1

A Universe without Inflation

(A model of Time)

Salim Yasmineh

Mail: sayasmineh@gmail.com

Abstract

The inflationary model explains the current observational situation that seems to indicate that the Universe is spatially flat, homogeneous and isotropic. This paper proposes a different scenario that introduces a new model of time for explaining these features of the Universe as well as a new interpretation of some quantum features.

Key words: inflation, time-asymmetry and past hypothesis.

1. Introduction

The standard big bang theory explains the expansion of the Universe, the spectrum of the cosmic microwave background radiation as well as plenty other observations. However, it leaves some questions unanswered and seems to demand very carefully chosen initial conditions [1]. Indeed, the current observational situation seems to indicate that the Universe is far more spatially flat, isotropic and homogeneous on large scales, than can be explained by an initial explosion. In particular, the observations of the cosmic background radiation show that the temperature of the early Universe was extremely uniform. This feature, known as the horizon problem cannot be accounted for by the standard big bang theory. Another special feature, known as the flatness problem requires from the big bang to specify the mass density of the early Universe with extreme precision [2]. These initial conditions were explained by Guth [3] by an inflation phenomenon at the early stage of the Universe. This inflationary scenario provides a dynamical mechanism that explains the evolution of the early Universe towards flatness, homogeneity and isotropy.

In this paper, we propose an alternative model or at least an alternative scenario explaining these seemingly special initial conditions of the Universe. We use similar arguments as the inflation model but instead of inflating space we propose to “inflate” time. The proposed expansion of time at the early stage of the Universe explains equally well the flatness problem, the horizon problem as well as many others but leads to a reassessment of the actual standard model of evolution.

2. Real-time-line

In order to introduce an “expansion” of time we propose to describe time (that we shall call real-time t_r) as evolving in a two-dimensional vector space. The real-time can be defined in a reference frame consisting of a two-dimensional coordinate system (for example a Cartesian coordinate system) with horizontal and vertical coordinate axis. The horizontal coordinate axis is a first time axis that we shall call physical-time axis t and the vertical coordinate axis is a second time axis that we shall call creation-time axis t_c (or entropy-time axis). We note that the physical-time axis t is the usual time axis defined by the actual laws of nature. The creation-time axis t_c will be defined in section 4. Any real-time instant t_r can thus be defined by an ordered pair of physical-time t and creation-time t_c coordinates represented by the couple $t_r = (t, t_c)$. A set of points in this two-dimensional coordinate system forms a trajectory-like line which we shall call a real-time-line t_r. An element of the real-time-line is simply defined by the following metric:

$$dt_r{}^2 = \delta_{ij} dt^i dt_c^j = dt^2 + dt_c{}^2 \qquad (1)$$

3. Spatially flat, homogeneous and isotropic Universe

We use the approach explained by Carrol [4] to derive an appropriate metric that takes into consideration the real-time-line introduced in section 1. A spatially homogenous and isotropic Universe evolving within a real-time-line can be represented at each point of the real-time-line by spacelike three-dimensional slices such that each slice is maximally symmetric. We thus consider spacetime to be $\boldsymbol{R^2\Sigma}$ where $\boldsymbol{R^2}$ represents a two-dimensional time metric and $\boldsymbol{\Sigma}$ is a maximally symmetric three-dimensional space metric. The five-dimensional spacetime can thus be expressed by the following sort of Robertson-Walker metric:

$$ds^2 = -dt_r^2 + a^2(t_r) d\sigma^2 \qquad (2)$$

where t_r is the real-time-line, $a(t_r)$ is a dimensionless scale factor and $d\sigma^2$ is the metric on $\boldsymbol{\Sigma}$.

In order to simplify the above five-dimensional spacetime metric (2), we propose to introduce an initial era in the evolution of the Universe that we shall call a creation-era and analyze the features of the pacetime metric inside and outside this creation-era. In conformity with the present observations of a spatially homogenous and isotropic Universe, we presume that the schematic behavior of the real-time-line is different inside than outside the creation-era. Outside the creation-era, the real-time-line should almost be confused with the physical-time axis as the fundamental laws of physics governed by physical time seems to work pretty well. On the other hand, by using similar arguments as those used by the inflation model, we postulate that inside the creation-era, the real-time-line should be “swollen” along its creation-time axis.

Indeed, we schematically presume that at the “beginning” of the creation-era, the real-time-line t_r evolves exclusively along the direction of the creation-time t_r axis. Each point t_r can thus be defined by $t_r = (0, t_c)$ or probably by $t_r = (\varepsilon, t_c)$ where ε is a physical-time coordinate expressing an unstable fluctuation along the physical-time axis, less or equal than Plank’s time. We also presume that each spontaneous break-up of symmetry may have been probably accompanied by a corresponding directional-variation of the real-time-line (i.e., a sort of an inflexion or discontinuity in the relation between the creation time t_c and the physical time t). In order to explain the current observational flatness and horizon constraints of the Universe, we presume that between at least two breaking-ups of symmetry, the projection of the real-time-line t_r on the creation-time axis had an exponential form with respect to that on the physical-time axis.

This “beginning” can be explained by a plausible scenario where the physical-time component ε of the real-time-line t_r kept fluctuating between $t = 0$ and $t{\sim}10^{-43}s$ (Planck’s time) until a first spontaneous breaking-up of symmetry (may be at $t \sim 10^{-43} s$) had generated a differentiation between gravity and the other fundamental forces that sparked a slow directional deviation of the real-time-line t_r. The slow deviation can be translated by considering an exponential growth of the creation-time component with respect to that of the physical-time component.

Triggered by a final breaking-up of symmetry, the direction of the real-time-line t_r was severely deviated such that the projection of the real-time-line t_r on the physical-time axis started to become exponentially bigger than that on the creation-time axis. The rapid deviation can be translated by a logarithmic evolution of the creation-time component with respect to that of the physical-time**.**

In view of the above, and taking in mind that we are familiar with the physical-time axis, the creation-time component t_c of the real-time line t_r may very schematically be expressed in function of the physical-time component t according to the following relation:

$$t_r \propto \begin{cases} (0,\ t_c) & t_c < 0 \\ \left(t,\ b(e^{t/\tau} - 1)\right) & 0 < t < \tau \\ \left(t,\ b\left(ln\left(t/\tau\right) + e - 1\right)\right) & t \geq \tau \end{cases} \qquad (3)$$

where τ represents the physical-time coordinate of the real-time-line t_r at the creation-era boundary that may correspond to the symmetry break-up that separated off the electromagnetic and weak forces (i.e. around $\tau \sim 10^{-32} s$) and b is just a multiplicative constant that has the dimension of time. It should be noted that the above relation (3) depicted in Fig. 1 is illustrative, as the range of possible relations of a "time-expansion" scenario inside the creation-era is very large.

For $t < \tau$ (i.e. inside the creation-era), the physical-time component t is either equals to zero or is very small compared to the creation-time component t_c and thus, during that era, the physical-time component t can be neglected and the real-time-line t_r can simply be approximated by its projection on the creation-time axis (i.e. $t_r \sim t_c \propto e^{t/\tau} - 1$) as shown in Fig. 2. Note that unlike the physical-time component t who had a starting instant ($t = 0$), the creation-time component does not necessarily need to have one. In that case, the real-time-line t_r may have had an infinite past along the creation axis and the physical-time component would have only been created at a first breaking-up of symmetry. (As a variant, both components t and t_c may have been created simultaneously and in that case, the first line of the relation (3) should be omitted).

For $t \geq \tau$, (i.e. outside the creation-era), the projection of the real-time line t_r on the creation-time axis t_c is very small compared to that on the physical-time axis t and can thus be neglected. The real-time-line t_r can simply be approximated by its projection on the physical-time axis (i.e. $t_r \sim t$). Thus, outside the creation-era the real-time-line t_r behaves almost as the familiar physical time as shown in Fig. 2.

To resume, we can thus postulate that outside the creation-era the real-time-line is physical-dominated and evolves asymptotically along the physical-time axis whereas, inside the creation-era, it is creation-dominated and evolves asymptotically along the creation-time axis. However, for a more accurate model both components of time should be taken into consideration. Nevertheless, as a first approximation, we can simply consider that outside the creation-era ($t \geq \tau$), the real-time-line is a one-dimensional time defined by the physical-time axis (i.e. $t_r \sim t$) and that inside the creation-era ($t < \tau$), the real-time-line is also a one-dimensional time defined by the creation-time axis given in function of the physical-time coordinates (i.e. $t_r \sim t_c \propto e^{t/\tau} - 1$). Thus, spacetime can be simply expressed by two separate four-dimensional manifolds $\boldsymbol{R\Sigma}$ according for example the following Robertson-Walker metrics:

$$ds^2 = -dt_c^2 + a^2(t_c)d\sigma^2 \text{ for } t < \tau \qquad (4a)$$

$$ds^2 = -dt^2 + a^2(t)d\sigma^2 \text{ for } t \geq \tau \qquad (4b)$$

Each one of the above metrics obey the following Friedmann equations:

$$H^2 = \frac{8\pi G}{3}\rho - \frac{k}{a^2} \qquad (5a)$$

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3p) \qquad (5b)$$

where a is the scale factor that stands for either $a(t_c)$ or $a(t)$, H is the Hubble parameter, G is the gravitational constant, ρ is the energy density, k is the spatial curvature, and p is the pressure. Friedmann equation (5a) can be written in the form:

$$|\Omega - 1| = \frac{|k|}{a^2H^2} \qquad (5c)$$

where Ω is the density parameter measuring the ratio between the density and the critical density. A flat space is represented by $\Omega = 1$ [1,4].

4. Inside and outside the creation-era

Outside the creation era ($t \geq \tau$), the real-time-line t_r is approximated by the conventional physical-time axis t and thus the scale factor $a(t)$ corresponds to that of the standard (non-inflationary) evolution.

However, inside the creation era ($t < \tau$), the real-time-line t_r is approximated by its projection on the creation-time axis $t_r \sim t_c \propto e^{t/\tau} - 1$ indicating a time "inflation" with respect to physical-time axis t. The real time spent by the early Universe inside the creation-era is tremendously bigger than the short period of physical time inside the creation-era boundary solving thus, the horizon problem. In fact, if $\tau \sim 10^{-32} s$, the real time inside the creation-era is about 10^{32} times more than what is actually suggested and there was thus plenty of time for the Universe to become isotropic and spatially homogenous.

Time-wise, the creation-era can schematically be compared to a very deep "well of time" whose depth flows along the creation-time axis and whose relatively very tiny diameter flows along the physical-time axis. An observer outside the creation-era who lives in a physical-dominated-time and who traces the history along the physical-time axis would never see that time had had a long journey in coming out from the well and would simply think that the history in the creation era was a very short lapse of time (corresponding to the diameter of the time well).

The "time inflation" gives equivalent results as the space inflation. Indeed, if we take the example of a matter-dominated or a radiation-dominated creation-era or other types of creation-era, with respect to the physical-time axis, we get an accelerated expansion.

In a matter-dominated creation-era ($p = 0$), the scale factor is given by the following relation:

$$a \propto {t_c}^{2/3} \sim \left(e^{t/\tau} - 1\right)^{2/3} \qquad (6)$$

In a radiation-dominated creation-era ($p = \rho/3$), the scale factor is given by the following relation:

$$a \propto {t_c}^{1/2} \sim \left(e^{t/\tau} - 1\right)^{1/2} \qquad (7)$$

Both relations lead to: $\ddot{a} > 0$ and thus by substituting $\ddot{a} > 0$ into the Friedmann equations (5a, 5b), we get [1]:

$$p < \rho/3 \quad (8)$$

$$\frac{d\left(H^{-1}/a\right)}{dt} < 0 \quad (9)$$

In particular, relation (9) forces the value of Ω in equation (5c) to 1 which solves the flatness problem. However, according to this scenario, the space inflation is an illusion and it simply results out of observing the creation-era with respect to the very small scale ($t < \tau$) of the physical-time axis. In fact, with respect to the real-time line, the expansion is simply a conventional expansion.

Indeed, the advent of gravity inside the creation-era initiates a regular expansion of the universe along the real-time-line which has an exponentially bigger creation-time component than a physical-time component. In reality, according to the scenario proposed in this paper, the evolution of the Universe inside the creation-era takes an exponentially longer time than what is misleadingly suggested by the physical-time component and thus, the inflation illusion and horizon illusion simply results out of tracing the history of the universe solely within the physical-time axis.

Thus inside as well as outside the creation-era the expansion pace of the Universe is regular with respect to the real-time-line. In fact, this regular expansion does not even need to be initiated by any bang and even less by a big bang. Purely random fluctuations, even presenting very low probabilities, would have had plenty of time to accumulate regularly and little by little along the creation-time axis before the advent of gravity that generated the physical-time component. In that case, the evolution of the Universe would have resulted out of a very slow and more or less steady process. On the other hand, it should be noted that the mechanism of false vacuum and true vacuum explaining the inflation model can still be used. In particular, the energy locked in the false vacuum has according to the present scenario plenty of time to decay thus releasing its energy at a very slow pace during the creation-era.

5. Time arrow

Laws of nature are generally time-symmetric whereas, some behaviors especially in thermodynamics seem to be time-asymmetric creating a time arrow leading to a global entropy increase. The increase in entropy is sometimes explained by a cosmological boundary condition called the Past Hypothesis claiming that in the very distant past, entropy must have been much lower [5, 6].

In this section, we will try to give an explanation of the time arrow and the past hypothesis. Indeed, according to the definition in section 1, the real-time-line evolves in a two-dimensional coordinate system defined by the physical-time axis t and the creation-time axis t_c. We have seen that the physical-time axis t is the usual time axis defined by the fundamental laws of nature which is time-symmetric. However, we presume that the creation-time axis t_c is responsible for the generation and growth of the space of states in the Universe.

The evolution of the space of states implies that some states at later coordinates of the creation-time axis t_c have no predecessors which thus induces irreversibility within the creation-time axis t_c and which in its turn induces asymmetry within the real-time-line t_r. Thus, the real-time-line has a time arrow while the physical-time axis is reversible because it involves no creation of space of states. Therefore, the laws of nature seem to be reversible only because we mistake the real-time-line t_r for the physical-time axis without taking into consideration the creation-time component generator of entropy.

Indeed, the creation-time axis is a creator of entropy and according to the schematic relation 3, the creation-time component increases logarithmically with respect to the physical-time component which seems to be in agreement with entropy measured by the logarithm of the number of arrangement of states that are macroscopically indistinguishable. However, we would expect that the entropy growth inside the creation-era should be exponential.

On the other hand, the creation and development of the space of states along the creation-time axis t_c is a dynamic source of entropy generation that naturally explains the low entropy past and there is thus no need to pose temporally asymmetric boundary conditions such as the Past Hypothesis.

6. Interpretation of wave function collapse

The real-time-line t_r can be imagined as being continually and dynamically constructed at each "present instant" out of the creation-time axis t_c and the physical-time axis t. In other words, for a given event, the past of that event is already constructed within the real-time line whereas the future of the event is not yet constructed. As if the real-time-line t_r is continuously plaited at each "present instant" by interlacing two time-strands corresponding to the creation-time and physical-time axis. The future of the "present event" is not yet formed and the creation-time strand as well as the physical-time strand are not interlaced yet.

On the other hand, an observation is always an information coming from the past (even if it is an infinitesimal past, it is still the past). In other words, an observed event is defined by a point on the real-time-line.

Thus, for any observable, when no observation is done yet, the quantum state $|\psi\rangle$ is initially defined by a superposition of vector projections in an eigenbasis $\{|\phi_i\rangle\}$. In other words, the quantum state $|\psi\rangle$ is initially a linear combination of different possible states. When we measure the observable, we look into its past within the real-time-line which is already unchangeably formed and thus, we see only one state $|\phi_i\rangle$ out of all possible states. This scenario gives a possible explanation to the wave function collapse.

The same scenario can be used to interpret quantum entanglement knowing that the correlation between the constituent parts of an entangled system is formed through two different channels, one of which (the creation-time-axis) is infinitesimal.

7. Conclusion

The present simple model of a real-time-line in a two-dimensional space vector solves the flatness problem and the horizon problem in an equivalent manner as the inflation model. In addition, it allows postulating that the creation-time component of the real-time-line is responsible for the irreversibility of time and the increase of entropy thus explaining the paradox between the reversible physical laws and the arrow of time. However, we think that in order to have a better understanding of the Universe it is necessary to describe the laws of nature in a real five-dimensional metric composed of two dimensions of time and three dimensions of space.

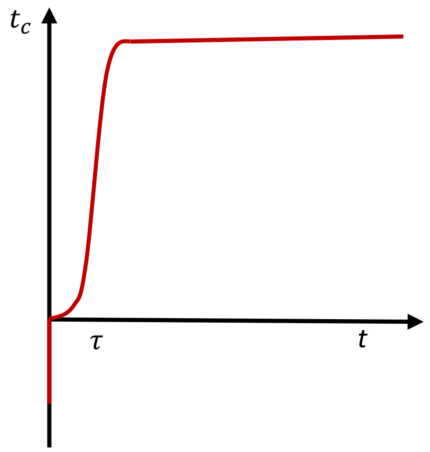

Fig.1 represents the real-time-line before and after the creation-era denoted by its physical-time coordinate τ.

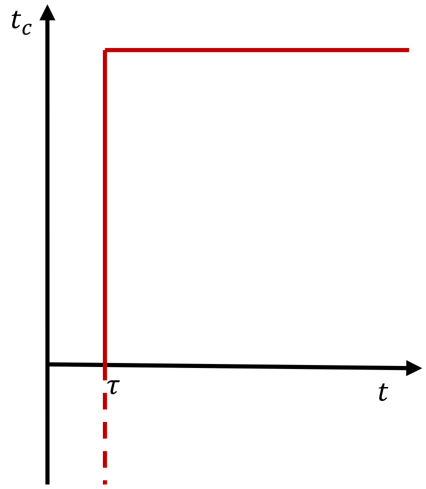

Fig.2 represents an approximation of the real-time-line before and after the creation-era.

References

[1] A. Liddle, *An introduction to cosmological inflation*, astro-ph/9901124v1 (1999).

[2] A. Guth, *Inflation and the new era of high-precision cosmology*, MIT physics annual (2002).

[3] A. Guth, Phys. Rev. 23, 347 (181).

[4] S. Carroll *Spacetime and Geometry*, Pearson Edition (Ch. 8).

[5] C. Callender, *Thermodynamic asymmetry in time* Stanford (2001).

[6] S. Carroll *From Eternity to Here*.