A Planck Vacuum Cosmology

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Both the big-bang and the quasi-steady-state cosmologies originate in some type of Planck state. This paper presents a new cosmological theory based on the Planck-vacuum negative-energy state, a state consisting of a degenerate collection of negative-energy Planck particles. A heuristic look at the Einstein field equation provides a convincing argument that such a vacuum state could provide a theoretical explanation for the visible universe.

1 Introduction

Cosmology, taken as a whole, is the study of the origin and evolution of the universe [1, p. 1144]. The universe is the visible (observable by whatever means) universe that exists in free space. At present there are two major competing cosmologies that theoretically describe the real observed universe, the big-bang cosmology [2] and the quasi-steady-state cosmology [3], the big-bang cosmology being considered by most cosmologists as the major one of the two. Both cosmologies claim some type of Planck state as the origin for their calculations; in the big-bang case it is a point source at time zero in which an explosion takes place, subsequently creating the expanding universe; while in the quasi-steady-state case a background field called the "creation field" creates free Planck particles (PP) on a quasi-continuous basis that immediately decay into a large number of particles, subparticles and fields.

The present paper presents a new cosmological model called the Planck-vacuum (PV) cosmology. The PV (briefly described in Appendix A) is an omnipresent negative-energy state that is assumed to be the Planck state that is the foundation for the visible universe, its expansion, and also its eventual contraction. The addition of the PV to the visible universe in a cosmological model requires a name to distinguish the combination from the visible universe of standard cosmology. The name used here is "cosmos" and includes, correspondingly, the PV and the visible universe. As might be expected, this new model differs significantly from the two models mentioned in the preceding paragraph.

We begin with a brief look at the standard Einstein metric equation

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} = \frac{8\pi}{m_* c^2/r_*} T_{\mu\nu} \tag{1}$$

where $G_{\mu\nu}$ and $T_{\mu\nu}$ are the Einstein and energy-momentum tensors, and G and c are the gravitational and speed-of-light constants. The force $m_* c^2/r_*$ in the denominator of the final expression is the ultimate curvature force that can be applied to the spacetime of General Relativity or to the PV [4]. Compared to this force, the relative curvature force the sun, a white dwarf, or a neutron star exert on spacetime and the PV is 0.00001, 0.001, and 0.5 respectively. With the help of Appendix A, the Einstein equation can also be expressed in the form

$$\frac{G_{\mu\nu}/6}{1/r_*^2} = \frac{T_{\mu\nu}}{\rho_* c^2} \tag{2}$$

where r_* is the Compton radius of the PP and ρ_* is its mass density. The ratio $1/r_*^2$ can be thought of as the PP's Gaussian curvature. In this latter form both sides of the equation are dimensionless. As the curvature force, the mass density, and the Gaussian curvature are intimately related to the PPs in the negative-energy PV, it is easy to conclude that the Einstein equation and General Relativity must also be intimately related to that vacuum state.

The PV-cosmology modeling begins in the next section which concerns the expansion of the cosmos. Since little is known about the PV at the present time, however, the calculations in that section and the one following it are a bit sketchy and of a cursory nature.

The PV cosmology must address the question of how PPs from the PV are injected into free space to populate the visible universe with the particles and fields upon which the larger components of the universe are built. A scenario for this injection process that somewhat parallels the quasi-steady-state theory of PP creation is presented in Section 3, the main difference being that in the quasi-steady-state model the PPs evolve from "creation fields" while in the present theory they spring directly from the negative-energy PV state.

A comments Section 4 closes the main text of the paper. Appendix A gives a brief description of the PV theory to date and Appendix B compares the PV to the cosmological-constant term in the Einstein field equation.

2 Cosmological expansion

The mass density of the degenerate PV state in the PV cosmology is roughly equal to the PP mass density

$$\rho_* \equiv \frac{m_*}{4\pi r_*^3/3} \approx 10^{94} \ [\mathrm{gm\ cm^{-3}}] \tag{3}$$

where m_* and r_* are the PP mass and Compton radius respectively. If we somewhat arbitrarily take the universal mass density as $\rho_m \sim 10^{-30}$ [gm cm^{-3}], then the ratio $\rho_m/\rho_* \sim 10^{-124}$ is vanishingly small. Thus it is unreasonable to expect that the visible universe can effect the expansion or contraction of the cosmos as it does for the universe in the big-bang and quasi-steady-state cosmologies. This fact leads to the conclusion that the expansion of the universe must be determined by that of the PV itself.

The expansion of a homogeneous and isotropic universe is characterized by the expansion factor S ($= S(t)$) in the Robertson-Walker line element [3, p. 111]

$$ds^2 = c^2 dt^2 - S^2 \left[\frac{dr^2}{1-kr^2} + r^2 d\theta^2 + r^2 \sin^2\theta \, d\phi^2 \right] \quad (4)$$

where (t, r, θ, ϕ) are comoving coordinates, and where $k = +1$, $k = -1$, and $k = 0$ denote a universe with a positive, negative, or zero curvature respectively. The Robertson-Walker metric is used to determine the "kinematic" properties of the universe for any given S, the dynamics of the expansion only appearing implicitly in the time dependence of S. For example, (4) can be used to derive the standard expressions for the redshift z [3, pp.112-113] and the Hubble constant H [3, pp.118–119]:

$$1 + z = \frac{1}{S} \quad (5)$$

$$H = \frac{\dot{S}}{S} \quad (6)$$

without specifying the particular dynamics of the expansion. Thus these relations are equally valid in the big-bang, quasi-steady-state, and PV cosmological models.

To determine the dynamics of the expansion factor in the big-bang and quasi-steady-state cosmologies, some form of the Einstein equation (2) is used. Both models start by calculating the Einstein tensor $G_{\mu\nu}$ from the metric coefficients of the Robertson-Walker line element (4). The standard big-bang cosmology then assumes various energy-momentum tensors for the right side of (2) to derive the Friedmann equations for S in the various phases of the expanding universe [2, pp.48–50]. An early version of the quasi-steady-state model modifies the numerator on the right side of (2) to include a "creation field" for generating PPs, then derives Friedmann-like equations for the expansion-factor dynamics [3, pp.322–324]. As the expansion-factor dynamics in the PV-cosmology model is determined by the expansion of the PV itself, however, it isn't clear what part the Einstein and Friedmann-like equations may or may not play in the research surrounding the PV cosmology.

There is no compelling evidence that the constants governing the fundamental laws of physics were once different from their present values [1, p. 1056]. This statement bares significantly on the nature of the PV expansion — it implies, in effect, that the PV expands by an increase in its content rather than a change in its properties. Assume that the number density of the PPs in the PV decreases as the PV expands for example. Then the density of the virtual fields of the quantum vacuum [5] would also decrease because the PV is the source of the quantum vacuum [6]. This in turn would decrease the magnitude of the dominant Bethe term [7, p. 208] in the $2S_{1/2} - 2P_{1/2}$ Lamb shift of atomic hydrogen as the Bethe term is proportional to the density of the virtual fields [5, p. 91]. Thus the 2S-2P transition frequency of the atom would decrease as the PV expands, contradicting the assumption in the first sentence of the paragraph.

3 Planck Particle creation

It is assumed that a sufficiently stressed PV will release one or more of its PPs into the visible universe in a manner resembling a mini-big-bang outburst. "[This] requirement is in agreement with observational astrophysics, which in respect of high-energy activity is all of explosive outbursts, as seen in the QSOs, the active galactic nuclei, etc. The profusion of sites where X-ray and γ-ray activity is occurring are in the present [quasi-steady-state] theory sites where the creation of matter is currently taking place" [3, p. 340]. It is then assumed that the new free-space PP decays into a number of secondary particles. The lifetime of the free PP is assumed to be governed by the time required ($t_* = r_*/c \sim 10^{-44}$ sec) for the internal PP fields (traveling at the speed of light) to decay within the confines of the PP Compton radius r_*.

It is too early in the PV-cosmology theory to present any substantial analysis concerning the details of the activity mentioned in the previous paragraph. We are left, then, with a heuristic description of the PP-creation process in terms of the Einstein field equation. Taking the (covariant) divergence of (2) gives

$$G^{\mu\nu}_{;\nu} \equiv 0 \qquad \Longrightarrow \qquad T^{\mu\nu}_{;\nu} = 0 \quad (7)$$

showing that the standard Einstein equation provides no mechanism for creating PPs due to the vanishing divergence of the energy-momentum tensor. Assume that at some point x^α ($\alpha = 0, 1, 2, 3$) in empty spacetime ($T^{\mu\nu} \approx 0$ before x^0) a PP is ejected from the PV into the free space of the visible universe. In the standard action (see Appendix A)

$$\mathcal{A} = \frac{1}{2c} \left(\frac{\rho_* c^2}{1/r_*^2} \right) \int \frac{R}{6} \sqrt{-g} \, d^4x + m_a c \int ds_a \quad (8)$$

whose variation yields (2), the world lines are considered to be continuous in the full range $0 < |x^\alpha| < \infty$. At the point x^α where a PP is created, however, the PP world line begins. It is possible to modify (8) in that case so its variation leads to the modified Einstein equation [3, p. 323]

$$\frac{G^{\mu\nu}/6}{1/r_*^2} = \frac{T^{\mu\nu}_{(m_*)} + \mathcal{T}^{\mu\nu}_{(pv)}}{\rho_* c^2} \quad (9)$$

where, as interpreted here, the calligraphic tensor in the numerator at the right is associated with processes taking place within the PV.

The free-PP creation represented by (9) is explained physically as an interchange of energy and momentum between the PV and the PP injected into the visible universe. The divergence of (9) now leads to

$$T^{\mu\nu}_{(m_*);\nu} = -\mathcal{T}^{\mu\nu}_{(pv);\nu} \tag{10}$$

which is meaningful only if the right side of the equation leads to a positive free-space PP energy [3, p. 325]; i.e. only if the 0-0 component of the PV energy-momentum tensor is negative. That this tensor component is negative follows from the fact that the PV state is a negative-energy state. Thus we have

$$T^{00}_{(m_*)} = -\mathcal{T}^{00}_{(pv)} = +\rho_* c^2 \tag{11}$$

as

$$\mathcal{T}^{00}_{(pv)} = -\rho_* c^2 \tag{12}$$

since the PP mass-energy density of a PP *within* the PV is $-\rho_* c^2$.

4 Sundary comments

It is assumed that the origin of the light nuclei and the cosmic microwave background in the PV-cosmology model are essentially the same as those discussed in the quasi-steady-state model [3, pp.350-358].

Both the big-bang and the quasi-steady-state cosmologies are based on field theory, the big-bang cosmology on the quantum field theory of the early universe [2] and the quasi-steady-state cosmology on the so-called "creation fields". The choice of a field-theoretic approach reflects, of course, the current paradigm that fields are the fundamental building blocks of the particles and subparticles out of which the observed universe is constructed. With the advent of the PV theory, however, these fields now have a charged source (the PPs within the PV) as their origin. It is this charged source that is the foundation of the PV cosmology presented here.

The action integrals in (A8) of the appendix tie the creation field $\mathcal{C}_\mu$ of the quasi-steady-state theory [3, p. 321] directly to the PPs in the PV.

The calculations in Appendix B show that the PV cannot be identified with the cosmological-constant term in the Einstein field equation.

Appendix A: The Planck Vacuum

The PV [4] is a uni-polar, omnipresent, degenerate gas of negative-energy PPs which are characterized by the triad (e_*, m_*, r_*), where e_*, m_*, and r_* ($\lambda_*/2\pi$) are the PP charge, mass, and Compton radius respectively. The vacuum is held together by van der Waals forces. The charge e_* is the bare (true) electronic charge common to all charged elementary particles and is related to the observed electronic charge e through the fine structure constant $\alpha = e^2/e_*^2$ which is a manifestation of the PV polarizability. The PP mass and Compton radius are equal to the Planck mass and length respectively. The particle-PV interaction is the source of the gravitational ($G = e_*^2/m_*^2$) and Planck ($\hbar = e_*^2/c$) constants, and the string of Compton relations

$$r_* m_* = \cdots = r_c m = \cdots = e_*^2/c^2 = \hbar/c \tag{A1}$$

relating the PV and its PPs to the observed elementary particles, where the charged elementary particles are characterized by the triad (e_*, m, r_c), m and r_c being the mass and Compton radius ($\lambda_c/2\pi$) of the particle (particle spin is not yet included in the theory). The zero-point random motion of the PP charges e_* about their equilibrium positions within the PV, and the PV dynamics, are the source of the quantum vacuum [6] [5]. Neutrinos appear to be phonon packets that exist and propagate within the PV [8].

The Compton relations (A1) follow from the fact that an elementary particle exerts two perturbing forces on the PV, a curvature force mc^2/r and a polarization force e_*^2/r^2:

$$\frac{mc^2}{r} = \frac{e_*^2}{r^2} \quad\Longrightarrow\quad r_c = \frac{e_*^2}{mc^2} \tag{A2}$$

whose magnitudes are equal at the particle's Compton radius r_c.

Equating the first and third expressions in (A1) leads to $r_* m_* = e_*^2/c^2$. Changing this result from Gaussian to MKS units yields the free-space permittivities [4]

$$\epsilon_0 = \frac{1}{\mu_0 c^2} = \frac{e_*^2}{4\pi r_* m_* c^2} \quad [\text{mks}] \tag{A3}$$

where $\mu_0/4\pi = r_* m_*/e_*^2 = r_c m/e_*^2 = 10^{-7}$ in MKS units. Converting (A3) back into Gaussian units gives

$$\epsilon = \frac{1}{\mu} = \frac{e_*^2}{r_* m_* c^2} = 1 \tag{A4}$$

for the permittivities.

A feedback mechanism in the particle-PV interaction leads to the Maxwell equations and the Lorentz transformation. General Relativity describes the spacetime-curvature aspects of the PV. The ultimate curvature force [4]

$$\frac{c^4}{G} = \frac{m_* c^2}{r_*} \tag{A5}$$

that can be exerted on spacetime and the PV is due to a free PP, large astrophysical objects exerting a curvature force equal to Mc^2/R, where M and R are the mass and radius of the object. Equation (A5) leads to the important ratio

$$\frac{c^4}{8\pi G} = \frac{1}{6}\,\frac{\rho_* c^2}{1/r_*^2} \tag{A6}$$

where $\rho_* \equiv m_*/(4\pi r_*^3/3)$ is the PP mass density and $1/r_*^2$ is its Gaussian curvature.

Using (A6), the Einstein-Hilbert action $\mathcal{A}_g$ can be expressed as

$$\mathcal{A}_g = \frac{c^3}{16\pi G}\int R\sqrt{-g}\,d^4x = \frac{1}{2c}\left(\frac{\rho_* c^2}{1/r_*^2}\right)\int \frac{R}{6}\sqrt{-g}\,d^4x \tag{A7}$$

leading to the total PP-creation action [3, p. 321]

$$\mathcal{A} = \frac{1}{2c}\left(\frac{\rho_* c^2}{1/r_*^2}\right)\int\frac{R}{6}\sqrt{-g}\,d^4x + m_a c\int ds_a + \\ + \frac{f}{2c}\int \mathcal{C}_\mu \mathcal{C}^\mu\sqrt{-g}\,d^4x - \int \mathcal{C}_\mu\, da^\mu, \qquad \text{(A8)}$$

which includes the usual inertial second term, and the third and fourth creation-field terms containing $\mathcal{C}_\mu$. The effect of the PV PPs on this equation is clearly evident in the parenthesis of the first term which is the ratio of the PP's mass-energy density to its Gaussian curvature.

Appendix B: Cosmological constant

The Einstein equation including the cosmological constant Λ is

$$\frac{(G_{\mu\nu} + \Lambda g_{\mu\nu})/6}{1/r_*^2} = \frac{T_{\mu\nu}}{\rho_* c^2}, \qquad \text{(B1)}$$

which can be expressed as

$$\frac{G_{\mu\nu}/6}{1/r_*^2} = \frac{T_{\mu\nu} + \mathcal{T}_{\mu\nu}}{\rho_* c^2}, \qquad \text{(B2)}$$

where

$$\mathcal{T}_{\mu\nu}^{(vac)} \equiv -\frac{1}{6}\frac{\rho_* c^2}{1/r_*^2}\,\Lambda g_{\mu\nu} \qquad \text{(B3)}$$

leads to

$$\rho_{vac}c^2 \equiv \frac{\mathcal{T}_{00}}{g_{00}} = -\frac{1}{6}\frac{\rho_* c^2}{1/r_*^2}\,\Lambda \qquad \text{(B4)}$$

which is often seen as the "vacuum energy".

From (B4)

$$\frac{\rho_{vac}}{\rho_*} = -\frac{1}{6}\frac{\Lambda}{1/r_*^2} \qquad \text{(B5)}$$

the ratio being negative for a positive Λ. If the vacuum density ρ_{vac} is identified as the PP mass density ρ_*, then

$$\Lambda = \frac{6}{r_*^2} \approx 2.3\times 10^{66}\,[\mathrm{cm}^{-2}]\,. \qquad \text{(B6)}$$

As Λ should be close to zero, it is clear that the PV is not related to the cosmological constant.

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