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AN ETERNAL UNIVERSE

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ABSTRACT

We present a new generalized solution of Maxwell--Einstein equations (which are non-minimally coupled) which leads to some fascinating aspects of the Universe. The Cosmos has no singularity due to the coupling of longitudinal electromagnetism with space-time. It contains the Milne-Schucking cosmos as a limiting case. Our model contains a free parameter (the longitudinal electromagnetic field) which allows one to fix the density of highest compression of the Cosmos.

Alternativelly the parameter allows one to adjust our cosmos to the presently observed Hubble constant and the deceleration parameter.

The model seems to be a viable candidate for our real cosmos as it allows one to extend the time scale of the Universe to arbitrarily large values i.e., it is able to provide the necessary time scale for the origin of life. We speculate that the entropy is finite but intelligence in the Universe may be infinite.

One of the most profound discoveries of our century is the expansion of the Universe. The standard assumptions of cosmology together with Einstein's classical equations of gravitation applied to the whole universe lead then to a very far reaching prediction about our cosmos: it literally exploded out of a singularity some 10^{10} years ago. The best measurements of the density of matter and radiation in this cosmos lead then to the prediction that the space section is infinite (open cosmos) whereas the lifetime of the cosmos is finite. If anything this seriously spoils the symmetry of space and time.

Ever since the big bang was discovered (by Friedmann, Hubble, Einstein, Gamow and others) people have tried hard to avoid or to discuss away the big bang singularity.

Others have of course hailed the big bang as it provides the ideal testing ground for modern particle theories. Those who fell uncomfortable with a classical singularity have either tried to change the right hand side of Einstein's equation (particle creation)[1] or the left hand side (extremely nonlinear theories)[2].

Until today notably Hoyle has pursued the idea of a stationary universe which, although infinitely expanding, fills the voids constantly by creation of new matter.This steady state cosmology was once very much accepted as it rested on intelligible and beautifully devised philosophical principles. What Killed the steady state theory was the discovery of the 3^{o}K background radiation together with the belief that this 3^{o}K radiation is the relic of a much hotter cosmological epoch, where the element Helium was cooked. Until today however nobody has been able to explain where this $3^{o}K$ background radiation comes from and how it was produced. As a matter of fact one of the magic numbers to be explained in standard cosmology is the ratio of the number of photons to the number of baryons in our universe now (it is of the order of 10^{9}). It is then a matter of taste if one prefers a universe with an initial high specific entropy or a universe where a $3^{o}K$ background radiation is produced (ad hoc) along with matter. In order to arrive at a dimensionless number we may take the rest-mass of an electron as a typical temperature $T_{el} = m_e c^2/k_B \cong 10^{10}\ {}^{o}K$ and we arrive at the same large number $T_{el}/T_{backg.} \sim 10^{9}$ as in standard cosmology.

Both theories will have to explain why Nature choose exactly this number. We are as yet far from such an understanding. Neverthless people have speculated that this large number may be related to the number of cycles of our universe and this leads us to another intringuing question. Is it possible to say something about the universe before the big bang ? Obviously such a question can only be assessed if one is able to remove the singularity in some prescribed physical sense. We pursue here an idea which does exactly this: remove the big bang singularity in a well-prescribed physical way, Keeping as a limiting case the standard cosmology.

To this end and for other reason which we shall explain as we go along, we consider a "photon gas" interacting non-minimally with gravity. For the Lagrangian we choose (see Novello-Salim[3])

(1) $$L = \sqrt{-g}\ [-\tfrac{1}{4} f^{\mu\nu} f_{\mu\nu} + \beta R A_\mu A^\mu + \tfrac{1}{k} R]$$

where $\beta = \pm 1$, k is Einstein's constant $f_{\mu\nu} = A_{\mu,\nu} - A_{\nu,\mu}$.

The field equations are obtained varying $g_{\mu\nu}$ and A_μ independently and they read

$$(2)\qquad (\frac{1}{k} + \beta A^2)(R_{\mu\nu} - \frac{1}{2} Rg_{\mu\nu}) = -E_{\mu\nu} + \beta\Box A^2 g_{\mu\nu} - \beta RA_\mu A_\nu - \beta A^2{}_{,\mu;\nu}$$

and

$$(3)\qquad f^{\mu\nu}{}_{;\nu} = -\beta RA^\mu$$

where

$$E_{\mu\nu} \equiv f_{\mu\alpha} f^\alpha{}_\nu + \frac{1}{4} g_{\mu\nu} f_{\alpha\beta} f^{\alpha\beta}$$

We note that both Einstein's and Maxwell's equations are modified in a fundamental way: the photon gets a rest mass $m \propto R$ and the gravitational constant gets "renormalized" $\frac{1}{k} \rightarrow \frac{1}{k} + \beta A^2$. We note in passing that our choice of the Lagrangian is the only one which does not necessitate the introduction of a new dimensional constant (one can of course consider also powers of $RA^\mu A_\mu$!).

Applying straightforward and well known techniques we construct now a solution to our field equations (2) and (3). We put

$$(4)\qquad ds^2 = g_{\mu\nu} dx^\mu dx^\nu = (cdt)^2 - S^2(t)[d\chi^2 + \sin^2\chi(d\theta^2 + \sin^2\theta d\theta^2)]$$

and seek for a solution with $A_\mu = (A_0(t),0,0,0)$. We find that

$$S(t) = (t^2 + p^2)^{1/2}$$

$$A^2(t) = \frac{1}{k} (1 - \frac{t}{(t^2+p^2)^{1/2}})$$

in which p is a constant.

Re-writting equation (2) in the following way

$$R_{\mu\nu} - \frac{1}{2} Rg_{\mu\nu} = \frac{1}{\gamma} T_{\mu\nu}$$

(where $\gamma \equiv \frac{1}{k} - A^2$, and $\beta = -1$)
we find that e.g. $R_{00} = -\frac{3}{p^2}$ for $t = 0$ i.e. the energy-momentum tensor does not diverge at $t = 0$, the time of the strongest contraction of our cosmos.

What is the interpretation of our solution ?

First of all, we note that we have one extra arbitrary constant which is related either to $q \equiv -\frac{\ddot{S}S}{\dot{S}^2} = -\frac{p^2}{t^2}$ the deceleration parameter or to A^2 at $t = \infty$.

What is the meaning of the photon potential ?

It is trivial to check that the cosmos does not contain free photons i.e., $E_{\mu\nu} = 0$, but neverthless the "longitudinal photon field" curves space-time.

And this leads to a new deep interconnection between electrodynamics and space-time. (Could we think of the unification of gravity with electromagnetism ?). We mention that as a limit $A^2 = 0$ implies $p = 0$ and we end up with flat space-time (in Milne-Schucking coordinates).

For $p \neq 0$ we have, for instance, $R_{AB}R^{AB} \neq 0$ whereas the scalar of curvature R is always zero.

We note that it is not possible to create A_0 without at the same time generating A_1, A_2, A_3 by an external current; so, a non null A_0 is an initial condition (Deus ex machina ?) about spacetime and electromagnetism;it cannot be generated but once there it cannot be destroyed either. A number of questions arise, naturally. What is the present value of A^2, what is its physical significance and what is its influence on our real universe ?

The answer to the first question we have giving already since A^2, i.e., p^2 is related to the deceleration parameter of our actual universe by $q_0 = 1 - \frac{1}{k^2 \gamma_0^2}$.

The answer to the second question is that the longitudinal electromagnetic potential curves spacetime and thereby changes the physics of the Universe; and this brings us to the consideration of the third question.

Applying standard perturbation techniques to our cosmological solution[4] we find that perturbations grow essentially as in standard cosmology (note however that there is no singularity at $t = 0$). As a consequence (see the results of Lifshitz et al.) we have that in the contracting phase ($t < 0$) of our Universe perturbations grow faster than in the expanding phase ($t > 0$), and this leads to a fundamental problem: if relative perturbations $\delta\rho/\rho$ grow like a power of t how can in an eternal universe matter survive and not go into blackholes ?

They only way out of this dilemma of which we are aware is that $\delta\rho/\rho$ itself is statistically related to the density i.e., $\delta\rho/\rho \cong \rho^m$ (for $m > 0$). In this case we find that there is in principle an infinite amount of time to form galaxies, most galaxies are infinitely old: they were pre-formed in the contracting phase and survive in the expanding phase (compression of swiss cheese with subsequent dilatation – the number of holes is preserved in the process).

Let us pause for a moment to see what we have achieved.

We have a universe which is infinitely old, which got compressed to a density ρ_{max} which we can fix arbitrarily and we have avoided the problem of generation of infinite entropy (by relating entropy production to the actual density of the Universe).

In order to reconcile our ideas with Hoyle's[5] about a biological universe of age of $10^{40.000}$ years[*] we need $1/H_0 = (t_0^2 + p^2)/3t_0 = 10^{40.000}$ years , $q_0 = -p^2/t_0^2$, which is obviously possible as long as $q < 0$.

The present uncertainty about q_0 does not rule out negative q's. We further point out positive aspects of our cosmos: it does not have a particle horizon. This is of fundamental importance for the presently observed homogeneity and isotropy of the 3^oK background radiation.

Note that we have not included matter or radiation in our universe and that these are to be considered as perturbations to our cosmos which is predominantly curved by means of scalar photons.

[*]Hoyle does not give a time but a probability $P = 10^{-40.000}$. To transform a probability into a time take any physical process i.e., collisions of particles, choose a typical time for the collision process and multiply by the probability to arrive at $10^{40.000}$ seconds, hours, years or days of Brahma: it does not matter. The error in estimate the time unity is much smaller than the error in estimate the probability. As a matter of fact Yocke[6] estimates this probability to be 10^{-1000} and the true may not even lie in between these numbers.

Two possibilities arise to have a sufficiently old universe: either S_0 is large – which means that the Universe was never very dense and thereby never very hot (this would guarantee biological conditions for all of the cosmic epoch); or $1/H_0$ is very large and S_0 small. In this case biological reactions will only occur (or re-occur) in the late expanding phase and existence of life would only occur at a finite time; whereas in the first case, life could have existed eternally in the universe, leading to the intriguing hypothesis that there may be colonies in the space which are infinitely more intelligent than we are.

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