

Emergence of structure and acceleration in a matter dominated universe: I. Newtonian and Post-Newtonian Treatment

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Abstract

Recent observations suggest: the existence of an apparent acceleration-related cosmological parameter, total density of less than 20density ρ_{crit} , and fluctuations in the cosmic background radiation corresponding with less than $1 : 10^5$. In the model offered here the acceleration is shown to be a necessary result of the most obvious correction to the cosmological principle: the introduction of a locally variable homogeneity/isotropy. Both the reduced density and background fluctuation can be explained in this context. The value for a "cosmological parameter" in the observer's frame is obtained using Newtonian and Post-Newtonian approximations for a locally non-homogeneous universe. Whereas first order backreaction does not exist, second order backreaction can generate enough acceleration to fit the SN1 survey results. Preliminary analysis shows that the correction should also yield this cosmological parameter in the fully relativistic treatment. In contrast with recent suggestions this solution does not require the presence of left-over vacuum energy density (false vacuum), or global non-flat metrics. Tests that may distinguish between the models are also be presented.

1 introduction

In the standard cosmological model the universe is assumed to be spatially homogeneous and isotropic (the cosmological principle, Einstein 1954, Peebles 1998, hereafter P98, and references therein, Turner 1999, here-

after T99). The Friedmann Robertson-Walker (FRW) scenario resulting from these assumptions successfully explains the following observations:

- I. The hubble expansion
 - II. The hot big-bang: the existence of the cosmic background radiation (CBR), and big-bang nucleosynthesis (BBN) products.
 - III. The isotropy of the CBR as observed from earth.
 - IV. The observed isotropy of BBN products.
- (References: P98, T99, Schramm & Turner 1998, hereafter ST98, and references therein).

In the FRW scenario there are several problems. These problems are grouped into three main categories:

Problems of classical geometry:

- i. The Euclidicity problem: Why is the universe so nearly Euclidean?
- ii. The topology problem: Why is the topology of the universe trivial? Why is there no evidence for non-trivial; global topologies, such as toroidal, multiply connected Meisner spaces, worm holes, Klein bottles, and others. For examples, data from gravitational lensing could have, in principle, yielded evidence of non-trivial topological structure — but no obvious ones were ever found.
- iii. The flatness problem (In FRW universes, why is $\Omega \sim 1$?)
- iv. The singularity problem (What are the paths of particles and/or fields at $t \rightarrow 0$? It is not whether there is a singularity, but rather whether there are unique solutions!)

Problems of large numbers:

- v. The total entropy and total mass problem: Why is there so much mass relative to the Planck mass? Given the mass and energy of the universe, why is there so much more entropy than the minimum appropriate entropy? In other words, why is the fermions to bosons ratio such that it necessitates high entropy?
- vi. The Barion assymetry problem: Why is the ratio of Barions to photons $\frac{n_B}{n_\gamma} \sim 10^{-9}$ so small?
- vii. Why is it that at the Planck time the universe is $\sim 10^{29}$ times larger than the Planck size? What is the

source of these large numbers?

Problems of homogeneity and isotropy:

viii. Large scale homogeneity and isotropy: It was suggested that *ab initio* the conditions at points initially far from each other were chaotic and/or uncorrelated. If this was the case the expansion of the universe would have a nearly zero probability of evolving to the relatively homogeneous and isotropic state that it is today. So why is it so isotropic and homogeneous? ix. The horizon problem: In the CBR period there would be $\sim 10^6$ causally disconnected regions. These regions are correlated to within the $1 : 10^{-5}$ temperature range measured in the CBR fluctuations. The probability of such occurrence, assuming vi, is $\sim 10^{-24t_0-30}$, which is exceedingly small.

x. The actual origin of the fluctuations that DO give rise to galaxy formation: What is it? (References: Linde 1990 and references therein. .)

xi. In this paper we are particularly concerned with problems of homogeneity and isotropy (viii-x). We are especially concerned with the observation that the isotropy of the universe (local frame) or "clumpiness" of the universe (global absolute space Newtonian frame) is significantly decreasing. Above all we will try to solve the new observational questions.

New observational questions:

xii. Why is the universe accelerating at the present epoch? How large was its acceleration just after recombination? (Some references give; $H \approx 30$ in CBR fluctuations). Did it accelerate in the radiation dominated era as well?

xiii. Why is it that galaxies and stars seem to form earlier than most dark matter scenarios would allow?

xiv. Why is there so little dark matter, or why is $\rho \sim 0.1 - 0.4\rho_{crit}$ where ρ_{crit} is the critical density. xv.

Why is the fractal dimension of the universe of order 2? Inflationary models of the last 17 years provided for a vacuum energy level that acts as an effective cosmological constant and quantum fluctuations to be

added to the FRW solution. This method helped answer i,iii,xi-x and, to a certain degree v (See: Linde 1990, L90, Turner 1997, T97, and references therein.). It is left to be seen if xiv can be satisfactorily explain with inflation. The problems ii, iv, xii-xiv are not so easy to explain in the traditional inflationary context. For one, assuming non-zero unobservable vacuum energy density to solve xii is somewhat akin to the unobservable fairy responsible for the blooming of roses in a rose garden hypothesis. Also xiii and xiv may place a strong limit on SU5 to SU2XU3 phase transitions because of a limit on the density of non-barionic matter. The inflationary models also raise several additional problems:

xvi. There is already some evidence that simple density fluctuations predicted by simple inflation do not fit the expected scale invariant density perturbations.

xvii. The problem of the (strong or weak) anthropic principle: According to the anthropic principle a small part of the universe in which chaotic inflation occurred is a "chosen" part in which local-entropy-lowering systems (life) had enough time to evolve. That is the reason we live in a low-probability inflated part of the universe. (It should be emphasized that one must use the thermodynamics language only, because our understanding of the biological evolution of introspective intelligence is incomplete.) This assumption is problematic because it cannot yet be scientifically tackled: With 1 out of N systems undergoing inflation, can we show that the probability to create introspective life is exactly 1:N? If the calculated answer is, for example, 3:N, then we live in a universe that was especially selected for us — a result at odds with the scientific principle. If, on the other hand, the answer is exactly 1:N, the principle may be placed on firmer grounds. xviii. Lack of evidence for magnetic monopoles, cosmic strings, domain walls, textures, and global Goldstone effects: It is inconceivable that any of these structures exist in large numbers in the present day universe. Some studies are dedicated to the finding of upper limit on the number of such topological defects. The resulting numbers are very small. Note, however, that such studies are after the fact..

xix. Problems with phenomenological high-energy theories: Several grand-unification schemes in high-energy

physics are consistent with the inflationary scenario, but not necessarily with the observations in I-VI and i-xvii. ;

In the work discussed in this paper inflation is NOT assumed a-priory. CHANGE of homogeneity IS assumed. It is interesting to note that many authors use the change of homogeneity as an observational evidence for the direction of the time arrow, (e.g. Gell-Man and Hartle 1993,) without requiring that the homogeneity requirement of the FRW model be relaxed! The requirement of uniformity is therefore relaxed - but not discarded. Time dependent homogeneity (in a Newtonian absolute space sense) or time dependent isotropy (in an observer mounted frame of reference) is introduced into the "Newtonian cosmology"; equations, then post-Newtonian equations and then a fully relativistic composite metric is discussed. ; The change of homogeneity assumptions are based on the following observations: The level of temperature fluctuations in the CBR on the smallest observable angular scale ($l \sim 100 - 1000$) are of; order of at least 1 in 10^6 . These fluctuations are probably correlated with the underlying density fluctuations. At present the density fluctuations on similar scales are at least $10^{10} : 1$, using a 2D fractal universe (Ref: P98, others???) I am not sure of this last statement. The above ratio is from galaxy-intergalactic ratio). Fluctuations on stellar scales are, off course, of order 10^{23} (stellar density): 10^{-6} (inter galactic density). ;Note that if one assumes that stars formed at $z \sim 8$ (Nature reference 1998), then fluctuations of $1 : 10^6$ in CBR turn into $10^{23} : 1$ at $z \sim 8$. The angular scale of these fluctuations at CBR horizon is of order

$$\delta\theta \sim \left(\frac{\text{Number of stars that formed at } z \sim 8 \times R(t_{CBR})}{R_{t_0}} \right)^{-1} \times \frac{1}{d_L}, \quad (1)$$

where d_L is the distance to the CBR fluctuations. A similar calculation will yield a large change of homogeneity when galaxy formation is concerned (Nature paper on galaxy formation).

In section §2 we introduce the Newtonian variable-isotropy/homogeneity solution and show how xii - xiv

may be reconciled with. In section §3 we present a post-Newtonian solution, and show that our assumptions are consistent with the premises of general relativity. In section §4 we discuss a self-organized criticality model that helps explain the homogeneity of the universe in spite of its changing isotropy. In section §5 we discuss the need for early inflation, and reconsider the possible results for such inflation. In section §6, the last section, we present our conclusions and the unanswered questions