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Big Bang As the Collapse of an Ordered Spin System

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The entropy of a spin system interacting with a free particle representing the inertia of the universe in the early stages is calculated. The conversion from a state of minimum entropy and minimum inertia with maximum spin order to a state of maximum entropy and *maximum inertia* is analogized to the big bang.

1. INTRODUCTION

In the absence of a consistent theory of quantized gravitation (Binnell and Davies, 1982) the problem of cosmological evolution lies open for speculation. The inflationary model (Nair, 1983) of rapid expansion after $t = 10^{-35}$ sec solves the problem of causality and flatness, but in no way accounts for the primordial beginnings of galaxies. Both standard big bang cosmology and the inflationary model fail to predict the proper growth rate for perturbations that are inserted in the early stages of evolution. Though the inflationary model has this unsolved mystery associated with it, the historical idea (Coleman, 1977) of the vacuum making a transition from an elevated state to a state of lower potential and thus providing energy for particle creation has opened a new avenue of cosmological thought. Quartic potentials, which arise from conformal invariance (Fubini, 1976), along with Weinberg-Coleman potentials (Coleman and Weinberg, 1973), which arise from the radiative corrections of the scalar field interacting with a vector gauge field, may not in the end represent the initial situation prior to and during the inflationary epoch. Whether the Higgs field and subsequent mechanism, which so beautifully explained how particles spontaneously dress themselves with a rest mass, has a lasting value is a completely open question. Only future high-energy experiments can make this assessment. It is clear that without a more precise theory of particle interactions, the

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initial mixture of gauge fields, vacuum, gravity, and matter fields is totally arbitrary.

There are those who subscribe to a belief in pregeometry, some initial state prior to the big bang when the metric disappears and matter with a very high ambient temperature conspires to create the space-time metric structure (Akama and Terazawa, 1983). One can also show that fluctuations of a scalar field make flat space unstable and leads to superheavy bosons of mass commensurate with the Plank mass, $m_p = (\hbar c/G)^{1/2}$ (Padmanabhan, 1983). There are other ways to initiate a cosmic expansion (Novello, 1983) by introducing a scalar field coupled to the metric and examining the behavior of the renormalized gravitational and cosmological constants around the minimum of the field. A cosmic repulsion is generated when the gravitational constant becomes negative, provided the mass of the scalar field is small enough. It is also of interest that torsion (Hehl *et al.*, 1976) is connected with repulsive gravitational effects. Torsion, whose source is related to the spin of fundamental matter sources, could very well be instrumental in initiating the initial flash if fundamental spins are initially aligned. Whatever the true picture, a correct theory of gravity at such enormous densities may look quite different than present-day gravitational theory.

Recent studies (Narlikar, 1979; Padmanabhan, 1983) have dealt with a simplified model of quantum gravity where the conformal factor is quantized. The analysis shows that quantum fiuctuations in the scale factor can prevent a collapse to a singularity. Such results are encouraging, for they intimate that gravitational theory is consistent with quantum mechanics in that unphysical singular points are avoided.

The approach taken in this note is a thermodynamic one. The total entropy of a spin system coupled to the inertia of the primeval fireball is computed. It is shown that the two stationary points are the initial spin-ordered minimum and a final state of high inertia and maximum spin disorder.

Whether spin is the correct dynamical variable or not is really not important. Any double-valued quantum mechanical variable which takes on positive and negative values will suffice. It is not out of the question that this double-valued variable could very well be the source of mass, pairing leading to a zero-mass particle and unpaired states leading to massive states. In this regard, investigations (Adler *et al.*, 1976) have pointed out that gravitation might very well be the result of photon pairing instabilities in a conformally flat spacetime. Such a mechanism would identify the gravitational field with a conventional quantum field in much the same way that Landau-Ginzburg theory describes Cooper pairing of electrons in the theory of superconductivity. Whatever the ultimate source of gravity, a spin system used here represents crudely the ordering of double-valued quantum states. If we think of the Higgs mechanism as an ordering or alignment process in a space occupied by statistical number of Higgs spins, with the gauge field playing the role that the magnetic field does in the theory of paramagnetism, we arrive at an intuitive picture of what these twofold quantum variables might represent.

2. THE ENTROPY OF INERTIA AND SPIN

In what follows, I treat a spin system of elementary spins as distinguishable particles.

The degeneracy function for such a system of $N/2+m$ up spins and $N/2-m$ down spins is

$$g(N, m)=\frac{N!}{(N/2)!(N/2)!}e^{-2m^2/N}, \qquad 1 \ll m \ll N \tag{1}$$

For a particle of mass 10^{54} g, confined to within the Planck length $L=(G\hbar/c^3)^{1/2}\approx 10^{-33}$ cm, we have $E=n^2h^2/8ML^2$. Now $\delta E=h^2 2n\,\delta n/8ML^2$, or

$$\delta n=\frac{1}{2^{1/2}E^{1/2}}\left(\frac{4mL^2}{h^2}\right)^{1/2}\delta E$$

for the number of states between E and $E+\delta E$. We have for the total degeneracy function of spin plus inertia

$$g=\frac{N!}{(N/2)!(N/2)!}\,e^{-2m^2/N}\,\frac{1}{2^{1/2}}\left(\frac{4mL^2}{h^2}\right)^{1/2}E^{-1/2}\,\delta E \tag{2}$$

where $2m$ is the number of up spins minus the number of down spins and E is the energy of inertia of the universe.

Let us assume that the energy of the spin system is $E_s=2m\mu_0$, where we have used the analogy with paramagnetism. Thus, by energy conservation

$$2m\mu_0+E=E_0, \qquad 2m=(E_0-E)/\mu_0 \tag{3}$$

where E_0 is the total energy. Now equation (2) becomes

$$g_{\text{tot}}=\frac{N!}{(N/2)!(N/2)!}\left\{\exp\left[-\frac{2}{N}\left(\frac{E_0-E}{2\mu_0}\right)^2\right]\right\}\frac{1}{2^{1/2}}\left(\frac{4mL^2}{h^2}\right)^{1/2}E^{-1/2}\,\delta E \tag{4}$$

for the total number of microstates consistent with (3).

Taking the log of equation (4), we have

$$\ln g_{\text{tot}}=\ln A+\ln B-\frac{2}{N}\left(\frac{E_0-E}{2\mu_0}\right)^2-\frac{1}{2}\ln E+\ln\delta E \tag{5}$$

where

$$A=\frac{N!}{(N/2)!(N/2)!}, \qquad B=\frac{1}{2^{1/2}}\left(\frac{4mL^2}{h^2}\right)^{1/2}$$

We may neglect $\ln \delta E$, as is common in statistical calculations because we are dealing with a narrow uncertainty of energy. The stationary points of equation (5) are found from

$$\frac{d}{dE}(\ln g)=0, \qquad \frac{2}{N\mu_0}\left(\frac{E_0-E}{2\mu_0}\right)-\frac{1}{2E}=0 \tag{6}$$

Written out, equation (6) reads

$$E^2-E(E_0)+N\mu_0^2/2=0 \tag{7}$$

with solution

$$E_1=\tfrac{1}{2}E_0\pm\tfrac{1}{2}(E_0^2-2N\mu_0^2)^{1/2}$$

Now for $E_0^2> N\mu_0^2$ we have

$$E_1=E_0-\frac{N\mu_0^2}{2E_0}, \qquad E_2=\frac{N\mu_0^2}{2E_0} \tag{8}$$

The second derivative of (6) is

$$\frac{d^2}{dE^2}\ln g=\frac{1}{2E^2}-\frac{1}{N\mu_0^2}$$

For reasonable values of $E_0^2> N\mu_0^2$, μ_0, N we see that E_2 is a local minimum and E_1 is a local maximum of the entropy function. Thus, the spin order would collapse and yield its energy to the inertia of the primal source. This would correspond to the initial expansion, which could either occur before or during the inflation period.

Also note that for the degeneracy function of the inertia of the universe to be considerably larger than 1 we have

$$\left(\frac{4mL^2}{h^2}\right)^{1/2}E^{-1/2}>1 \qquad \text{or} \qquad 10^{42}>E \text{ (ergs)}$$

We can justify the number by assuming that gravity would soon provide a negative energy and allow for the corresponding amount of cosmic kinetic energy that is observed. Perhaps gravity only manifests itself in an attractive sense after $t=10^{-35}$ sec and the spin system we have created is torsional in nature. There are some who believe that the total mass energy of the universe is zero and will remain zero. This is a completely open question and will not be addressed here.

I might also remark that the suggestion (Alvarez and Gavela, 1983) that an entropy increase came from the collapse of dimensions higher than four intimates a mechanism similar to this one, except that in their model entropy flows from the collapsed dimensions to four-dimensional space-time and in this model entropy is generated by increasing spin disorder.

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