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Entropy of the Universe and Standard Cosmology

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Abstract By means of a variant approach to Standard Relativistic Cosmology, we hint that the entropy of the Universe is growing with $t^{3/2}$, where t stands for time-coordinate. Then, the absolute temperature obeys Standard $t^{-1/2}$-dependence. We make contact with our previous paper (Berman, Int. J. Theor. Phys., 2009), in the context of a Machian Universe; but we also consider the dependencies of the scale-factor and energy density, with time, as in Standard treatments.

Keywords Cosmology · Einstein · Universe · Entropy · Temperature

1 Introduction

The purpose of the present paper is to show that the entropy of the Universe grows with time, when we consider a Machian variation of Standard Cosmology. Even though the entropy is not constant, we shall find the correct Standard Cosmology result relating the absolute temperature with the age of the Universe.

In a previous paper [5], we have shown that, in the correct Newtonian limit, Einstein's field equations yield a solution for energy density, cosmic pressure, and, possibly, a time-varying cosmological term, proportional to R^{-2}, where R stands for the radial distance in local Physics, or the scale-factor in cosmological situations. From it, we found a growing entropy in the Universe, scaled as $R^{\frac{3}{2}}$. Though Standard Cosmology [10], introduces constant entropy, we did show that the Universe had an absolute temperature T proportional to $R^{-\frac{1}{2}}$. This was contrary to the Standard Cosmology result, namely $TR =$ constant. Nevertheless, we shall show now, that the time-dependence of T, in our framework, yields the same $t^{-\frac{1}{2}}$ time-dependence as in Standard Cosmology, provided that the Universe is Machian, in the sensethat the scale-factor R be linearly proportional to t. If not, we still show that other results are kept intact.

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2 Time-Dependence of Temperature

Consider Robertson-Walker's Universe, with constant deceleration parameter [1, 6],

$$q \equiv m - 1 \equiv -\frac{\ddot{R}R}{\dot{R}^2} = \frac{\kappa}{6H^2}\sum \rho_i(1 + 3\alpha_i). \tag{1}$$

In the above, we are employing a multi-fluid model, with perfect gas equation of state, where q, ρ_i and α_i represent deceleration parameter, energy density of fluid number i ($i = 1, 2, 3, \ldots$) and $\alpha_i = \text{constant}$.

Now, we define the density parameters,

$$\Omega_i \equiv \frac{\kappa}{3H^2}\rho_i(t). \tag{2}$$

Einstein's field equations, produce the following relation,

$$H^2 = \frac{\kappa}{3}\sum \rho_i. \tag{3}$$

The multi-fluid cosmic pressures, are given by,

$$p_i = \alpha_i \rho_i \quad \text{(no summation)}. \tag{4}$$

From Berman's theory for $q = \text{constant}$, we find:

$$H = \frac{1}{mt} = \frac{1}{(1+q)t} \quad (q \neq -1). \tag{5}$$

The obvious solution for the above equations, with constant density parameters, is,

$$\rho_i = \rho_{i0} t^{-2} \quad (\rho_{i0} = \text{constant}). \tag{6}$$

Notice that we may yet consider a vacuum constant energy density, but may, in many Cosmological theories, be of type (6), i.e., as in [2–4], where, we have $\frac{\Lambda}{\kappa} \propto t^{-2}$.

If solution (6) does apply to radiation, which is black-body's, we find,

$$\rho_{\text{rad}} = \rho_{\text{rad0}} t^{-2} = aT^4, \tag{7}$$

where ρ_{rad0} and a are constants.

We find that,

$$T = \left(\frac{\rho_{\text{rad0}}}{a}\right)^{\frac{1}{4}} t^{-\frac{1}{2}}. \tag{8}$$

Relation (8) is pretty standard [9, 10].

3 Entropy of the Universe—Machian Limit

Now recall our previous paper [5], where the following law had been proposed,

$$\rho_{\text{rad}} \propto R^{-2}, \tag{9}$$

from which we would obtain,

$$T \propto R^{-\frac{1}{2}}. \tag{10}$$

Relations (9) and (10), were based on the Newtonian limit of Einstein's field equations, and, in Sect. 2 above, we were talking of Standard Cosmology. The bridge between both formulations lies in the Machian relation,

$$R \approx ct. \tag{11}$$

In the Machian approach, R stands for the causallyrelated radius, but Berman has long ago stated that the scale-factor could be identified with this radius [5].

We now find the following entropy dependence, through relation (8) [8]:

$$S = S_0 t^{\frac{3}{2}} \quad (S_0 = \text{constant}). \tag{12}$$

Of course, it matches our original result [4, 5]. It is only when we make the Machian hypothesis above (cf. relation (10)), that with find the law (12), because we "escape" from the framework of Standard Relativistic Cosmology, where $RT = \text{constant}$, and, S is also constant.

4 Matching General Relativity

When we turn to the theory of constant deceleration parameters, we find, for each phase of the Universe, the scale-factor,

$$R = (mDt)^{\frac{1}{m}} \quad (D = \text{constant}). \tag{13}$$

When Einstein's field equations are produced, and if we impose relation (6), we find the correct solutions given by Standard Cosmology, i.e., the scale-factor depends on $t^{\frac{2}{3}}$ for matter, and $t^{\frac{1}{2}}$ for radiation. With these results, we find, as usual [7],

$$\rho_{\text{rad}} \propto R^{-4}, \tag{14}$$

and,

$$\rho_{\text{matter}} \propto R^{-3}. \tag{15}$$

Relation (6) is now validated, so now we reached a happy end.

5 Final Comment

We have found that the entropy of the Universe grows with time. This matches our previous paper result [5]. Our happy end resolves once more, one of the crucial problems of Standard Cosmology.

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