

Expanding Boundary Pressure Process All Pervading Dark Energy Aether in a Friedman Dust Universe with Einstein's Lambda

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Abstract

In this paper, the cosmological model that was introduced in a sequence of three earlier papers under the title *A Dust Universe Solution to the Dark Energy Problem* is used to make a more detailed study of the role of dark energy mass as a conserved with time substance that permeates the expanding universe. It is shown that if dark energy is to be conserved over all time it has to satisfy the cosmological vacuum polarisation equation over the pre-singularity range of contraction and the post-singularity range of expansion in order for it to remain in a self mechanical equilibrium inside and outside the boundary of the expanding universe and so be able to be always and everywhere permeable to the positive gravity *dark mass* and visible mass material within the universe.

Keywords: Dust Universe, Dark Energy, Dark Mass, Friedman Equations, Vacuum Polarisation, Mechanical Equilibrium, Conservation of energy

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1 Introduction

The work to be described in this paper is an application of the cosmological model introduced in the papers *A Dust Universe Solution to the Dark Energy Problem* [23], *Existence of Negative Gravity Material. Identification of Dark Energy* [24] and *Thermodynamics of a Dust Universe* [32]. The conclusions arrived at in those papers was that the dark energy *substance* is physical material with a positive density, as is usual, but with a negative gravity, $-G$, characteristic and is twice as abundant as has usually been considered to be the case. References to equations in those papers will be prefaced with the letter *A*, *B* and *C* respectively. The work in *A*, *B* and *C*, and the application here have origins in the studies of Einstein's general relativity in the Friedman equations context to be found in references ([16],[22],[21],[20],[19],[18],[4],[23]) and similarly motivated work in references ([10],[9],[8],[7],[5]) and ([12],[13],[14],[15],[7],[25],[3]). Other useful sources of information are ([17],[3],[30],[27],[29],[28]) with the measurement essentials coming from references ([1],[2],[11]). Further references will be mentioned as necessary. The application of the cosmological model introduced in the papers *A* [23], *B*,[24] and *C* [32], in paper *E*, ([36]), is to the extensively discussed and analysed *Cosmological Coincidence Problem*. In the paper *D*, [34], it was shown that the quantum vacuum polarisation idea can be seen to play a central role in the Friedman dust universe model introduced by the author. An essential part of that role involves the relations between three pressures at the boundary of the expanding universe. In particular of fundamental importance is a relation between pressure from the *CMB*, P_Γ , pressure from all the rest of the universe which is not *CMB* and not dark energy, P_Δ , and pressure from dark energy itself, P_Λ . This relation takes the form

$$P_\Gamma = P_\Delta + P_\Lambda \quad (1.1)$$

$$P_\Lambda = c^2 \rho_\Lambda \omega_\Lambda = -c^2 \rho_\Lambda \quad (1.2)$$

$$\omega_\Lambda = -1. \quad (1.3)$$

Equation (1.2) together with equation (1.3) is the well known specification implying negative pressure, P_Λ , from the dark energy density in the Einstein form $\rho_\Lambda = \Lambda c^2 / (8\pi G)$. In earlier work, I have referred to the equation (1.1) as representing a mechanical equilibrium between the Γ field and the Δ and Λ fields combined. I now think that designation while remaining *formally* correct should be presented with a changed interpretation because

of the negative pressure associated with the dark energy field, Λ , field. In the usual specification of a mechanical equilibrium two pressures $P_1 = P_2$ are said to be equal where there is no complication of possible negative parts for either of them. Pressures on either side of a boundary between non-miscible liquids for example are said to be in mechanical equilibrium if the boundary is not accelerating. In such a case, although the pressures act at the boundary in opposite directions they are both taken as positive. Mechanical equilibrium in thermodynamics is a very contentious area of research so that my explanation in this context is very minimal. As a result of these complications it is desirable to express equation (1.1) in the alternative form using a modulus sign, $|\cdot|$. The term *boundary* of the universe at time t refers to a conceptual sphere of radius given by the function $r(t)$ defined earlier (A).

$$P_\Gamma = P_\Delta - |P_\Lambda| \quad (1.4)$$

$$P_\Delta = P_\Gamma + |P_\Lambda|. \quad (1.5)$$

In this form, all the pressures are expressed as positive quantities and the mechanical equilibrium between these three field can now be more safely reinterpreted as a mechanical equilibrium between the Δ field and the Λ and Γ fields combined. This version of the equilibrium condition at the boundary of the expanding universe makes good sense physically for at least two reasons. The first reason is that dark energy material exists on both sides of the expanding boundary of the universe so the $\pm|P_\Lambda|$ versions refer to the pressure direction on the boundary from dark energy material on one side or the other, whilst the gravitational pressure, P_Δ , is directed towards the material within the universe and so, on the boundary, is only effectively equivalent to a positive pressure towards the centre of expansion. This last property is a well-known result originating from Newtonian gravitational theory. Taking the total pressure, P , in the Friedman equations as positive is a rather anomalous convention which has caused much confusion which I attempt here to unravel. The second reason is that the form (1.4) rearranged as in (1.6)

$$P_\Lambda = -|P_\Lambda| = P_\Gamma - P_\Delta \quad (1.6)$$

$$P(t) = +P_G + P_\Lambda = P_\Delta(t) - P_\Gamma(t) + P_\Lambda \equiv 0 \quad \forall t. \quad (1.7)$$

clearly expresses the physics of the equilibrium condition. It is that the negative outward pressure P_Λ that would be exerted on the boundary from the dark energy inside the universe is equal to the difference of the outward

CMB pressure, P_Γ , less the inward pressure P_Δ exerted on the universe boundary from within by the positive G or normal gravitating material within the universe. The equations (1.6) and (1.2) firmly identify both the pressure P_Λ and the mass density ρ_Λ of the dark energy as coming from the quantities P_Γ and P_Δ both defined with meanings within the universe. Elsewhere, I have expressed the equation (1.6) using the *PEID* form which explains it in terms of the mass densities, $\Gamma(t)$, $\Delta(t)$ rather than the equivalent pressures,

$$\rho_\Lambda = \Delta(t) - \Gamma(t). \quad (1.8)$$

$$G\rho_\Lambda = G_+\Delta(t) + G_-\Gamma(t) \quad (1.9)$$

$$G_+ = +G \quad (1.10)$$

$$G_- = -G. \quad (1.11)$$

The equation (1.7) uses (1.6) to bring us back to the total pressure $P(t)$ which as indicated is identically *zero* for all t and so indicates that the whole history of the universe in this model is that of a *dust* universe. Clearly then the total pressure $P(t)$ cannot be responsible for the acceleration. This conclusion agrees with what was noted earlier that the acceleration is accurately determined by a generalisation of the Newtonian gravitation theory only involving adding to the inverses square law a linear law term involving Einstein's cosmological constant Λ . The realisation that the various pressures that we have been discussing earlier do not determine the dynamical behaviour of the system generates the question, *what is this complicated pressure structure all about?*

The immediate answer to the question at the end of the last paragraph is that the pressure structure that derives from the equilibrium relation between the three pressures, P_Λ , P_Δ and P_Γ generates the important relation, (1.8) or (1.9). This relation shows that *within* the spherical volume of the universe the constant valued dark energy density, ρ_Λ , is determined by the *dark mass* dominated quantity pair $\Delta(t)$ and $\Gamma(t)$. I emphasise *within* because both these quantities are part of the constant space and time conserved energy of the universe, M_U . However, the space-time constant *dark energy* mass density ρ_Λ , by initial assumption, exists everywhere in the universe's enveloping space with the same definite numerical value outside as inside. Thus the following subsidiary question presents itself: If the dark energy density inside the universe is given by (1.8) in terms of the internal constituents, Δ and Γ , how is it that outside the universe involving regions which will not have been reached by the internal constituents of

the expanding universe, the dark energy density ρ_Λ exist in its own right by assumption, with the same constant value as inside and apparently not generated by any internal influence? The unique character of this model does allow a satisfactory answer to this question which depends on the model's strict conformance to the principle of conservation of energy in contrast with the *standard big bang model*. This model involves two basic *positive* types of mass defined by their gravitational character, which is determined by whether the mass appears in the theory multiplied with $G_+ = +G$ or $G_- = -G$, where the gravitational constant G is always constant, $G > 0$. Dark mass and normal mass belongs to the G_+ category and dark energy belongs to the G_- category. An important way in which this model differs from the big bang type universe is that the beginning of time in this theory, rather than occurring at time $t = 0$, occurs at time $t = -\infty$ and the end of time occurs at $t = +\infty$. This can be interpreted as this universe lasts *for ever*. The reader may prefer to regard this infinite time scale as just one out of a possible infinite number of infinite contiguous periodic time scales and so reinforcing the lasting for ever concept. This last extension can be usefully incorporated in the theory, see paper (C). Let us now consider the situation at and after the start of time taken as $t = -\infty + t_\epsilon$, $t_\epsilon \approx +|0|$ at this stage the radius of the universe is infinitely large, $r(-\infty + t_\epsilon)$, and will decrease with advancing time. In other words, near the beginning of time the universe is a sphere occupying almost the whole of hyperspace and so the internal generating dark energy process (1.8) is operative almost everywhere in hyper space. It follows that the universe is full of the dark energy density ρ_Λ , though this density is itself small it adds up in total over the whole universe volume to a *very large amount* of dark energy mass. The universe also contains a much smaller density value, $\rho(-\infty + t_\epsilon)$, of conserved positive gravitational mass, M_U , so that $\rho(-\infty + t_\epsilon)V_U(-\infty + t_\epsilon) = M_U$. This conserved mass contains the mass of the universe that we see. The basic assumption in this model is that dark energy density, $\rho_\Lambda(t)$, exists everywhere and at all time so that if the radius of the universe at $t = -\infty$ is infinite and if the space is flat Euclidean then the universe has no outside and takes in all the hyper-universe so that all the dark energy is enclosed. After the small time elapse, t_ϵ , the universe will have acquired a small outside volume and a slightly smaller inside volume than it had initially. It follows that in principle there are two types of simple likely possibilities. Firstly, the contracting universe leaves no dark energy density outside as it evolves in time and keeps the original value inside at the same value as

given by formula (1.8). Secondly, as it evolves in time it leaves outside sufficient dark energy density to keep to the uniform constant density condition everywhere and so keeping the dark energy density inside at the same value given by formula (1.8) as outside. The first option means that the dark energy within the universe would decrease with decreasing volume consequently losing density to no recognisable sink and so implying dark energy is not conserved. This would also violate the assumption that dark energy density is constant everywhere and at all time. Thus we are left with only the second possibility and consequently the actual scenario has to be that as the universe contracts the internal pressure process described by the internal Δ and Γ fields precipitates the right amount of dark energy material outside in the space produce by the contracting universe. This process will continue for all time and, in particular, past the singularity at $t = 0$ when the volume is zero. Thus after the singularity, when the universe is in an expanding mode, it will encounter the pre-singularity dark energy density outside its boundaries precipitated in its contracting mode. Thus the main role of formula (1.9) is to keep the conserved and bounded dark mass within the universe freely permeable to or non interacting with the dark energy in which it swims by maintaining the self mechanical equilibrium of the dark mass density in the form,

$$P_{\Lambda,in} = P_{\Lambda,out} \tag{1.12}$$

$$\rho_{\Lambda,in} = \rho_{\Lambda,out}, \tag{1.13}$$

where $P_{\Lambda,in}$ is the dark energy pressure just inside the boundary and $P_{\Lambda,out}$ is the dark energy pressure just outside the boundary of the universe. Equation (1.13) gives the same condition in terms of densities. All this suggests that the dark energy density, although pressure identified, has also to be taken seriously as a genuine mass density. It also shows that the pre-singularity negative time phase is a necessary adjunct to making sense of this theory. The conclusion associated with this section is that the formula (1.9) together with the full time history of this model assures that dark energy and dark mass are both conserved over all time. The above argument is not meant to be mathematically rigorous but rather a plausibility construction. No doubt the reader can think of various improvements.

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