha_k\right\}\geq 0, \tag{17}$$

which is the entropy production due to heat conduction. The second term in (17) is relativistic in origin resulting from the inertia of the heat flux [6]. This lends further support to our claim that such terms must be present in Einstein's equations when the condition of adiabaticity is dropped.

Consequently, (7) is not the relativistic analogue of the first law but rather a combination of the first and second laws. Moreover, the tensor (10) cannot be used in Einstein's equations which result from a Robertson-Walker metric because, even though it is homogeneous, it is no longer isotropic. Hence, once the adiabatic condition is released, the highly restricted class of Robertson-Walker models is no longer valid and this leads to an even more profound modification of the standard model than is envisioned by the inflationary scenario.

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NOTE

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