Thinking inside the box opens the universe, gravity and cosmology in the light of the SMPP and general relativity

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Abstract. An experimentalist considers how the Standard Model of Particle Physics (SMPP) defines the real space-time of nature in the light of Einstein's General Relativity (EGR). In the discussion observation is preferred over mathematics and care is taken not to introduce other ideas which can only be demonstrated by arguments dependent on those ideas. The main conclusion reached is that the universe has a high probability of being open, a conclusion quite different from current fashionable models, denying both dark energy and the need for inflation. Because an inappropriate mathematical procedure has been followed in formulating dark energy models they should be rejected as unsound. A new procedure is proposed which leads to a simple open cosmology for the present era, one of the two eras suggested in a new "Two Era Cosmology" (TEC). Other parts of the discussion throw light on several aspects of gravity which cause confusion in more mathematical treatments. The paper can be thought of as providing the basis of many research proposals which the author is unable to follow through.

1. Introduction

The essential theme in this paper is that the whole of the natural universe can be modelled using only components of the Standard Model of Particle Physics (SMPP) moving within a four-dimensional space-time. The experimentalist doing the analysis knows that all observations use macroscopic devices and the results of observations can never be exact due to the particle nature of matter. The results are more correctly viewed as being the most likely result but will be affected by fluctuations in the actual value recorded. The experimentalist will observe nature and then pick some mathematics from his library which he finds is most appropriate to model and follow the natural phenomena observed. The direction of the discussion is towards an understanding of the natural universe, that is the real one and not the fashionable mathematically based ones.

Because of the complexity of the real universe all that scientists can do is make models which approximate reality. It is commonly understood that the way to model the universe is to divide the problem into two parts. The first part is to choose a background cosmological metric for the space-time which is smooth throughout space but may develop through time, observation supports Big Bang (BB) cosmologies in which the present state is one of expansion. Within that cosmological framework the next step is to represent the relative motion of the fluctuations in density by using Newtonian gravity and mechanics, a model which it is assumed will be independent of the changing cosmological metric. Newtonian methods are used to calculate the Cosmic Microwave Background Radiation (CMBR) and the fossil record of galaxy formation known as the Baryonic Acoustic Oscillations (BAO), two important
observations used to verify cosmologies.

It is clear that within this context the experimentalist must evaluate the role of Einstein's General Relativity (EGR) and Newtonian gravity. The experimentalist discovers that even for these classic ideas the context of the SMPP can provide illuminative commentary as detailed below. His thinking about all physics is confined within a box containing only the SMPP and observations made using its components.

A stimulus for undertaking this study was an article by Padmanabhan [1] which advocates careful examination of ideas used as premises in building models. The present article takes an extreme experimentalist view of fundamental assumptions with the hope that it will reveal different aspects of gravity and cosmology from the normally very mathematical viewpoint of these subjects.

2. Defining the box

One of the great successes of the twentieth century is the SMPP which encompasses absolutely everything which has been observed in the natural universe, physics, chemistry, and life are all included. All equipment and observations are of and by the components of the SMPP. The SMPP is made from discrete components interacting through quantum processes within a 4D system, all of these things are regarded as within the Box. It is perhaps important to remember that amongst the tools describing quantum phenomena is the vacuum state of turbulent particle hole fluctuations. One phenomenon observed in the Box and which seems to be an addition to the SMPP is EGR. This theory assumes that the 4D system is one in which space-time is curved rather than flat, it assumes that motion is along geodesics of the space-time. This motion within EGR is observationally supported by phenomena such as the Shapiro time delay and the use of GPS systems (so it is encompassed within the SMPP). The phenomena described by traditional Newtonian Mechanics called gravity can be deduced as a weak field approximation by describing the motions using an artificial flat space-time. Notice that although gravity was used to find EGR it should now be regarded as a model approximating Einstein's theory and is not necessarily as fundamental as is frequently supposed.

Everyday observations of the real natural world use large assemblies of particles, explaining the behaviour of such large systems requires the use of the probability ideas of Boltzmann to smooth over the detailed discrete structure and reduce the parameters describing phenomena to only a practical handful (emergent parameters). Einstein understood that relationships between such emergent physical quantities must remain unchanged by coordinate transformations, EGR then demands that these quantities are represented by tensors which transform according to the metric tensor defining the 4D space time.

Notable observations within the Box also include well known astronomical observations such as the Big Bang expansion of the universe, the light element abundances formed in the Big Bang Nucleosynthesis (BBN), the CMBR (which supports both the expansion of the universe and the Cosmological Principle), the BAO and the Hubble relationship which is now demonstrated by high quality supernova Ia data.

Not included in the Box are ideas which can only be said to be observed by using predictions dependent on models featuring the idea. The most notable of these is that the universe should be flat. Such an assumption eased many historical problems in cosmology and became enshrined in folk lore, the subsequent development of inflation reinforced that assumption to such an extent that non-flat universes are sadly but unwisely not considered by mainstream cosmologists.

3. A SMPP constructor kit toy

This toy construction of space-time contains all the information one can ever know about nature's space-time. Construction will start at a primordial boundary positioned so that the SMPP already applies. Scientists seek knowledge of this boundary. Knowledge of the distributions of the density of the SMPP content (necessarily with fluctuations because of the discrete nature of the SMPP) and the space-time curvature which together drive the evolution of the universe from this time forward will provide evidence to assist guessing earlier events.

In the SMPP particles exist in local Minkowski space-time with forward flowing time and are subject
to quantum effects. The particles experience events where they may collide and interchange properties with each other or they may decay. After an event each particle moves through space-time until another event is experienced. The interval between the events is time-like for massive particles, null for photon-like particles but never space-like, the proper time interval is zero or positive, it is invariant for relativistic transformations and can be measured. The intervals can be imagined as being joined together at the events to build an untidy scaffold-like structure, randomising contributions coming from quantum effects and the spatial distribution of particles. Each event occupies three dimensions (think in its centre of mass), one time like and two space-like, but the other end of each of the intervals will be in a different orientation making the whole a four-dimensional space-time. It is only four dimensions by common sense observation (also seen as only four dimensional by a gravitational wave probe [2]). Conservation of energy and momentum applies at each event so the whole structure automatically conserves these properties as time evolves.

The relativity theories of Einstein make the future unobservable because information transmission from beyond the light cone is forbidden. Observers can only know the interior of their past light cones, the next step in time will involve quantum uncertainty along each interval sticking out of the light cone, the future is unknown but the past is known, known absolutely perfectly. Perfectly because different observers must agree about the scaffold like structure in the overlapping regions of their light cones, there is no quantum uncertainty within the light cone (quantum effects are permanently recorded in the distributions of particles within the light cone such as for a Fermi gas of electrons).

Because of the certainty of the past every event marks a point in the real Natural Space-Time (NST), this NST is therefore sampled at discrete points by the observable SMPP. Macroscopic observers can only model the NST by smoothing over many discrete points. Such observers know that the resulting approximation to NST has large scale curvature but that locally the model will be asymptotically flat, these are the properties of space-time known through EGR. Notice that the structure of space-time, despite local flatness, must be extraordinarily curvy, every grain of dust has its own gravitational field extending outwards. A curviness totally unlike most mathematical considerations of the curvature of space-time.

4. Comments on Einstein's equation

The properties of the 4D space-time in EGR are given at each point by Einstein's Equation which in a co-ordinate free notation using SI units is:

\[ G = \left(8\pi G/c^4\right)T. \]  

This shows the relationship between the Einstein curvature tensor \( G \), representing the strain on space-time, and the mass-energy-momentum tensor \( T \), representing the stress on space-time, see e.g. Meisner, Thorne and Wheeler [3]. Here \( c \) is the velocity of light and the new fundamental constant \( G \) is introduced to match the units on the two sides of the equation, it is known to be Newton's constant from the origins of Einstein's theory.

Several ideas are worth noting. The first is that this equation represents ten non-linear simultaneous differential equations for components of the metric tensor. Even with zero stress \( T \) the non-linearity allows remote sources to strain the scaffold like structure and curvature can be present due to these remote sources. Secondly the mass-energy-momentum tensor \( T \) is a thermodynamic density, it is entirely constructed from properties of discrete components of the SMPP which have been excited out of the vacuum. This point of view shows \( T \) as the local intensity of vacuum excitation and it has an emergent character. A third comment on \( T \) is that it contains all the energy-momentum of the SMPP scaffold-like structure (a conservator of energy-momentum). When a space-time system is used to describe the relative positions of the points of the SMPP toy there is no physics involved, it is only the application of a mathematical representation, there can be no energy associated with the curved nature of the space-time. The curved nature must already be present in the distribution of the events. This leads to a fourth comment which is that in Chapter 17 of Meisner, Thorne and Wheeler [3] where they cite six
routes for guessing Einstein's equation only the first route has a good physical pedigree. The other routes should be ignored on the basis that they use a Lagrangian which implies that curvature stores energy, or they might be entirely just mathematics. This first method relies on the properties of the physical stress tensor $T$ (conservation of energy-momentum) being matched in mathematical space-time geometry only by the Einstein curvature tensor $G$, the physics drives a sensible choice of the mathematics.

The Einstein equation represents the flow and balance between stress and strain of space-time as time advances. It is a non-linear system of differential equations which operates at every point in space-time and its solution must encompass the whole of space-time and its contents, knowing the input boundary conditions for some early time allows the prediction of the whole of the future structure of stress and strain. Such a solution is clearly beyond any present or future human efforts. Making the assumption that the equation is a correct description of nature implies that nature knows the solution, this should provide powerful guidance, studying nature describes the solution. Nature's solution to Einstein's equation will be a close non-microscopic approximation to the concept NST formed by the SMPP toy. Because this solution is about real physical nature and encompasses the whole universe there is only this one solution, call it Nature's Unique Solution to Einstein's Equation (NUSEE), notice that it is the best approximation to NST that is consistent with EGR and that it can be observed.

The concept that this solution, NUSEE, is unique shows that the flow of energy and momentum is completely determined from the primordial boundary through to the future. The future is uncertain only because quantum processes at the apex of light cones randomise the sharing of energy and momentum amongst the available energy states at that point, the quantum process does not affect the flow of stress. Quantum uncertainty occurs at each event, between events the quantum state of a particle's motion occupies a finite volume of phase space. The transformation property of such phase space volumes between different coordinate systems in EGR is invariance so the quantum phenomena are the same whatever the coordinate system. The motional state occupied by a long-lived photon will be in a cell with curved space-time (observed as red shift for a CMBR photon or delay for a photon in a Shapiro delay experiment). For such a single particle the space is empty, no local stress, the curvature is entirely due to all the rest of the universe within the light cone. Quantum phenomena, by choosing stationary action, select the geodesic as the path to follow. For quantum phenomena to have any effect on Einstein's equations new concepts outside the SMPP would have to be present, there is absolutely no observation or realistic gedanken experiment which demands such inventions known at this time. Quantum gravity and quantum cosmology may be only pure mathematics.

This paper does not address the reason why space-time is curved, it simply acknowledges that such a description fits currently known facts. That the strength of the curvature, the strain, depends on the density of rods in the scaffold toy makes sense but the actual relationship of Einstein's equation has not been deduced, it is an observed fact.

5. Comments about gravity
Starting from SMPP and EGR, without any mention of gravity, the reference frame of nature is NUSEE. This frame is obviously so convoluted as to be irrevocably impossible to use. Introduction of any practical reference frame, even though a transformation to NUSEE is theoretically possible, will necessarily introduce artefacts, apparent physical objects, to represent all of the neglected features of NUSEE.

Imagine being a spaceman suddenly stranded above some point on Earth so that you fall straight down, you choose a frame of reference fixed relative to your body, what you observe is the massive Earth accelerating towards you. You seem to have discovered that nature provides a system which has lots of energy to accelerate the Earth towards you. This energy has got to be an artefact of your choice of reference frame because you know that the SMPP toy contains all the energy and momentum of the observable universe in the particle motion between events and that these quantities are conserved as time flows, there is no true energy available for this gravitational acceleration.

Moving your viewpoint to a new reference frame fixed to the Earth makes the acceleration seem a normal experience but this new frame also carries artefacts with it. These artefacts are the well-known
ones of centrifugal force and Coriolis force as well as Newtonian gravity. The gravitational potential energy so well known in Newtonian mechanics is a part of this structure of artefacts designed to make the NUSEE effects understandable in the context of a practical reference frame. Searching for gravity and the energies associated with it in Einstein's General Theory of Relativity will be fruitless since these "properties" of nature are artefacts of the observer's methods.

The energy needed to detect gravitational wave ripples in space-time by LIGO [4] and the energy required to radiate such ripples [5] will also be artefacts of the co-ordinate frame used to calculate such effects. The component parts of the detectors flow along their geodesic in NUSEE so that when you choose a reference frame without those ripples an energy representing responses to those ripples appears, dependent on the chosen reference frame and detectable in the laboratory. The computational calculations for such gravitational wave phenomena are unaffected by the change in viewpoint.

Most reference frames in common use (the Earth, the Solar system, the Galaxy and galaxy clusters) have the artefact of Newtonian mechanics which describes phenomena of interest with adequate accuracy. Departures from Newtonian mechanics are found in terms of particle motion (GPS satellite motion, the Shapiro time delay and Mercury's orbit) where small corrections to the Newtonian approximation are calculated using Post Newtonian methods allowing for curvature. Computational calculations are unaffected by the different viewpoint described above. Such departures were of course essential in Einstein's development of his General Relativity and provide the experimental proof of the curvature of space-time.

6. Comments on entropic forces

There is a movement towards concepts which imagine that gravitational effects may find an explanation through thermodynamic type relationships [6]. In that case choosing the most probable configurations using Boltzmann's ideas implies that an entropy should be associated with such ideas. Intrinsic to such methods is the ability to select ensembles which are subsets of the contents of the light cone on which probability calculations may be made, but note that curvature can be present because of remote sources and it is hard to define such ensembles. Verlinde [7] proposes that gravity is an entropic force where the mechanism depends on drawing entropy from some inexhaustible source such as a heat bath, he comments that such a force is not associated with a real potential energy. From other considerations he finds an entropy change $\Delta S$ as a particle of mass $m$ moves a distance $\Delta x$ which is:

$$\hbar \Delta S = 2\pi k_B m c \Delta x.$$  \hspace{1cm} (2)

A proposition by Xiong [8] that the particles of the SMPP when they move cause an entropy change related to the properties of the strongly coupled vacuum (the heat bath) leads to the same relationship. Both authors are then able to use the entropic force concept in a reference frame where the small system considered is non-relativistic to derive the Law of Inertia, Newton's Law of gravity and the equivalence of gravitational mass and inertial mass. They point out that such a result should be expected because of the input of ideas into EGR. Nevertheless, it is interesting that just taking SMPP with EGR (not including its derivation) and the entropy source of Xiong applied to two isolated non-relativistic objects produces Newtonian mechanics. A result in good accord with the viewpoint of this article (think of the entropy density of the vacuum excitations in the same spirit as $T$ the energy-momentum density).

7. Solutions in empty space

The reference frame used in cosmology needs special attention but before moving on to that subject it is worth examining some mathematical solutions to Einstein's equations, they are not nature but can guide the interpretation of nature. This section is dependent on the searches by Vishwakarma for a meaning to the term "gravitational energy" [9] and for connections to Mach's Principle [10]. It is clear from the discussions above that the NUSEE concept connected to the SMPP toy embodies Mach's Principle completely.
In empty space the stress tensor is zero so Einstein's equation simplifies to $G = 0$, or $R = 0$ where $R$ is the Ricci tensor. The best-known solution to these equations is probably the Schwarzschild solution for spherical symmetry (one isolated mass). Other solutions are detailed by Vishwakarma [9], these show the gravitational effect at some point in empty space due to remote densities of energy, momentum and angular momentum. The curvature of empty space can carry gravitational information from all kinds of stress positioned anywhere in the cosmos and presumably, with clever mathematics, they could be combined to give the curvature of empty space-time everywhere.

The extreme example of finding the curvature at any point in empty space due to every source in the cosmos cannot be found simply by combining components (because of the non-linearity). There is however a special solution [9] if additionally, the Cosmological Principle is adopted, this is a symmetry condition that the universe is the same everywhere. This cosmological model solution for emptiness is well known but mostly ignored, it is the simplest Friedmann solution promoted briefly to prominence by Milne [11] in 1935. The hyperbolic geometry of this solution has an even longer history dating from the birth of curved geometry in about 1835 with its discoverer Lobachevsky.

8. Introducing cosmology

Normal treatments of the relative motions of planets, stars, galaxies and galaxy clusters begin by choosing a background simple metric. This approximation to NUSEE allows the treatment to proceed in complicated situations by using the artificial gravitational potential and Newtonian mechanics to describe the relative motions of bodies of matter. For the largest scale systems an ordinary flat metric reference background is not enough, the expansion of the universe must be described and this is done by using an expanding background metric, it is then assumed that Newtonian gravity and mechanics can be used when describing relative motions of objects.

The existence and properties of the CMBR confirms belief in the Cosmological Principle. This Principle is that the properties of the universe are uniform. At its discovery the fact that the temperature of the radiation varied in such a way as to be able to select a reference frame at rest with respect to the universe was a surprise in the context of special relativity, but in the present context is even more interesting. This "stationary" frame is valuable because it provides a frame very close to one at rest with respect to the SMPP toy model and NUSEE.

The assumption of uniformity allows a good mathematical solution to Einstein's equations to be made when the universe is not empty, a fact well known for 90 years but at that time without the modern observational support. The isotropic Friedmann–Lemaître–Robertson–Walker (FLRW) metric appropriate for an entire uniform universe is a natural rest frame for the CMBR, it has two parameters. The first is the overall curvature $k$ while the second is the scale factor $a(t)$ which varies with time. The overall curvature $k$ is the concept which determines whether the universe is spherical (closed, $k = +1$), flat ($k = 0$) or hyperbolic (open, $k = -1$), it has the same value throughout all of space-time no matter what else changes (it could only change if the whole universe were at a point enabling instant communication between all parts). If $k$ can be determined for any small part of space-time then it is known universally throughout space-time. A simple example of such a metric is that of Milne, it has $k = -1$ and $a(t) = ct$ where it is easy to see that the universe is expanding, in this case with the galaxies coasting apart, and which produces a product $HA = 1$ of Hubble's constant $H$ with the apparent age $A$ of the universe (both calculated from the function $a(t)$).

The Einstein equation with the stress tensor being made of uniform densities implies uniformity of the solution, the stress tensor in fact depends on the thermodynamic properties of the universe's content. Historically the first solution by Friedmann filled space with ordinary non-relativistic matter, called dust. The low momentum content of dust means that its pressure is zero. These solutions for dust are of only minor interest for present day purposes. It is now known that the solution for a radiation filled universe is a real example of a Friedmann universe where the stress due to particles with $E = pc$ dominates completely, this is the radiation era of the BB which lasts for a long time. The significant pressure of the radiation produces the product $HA = \frac{1}{2}$, but the expansion is insensitive to $k$, so that that parameter cannot be observed. This prediction for the rate of expansion of the radiation era is confirmed by
modelling nuclear reactions and light element production as the temperature of the BB falls through the 1MeV region. It is worth noticing that this is the only observation capable of supporting Einstein's source term in his equation, the local stress density being dominant in controlling the local expansion rate. Observations of light element abundances confirm that the idea successfully passes the test (see e.g. Steigman [12]).

The reference frame selected by the Friedmann radiation era model of cosmology has clearly generated a metric solution of of Einstein's equation which is a close representation of NUSEE. This is supported by the CMBR observations, the difference is that NUSEE contains the CMBR fluctuations but the Friedmann solution does not. The flow of matter along the geodesics of NUSEE when seen from the radiation era frame are modelled as if the matter moves about under the influence of the Newtonian gravity potential of the fluctuations (remembering that Newtonian mechanics is an artefact of the frame). It is seen that the actual mathematical calculations used to follow the development of the fluctuations will not be affected by the different viewpoint presented here.

9. Uniform models fail for later times
It is a feature of the Friedmann models of an expanding universe that the temperature falls with time. The CMBR is released when the temperature falls below the decoupling energy of electrons and protons so that the universe becomes transparent and the radiation mixing of energy amongst the particles becomes inefficient. The fluctuations will then grow and the fundamental assumption of the model, that the stuff is uniformly spread, is destroyed. However, if it is still possible to model the universe's expansion by using a FLRW metric (specifically how $a(t)$ varies with time) then Newtonian mechanics can be used to follow the fluctuations through to the formation of galaxies, a process which leaves behind some fossil evidence in the form of the BAO.

There are many calculations in the literature which attempt the simultaneous fitting of the CMBR and the BAO data by modelling $a(t)$. These generally assume a dark energy model and a high degree of sophistication is often attempted in which even the equation of state of the dark energy is parametrised (this whole procedure is criticised in the next paragraph). No notice is ever taken of the fact that the models assume in the first place that matter is uniformly distributed but the model predicts total failure of that idea, the matter falls into galaxy structures which are taken as valid output predictions. The whole concept used in dark energy models is, thus, logically unsound – its output does not match the input criteria. This is probably caused by the fact that dark energy models use an incorrect mathematical procedure. These models average the source density before solving the non-linear equations, these procedures do not commute (see e.g. p452 of Padmanabhan's textbook [13]) and have been evaluated in the incorrect order.

This mathematical error causes all dark energy models to represent the background metric of the present day by two fluids, a dark energy fluid and a dust fluid, although it is not the same as Friedmann's dust. Friedmann's dust behaves like matter in its interactions with gravity. This new kind of dust has weird gravitational properties, it slows the expansion of the universe through its gravitational attraction but at the same time it does not respond to the gravitational attraction of the true ordinary matter content which should move it into the galaxy structures. This new dust is as strange a fluid as the dark energy fluid but somehow its improbable nature never enters the fitting procedures of dark energy cosmologies. Methods have been attempted to deal with the difficulty of discovering how matter in galaxies affects the universe's expansion. Backreaction [14] fails to address the incorrect order of the calculations by only modelling modifications to the smoothing procedure before solving the equations. Another system, the timescape cosmology discussed by Wiltshire [15], partially addresses using nature's observed density structure to calculate effects after nature solves Einstein's equation but still incorporates the new dust.

10. The Milne-like reference frame
The best background metric to model the present-day universe is clearly shown by nature through use of NUSEE. There are two undisputed astronomical observations, the emptiness of space and the CMBR confirmation of the Cosmological Principle, which select uniquely consideration of a Milne-like
reference frame as a smooth background Friedmann model for the present-day era of cosmology. The concept of emptiness here is easily demonstrated by consideration of the apparent size of the nearest galaxy like the Milky Way. The angular diameter of the Andromeda galaxy can be verified with binoculars as about 0.01 radians (Moon sized). This means that for every volume of space containing a galaxy there are at least one million empty regions, one million to one are odds near the particle physics community's definition of a 'discovery'. One million regions where the Milne metric will be a good background metric while in the one other the matter is concentrated and cannot cause any uniform contribution to the curvature of the cosmos. Perhaps this is a Boltzmann type of argument, the most likely behaviour must be the one which is seen. The metric at any point is represented by the Milne-like background with all the local Newtonian potentials superimposed, this combination must control the motion of matter. The metric in free space is not uniform, only the background metric is uniform.

A new model for evaluation of $a(t)$ is proposed, the Two Era Cosmology (TEC). In this TEC the matter density contribution towards slowing the expansion of the universe is chosen to be the mode of the distribution rather than the average. The mode is chosen because it is the most probable and then the Boltzmann type of argument can be used. The mode density starts in the radiation era by being identical to the average but as matter groups into galaxies it will decrease smoothly and quickly settles near zero, the value which gives a Milne-like cosmology for the present era.

The universe's development is thus modelled as an early radiation era with $H\alpha = \frac{1}{2}$ followed by a later Milne-like era with $H\alpha = 1$. The transition between the two eras starts with a change from domination by radiation to a short period where matter dominates, a Friedmann model with $H\alpha$ at a value above $2/3$ (not enough matter to make a flat universe), followed quickly by the mass flowing from its role influencing cosmic expansion to one where it is concentrated in galaxies and does not influence cosmic expansion. The value of $H\alpha$ finally increasing to its empty space value $H\alpha = 1$.

There are no known observations which contradict this scenario, the SN1a data are well fitted (Vishwakarma [9]) and the age predicted (using $H\alpha = 1$) is greater than that in simple dark energy models, something favoured (Avelino and Kirshner [16]) by model independent data for Hubble's constant and the oldest stars.

This TEC scenario offers a better framework than the dark energy models do for calculations to predict the CMBR and BAO expected from a given primordial fluctuation distribution of densities. The TEC does not contain the error made in averaging before solving non-linear equations whilst equally well matching model independent data and it does not introduce imagined constituents. Such calculations will be remarkably similar to the dark energy ones since exactly the same physics will be used and there are only small differences in the cosmic expansion rates. The transition from the radiation era is achieved in a parameter independent way by using the mode of the density distribution of the fluctuations which will be followed through the calculations. No extra parameters will be introduced by adopting this concept. The parameters used during the fitting would have clear physical meaning, the initial density fluctuation distribution, today's value of Hubble's constant, the ordinary mass density and perhaps a dark matter fraction.

This dark matter concept has not been discussed above. There is some evidence of something else influencing the motion of galaxies which has been modelled in several ways. One is dark matter but another way invokes a modification of Newtonian gravity (MOND). A new artefact simulating MOND may well appear when it is noticed that a flat reference frame is adopted to calculate the motion in galaxies whereas the NUSEE frame has a Milne-like background metric with hyperbolic space sections rather than flat. A TEC fit of the CMBR and the BAO data offers the chance to evaluate how much dark matter is needed in addition to ordinary baryonic matter in modelling cosmology, this would be independent of estimation of that parameter from galactic kinematics. The observation of objects like the Bullet cluster [17] may indicate dark matter as the better option, if that is so then the possibility that dark matter is primordial black holes (Dolgov [18]) would be a comfortable idea within SMPP.

The author has not time nor enough energy available to acquire the skills necessary for the tasks described above and they must be left to others.
11. Summary of conclusions
The different perspective used in this study based just on the SMPP and EGR through NUSEE has lead to the conclusion that the only Friedmann model of the background expansion of the cosmos which satisfactorily represents observed reality without any additional assumptions is open with $k = -1$. Such a conclusion should have profound and widespread implications throughout physics and astronomy, including particularly a denial both of the dark energy concept and the need for inflation.

The different perspective also helps to understand the realms and roles of concepts in Einstein's equation and quantum phenomena. The only region where both operate is on the surface of the light cone. Einstein's equation guides the flow of macroscopic measures of stress through the light cone into the future conserving energy and momentum. Quantum processes acting microscopically randomise the way in which energy and momentum are distributed amongst the available quantum states on the light cone, also conserving energy and momentum. These two roles are quite separate. It seems that no extra assumptions beyond those of EGR and the SMPP are required to describe natural phenomena.

The toy model used in this study suggests that the particle content of the light cone may cause the curvature of space-time. It also shows that Mach's Principle really is incorporated within Einstein's theory, it is clear that the unique solution NUSEE embodying the whole of the light cone content in the whole of the solution within the light cone is exactly Mach's Principle.

The approximations which are inadvertently made when a reference frame is chosen cause phenomena to appear which are artefacts of the choice. The most important of these artefacts is Newtonian mechanics including gravity. In particular gravitational potential energy is such an artefact, there is no reason to include gravitational energy in the true natural stress tensor. In practice Newtonian mechanics and gravity is confined to describing the mutual interactions of the density fluctuations which must exist in a universe made of particles.

A final comment on the connection of particles to the vacuum as proposed by Xiong [8] is that his entropy is an intensive property of the vacuum implying that it is the thermodynamics of the vacuum which governs the structure of space-time. The SMPP vacuum is thought to be a many particle system (at the Planck temperature, Xiong [8]) so intensive properties such as its stress ($T$) can be expected. This would suggest that even when the particle density is near zero the stress would still be a properly defined emergent property because it is not the observable particles which define it but the hidden properties of the many particle vacuum. Because vacuum will be the same everywhere the Cosmological Principle would be expected because of the huge uniform Planck temperature.

Perhaps a coffee break discussion could take in the idea that if all the intervals in the SMPP toy were truly relativistic in the sense that there is no rest mass then all intervals are null like that of photons, the entire SMPP toy would reduce to a point. Rest mass causes time to flow?

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