A standard model mechanism for inflation

rbhayes@ncsu.edu, 919-515-2321

North Carolina State University, Nuclear Engineering Department

2500 Stinson Dr, Raleigh NC 27695

Abstract – This brief work tenets that inflationary genesis can be obtained within the standard model based on only a few general assumptions. These are that the origin began at a singularity of Planck length and that all quantum transitions take place within Planck time units. From these, the subsequent effects from the Pauli Exclusion Principle (PEP) and the uncertainty principle can then give rise to an inflationary origin.

Keywords – Pauli Exclusion Principle, Inflation, Standard Model

Introduction

The homogeneity and isotropy of the universe on large scales coupled with flat space-time is evidence for an early inflating universe (Sato and Yokoyama 2015, Uzan 2015). The inflaton (Turok 2002) can appear contrived as a "just so" fitted model that gives the correct result. Alternate models have been proposed by a number of other investigators including the bouncing models (Battefeld and Peter 2015, Lilley and Peter 2015, Qui and Wang 2015), varying the speed of light models (Bessada et al. 2010, Kragh 2006, Moffat 2016) and of course string theory (Alexander 2015, Lidsey et al, 2000). Many other options not fitting in these categories also exist (Creminelli et al. 2010, Das, 2015, Hollands and Wald 2002, Poplawski 2010) but in each case, some attempt to better explain various facets of observation or analysis assumptions are made. There are even models which attempt to simultaneously explain both inflation and dark energy (Capozziello et al. 2006, Hossain et al. 2015, Nojiri and Odintsov 2008). This paper will attempt to derive an inflationary effect from axiomatic principles using only standard model physics coupled with general relativity.

This approach initially requires that reversing universal expansion based only on general relativity drives everything into a singularity when no cosmological constant is present (Ellis 1984). Rather than back extrapolating to a defined state, it is reasonable to make our first assumption of Planck dimensional scales to and assume full quantum realization at this scale as considered elsewhere (Ragazzoni et al. 2003. Boyanovski et al. 2006). Our second assumption is that a quantum transition from one state to another occurs in a Planck time unit. We then accept these results in the first true moment of time with the universe constrained within the Planck length followed by the next instant of Planck having with all fermionic matter being subject to the Pauli Exclusion Principle (PEP).

Once the PEP requirement is enforced at the first moment, the premise of existence requires all fermionic matter to make a spatial quantum transition. The PEP effectively requiring all identical particles with an anti-symmetric wave function to have minimal overlap (so that there is no cancelation which for conserved particles such as leptons), forces them to change energy and or position to satisfy their existence requirement. The highest known packing density for fermions allowing minimal spatial discrimination requires density comparable to that of a neutron star (NS). The principle being that PEP here works locally as a repulsion force between adjacent fermions as presently occurs with valence electrons keeping atoms from overlapping (Kaplan 2006).

Analysis and Results

To derive our specially defined singularity, the FLRW metric given by Carroll et al (1992) as $H^2 = \frac{8\pi G}{3}\rho_M + \frac{\Lambda}{3} - \frac{k}{a^2}$ is considered where we assume *k*=0 and use $H^2 = (\dot{a}/a)^2$. In order to model the initial singularity, we allow the Hubble length *a* to approach zero where the proper time from general relativity $d\tau^2 = dt^2 - dx^2 d\Omega^2$ becomes ill defined. Here, both the spatial component *dx* and the temporal component *dt* approach zero as ρ_M goes to infinity in the limit of τ=0=*a*. Here, we make the assumptions that the singularity existed with a Planck length diameter and that the next change requires a Planck unit of time to be realized. This gives a radius ~1×10^{-35} m (1.6×10^{-35} m/2 = l_p = 0.5 $\hbar\, m_p^{-1}c^{-2}$ using the Planck mass m_p=2.177×10^{-8} kg = $(\hbar\, c/G)^{1/2}$) and subsequent changes then evolve in units of Planck time 5.4×10^{-44} s (l_p/c). After these, standard model (SM) physics alone are assumed.

Expansion Initiation

After the initial Planck time interval at the Planck length, the SM demands all fermionic matter is subject to conservation laws (boson and leptons) while also obeying the Pauli exclusion principle (PEP) due to their antisymmetric wavefunctions. Each fermion (quarks and leptons) then must make a quantum transition to any minimally orthogonal state adjacent to identical fermions. From SM, the nearest neighbor distance is expected to be comparable to that found in a neutron star where the number density is 0.16 fm^{-3} (Lattimer 2012). To attain this density, the spatial distance for nearest neighbors is ≈2×10^{-15} m which when this quantum transition spatial shift occurs in the Planck time, it gives a resultant effective velocity *v*~ 2×10^{-15} m / 5×10^{-44} s ≈ 1×10^{20} *c*.

The resulting kinetic energy *KE* can then be evaluated given that SM imposes conservation of momentum. With the first generation quarks having a bare mass of *m* ≈ 5 MeV/c^2 (Griffiths 1987), the resulting *KE* is then approximated by $\sqrt{p^2c^2 + m^2c^4} - m^2c^4 \approx pc$. Because this is just a quantum transition, the initial momentum is not calculated using γ (although eventually will have to be) such that $p = m_0 v = 10^{22}$

MeV/c. The resulting *KE* per quark is the on the order of 10^{22} MeV demonstrating negligible rest mass of all quark species undergoing this process.

The effective uncertainty principle energy for each fermion in this instant is given by $\Delta E \sim \hbar / \Delta t \approx 7\times10^{-22}$ MeV s / 5×10^{-44} s $\sim\times10^{22}$ MeV. This energy per particle gives rise to the familiar expectation of an effectively equivalent antimatter equilibria with matter in all SM particles.

The essential property being realized by accepting the assumptions up to this point are that the new fermions created from this uncertainty energy then are again subject to PEP causing a subsequent quantum transition in the second Planck time interval. This effectively has now become an unbounded chain reaction of particle creation and expansion. This places us on the familiar initial slope of the inflation era shown on the left of Figure 1. The size required to obtain 60 e-folding's then is only a radius of $\sim l_p \cdot e^{60}$ or just a few nm. With all space up to this point being filled with equivalent uncertainty energy as constrained by the PEP, effective homogeneity is established during the inflationary period.

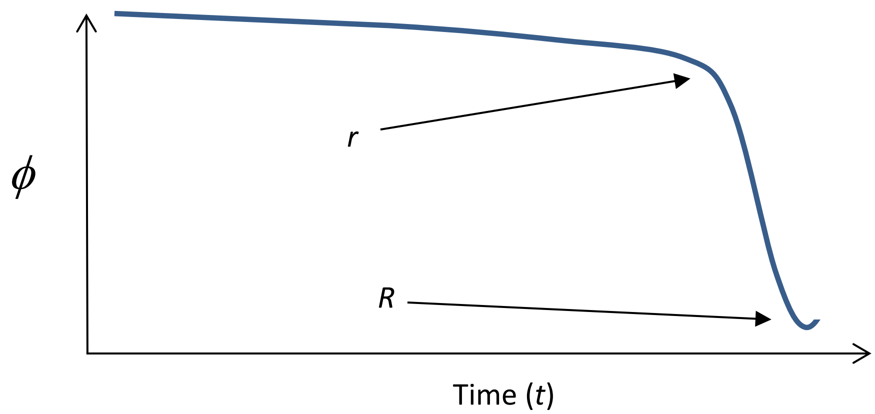

Figure 1. The traditional inflaton field ϕ shown with the superimposed effects from PEP subsequent to the initial singularity. The upward field trajectory after *R* is shown for familiarity.

Reheating

We can now recognize that the chain reaction causing inflation just described will continue unabated until such a time that gravity can start pulling the matter and antimatter back into photons and gluons (bosonic forms). This will occur at some radius of *r* as seen in Figure 1 when the resultant removal of the uncertainty fermions starts to slow the chain reaction as they convert to bosons (and so not subject to PEP). This attenuation of gravity continues until a much larger spherical volume scaled by the radius *R* is obtained having sufficient gravitational strength to effectively combine all antimatter with matter leaving only the residual matter particles we have today (Phillips 2016) as shown in Figure 1. From this, standard BB evolution continues after the initiation event as described elsewhere (Olive 1990).

Standard Newtonian gravity (or FLRW) then can state the spherical size required to give sufficient potential energy to scale with the uncertainty energy. At neutron star density (2.7×10^{17} kg m^{-3}), a sphere of radius 4×10^{10} m (2 light minutes) will then start to have sufficient force to initiate a decrease in the biased rate of the chain reaction due to matter antimatter conversion into bosons. This continues with increasing radius of the distribution until some larger radius *R*, where the gravitational attraction is sufficient to largely convert all matter and antimatter into bosonic forms. At this point, free expansion from momentum conservation is then allowed to evolve accordingly.

Discussion

The rapid "faster than light" expansion process is consistent with a homogeneous distribution, density and subsequent flat space within any horizon as required by current observation (Liddle 2001). Specifically, everything is forced to have the same temperature until sufficiently large spatial scales are reached to attenuate the process. Demonstration that this produces the expected power law for current observational density distributions (Vianna 2001) is left as a prediction of this model pending subsequent simulations sufficient to carry out this task.

Note that the experimental upper limit on the time for a quantum transition has experimentally been shown to only be many 10's of attoseconds (10^{-17} s, Ossiander et al. 2018) so the Planck assumption here is over 20 orders of magnitude smaller simply by assuming the Planck time genesis. Still, the assumptions not being currently validated by experimental measurements are few and do fall within possible limits. These limits also include genesis beginning spatially at the Planck length for all mass and energy (claimed consistent with general relativity). After this, it is simply taken that only standard model physics governed the subsequent evolution through reheating and on to our current expansion state with a formal calculation of *R* still to be done at another time.

Conclusion

By assuming genesis began at the Planck scale and evolved in Planck time units, an inflationary model is obtained based on a chain reaction of uncertainty energy creation of fermionic particles. This requires quantum transitions for fermionic matter not exceeding neutron star densities but making quantum transitions in a single unity of Planck time. The resultant predicted physics evaluated so far appear consistent with current inflationary genesis.

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