

# Can God find a place in physics?

## St. Augustine's philosophy meets general relativity

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### Abstract

In this speculative work I investigate whether God may find a place in theoretical physics. The comparison between some aspects of the nature of God, as deduced by the philosopher St. Augustine, and general relativity, suggests to identify God with a chronology violating region of spacetime. From this conclusion some physical suggestions can be drawn. Among them novel solutions to the homogeneity and entropy problems of cosmology.

## 1 Introduction

While discussing the possible limits of science we are often told that science can not enter the realm of faith; that God will certainly remain outside the reach of any physical investigation. This seems to be a widespread and rather modern belief. Centuries of conflicting relations between scientists and religious institutions have pushed towards this peaceful compromise although, especially from the religious side, there are every now and then attempts to influence the teaching and the development of science.

In this work I will try to analyze if God can find a place in modern theoretical physics, and if so, to identify the mathematical object that represents it. The hope is that an even tentative answer may impulse the research into some unexplored directions. Of course mine will be a rather speculative exercise and I would have not tried to put my considerations in an organized work, were not for the opportunity given by this contest. It was important to me that the contest was indirectly founded, through FQXi, by the Jhon Templeton Foundation, the latter being established to catalyze research on big questions not excluding those involving an interaction between science and religion.

## 2 St. Augustine's conclusions on the nature of God

Since our main aim is to find if there could be a place for God in physics, we need first to have some facts stated concerning the nature of God. Here I shall consider some

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conclusions reached by the philosopher St. Augustine that are largely independent of the sacred texts (the Bible) over which his thought had developed. St. Augustine of Hippo (354 - 430) believed that men have the duty, by the help of reason, to investigate as far as possible the message left by God to men through the sacred texts. According to St. Augustine, a better understanding of God would lead to a better understanding of God's plans for men, and hence to a better behavior of men in life. Here I will not focus on peculiarities of the Bible and consider instead as starting point some aspects of the nature of God shared by different religions. They are:

1. There is an entity which we call God that satisfies the following points.
2. God has created the world.
3. God cannot be wrong.

Our analysis will involve only these assumptions on the God side, while for those on the scientific side we shall take from our present knowledge of physics.

At the time of St. Augustine the Manichæans asked the following question "What was God doing before creating the world?". Any answer to the question seems to involve a paradox. If God created the world at one time and not at a previous time then God changed his mind concerning the possibility of creating the world, thus he was wrong in not creating it in the first place. The only conclusion is that God can not have created the world, because whatever decision God takes he has already taken it. This is a clear conflict with point 2 that states that God has created the world, and thus that the world has not always existed. The conclusion of the argument is in fact more general: the will of God is eternal as there can be no discontinuity in it, and so should be all the creations that follow from that will.

St. Augustine's famous reply can be found in the XI book of the *Confessions* [24, 23]. This book contains one of the most fortunate studies of the concept of time especially in the chapters starting from 14 where one can find the famous sentence "What, then, is time? If no one ask me, I know; if I wish to explain to him who asks, I know not." The reply that interests us is contained in chapters 10-13 where he considers some issues relating time, creation and God.

First he states that he will not reply (Chap. 12, Par. 14)

"like the man that, they say, answered avoiding with a joke the pressure of the question: 'God was preparing the hell for those who pry into such deep mysteries'. A thing is to understand, and another thing is to jeer. I will not answer this way. I would more likely answer: 'I know not what I know not' [ ]."

He clarifies that with *world* one must understand all the creations of God. He accepts the conclusion that the will of God is eternal, but denies that from that it follows the eternity of the world. According to St. Augustine all the times are created by God itself so that God comes "before" every time although this "before" must be understood in a causal but not in a temporal way. In fact St. Augustine says (Chap. 13, Par. 16)

“It is not in time that you precedes the times. Otherwise you would not precede them all. [ ] You are always the same, your years never end. Your years nor come nor go; ours instead come and go, for all of them will come. Yours are all together because they are stable; they don’t go because of those coming, as they do not pass. Instead these, ours, will be when all shall cease to be. Your years are one day, and your day is not daily, but today; because your today yields no tomorrow, nor it follows yesterday. Your day is the eternity [ ]. You created all the times and before the times you were, and without a time there wouldn’t be any time”.

Note that St. Augustine deduces, as the Manichæans did, that the will of God can not change, but he does not find in that any contradiction. For him, God does not perceive time as we do; not only God’s will is in a kind of permanent state but it is its very perception of time which shares this same permanence, this same eternal state.

I regard St. Augustine reply to the Manichæan question as logical given the premises. Of course although I claim that St. Augustine reply is logical I do not claim that with these considerations we are making science. Indeed, the main difficulty relies in the quite unclear subjects and verbs entering points 1,2 and 3. However, this problem can not be avoided from the start. It is the purpose of this work to convert in a more rigorous language the sentences so far appeared in this essay. For the moment let me summarize what St. Augustine deduced from 1,2 and 3 in the following additional points.

4. The will of God is eternal.
5. God created all the times, in particular God precedes all the times in a causal way. Nevertheless, God does not precede the times in a temporal way as the times did not exist before their creation.
6. Although God is not in our time, there is a kind of God’s perception of time radically different from that of humans. For God time is still, eternal, it is not perceived as a flow.

It is somewhat puzzling that St. Augustine used repeatedly the word ‘times’ in the plural form. Perhaps this is due to the fact that, although we often regard the Newtonian absolute time as the most intuitive and widespread notion of time, it wasn’t so at St. Augustine’s time. Another reason could be related with the concept of psychological and hence subjective time that St. Augustine had certainly elaborated (“Is in you, my mind, that I measure time” Chap. 28, Par. 36). We shall return on the relevance of this maybe accidental plurality later.

### **3 God and the chronology protection conjecture**

Starting from assumptions 1, 2 and 3 we have been able to derive further facts on God’s nature given by points 4, 5 and 6. Despite their somewhat vague formulations these conclusions will prove quite stringent. Indeed, as we shall see, points 3,4 and 6

will suggest the mathematical object through which we should represent God, while points 1,2 and 5 will allow us to put further constraints on a Universe admitting a God. These constraints will in particular offer new solutions to some old cosmological problems, a fact that some readers may regard as accidental while others, provided these solutions prove correct, may regard as evidence for the existence of God.

We now need to assume some familiarity of the reader with general relativity. In short the spacetime  $(M, g)$ , is a time oriented 4-dimensional manifold endowed with a Lorentzian metric of signature  $(-, +, +, +)$ .

It is believed that any reasonable spacetime should satisfy, along with Einstein's equations, some additional causality requirement [9]. One of the weakest requirements that can be imposed on spacetime is that of chronology: there are no closed timelike curves (sometime called CTC).

The fundamental problem of justifying chronology has received less attention than deserved.

It is quite easy to construct solutions of the Einstein equations that violate chronology, consider for instance Minkowski spacetime with the slices  $t = 0$  and  $t = 1$  identified, or think of Gödel or Kerr's spacetimes. Thus the problem is not if spacetime solutions of the Einstein equations can admit CTCs but rather if reasonable spacetimes not presenting CTCs may develop them.

S. Hawking argued that the laws of physics will always prevent a spacetime to form closed timelike curves, in fact he raised this expectation to the status of conjecture, now called *chronology protection conjecture* [25]. According to it the effects preventing the formation of CTCs may also be quantistic in nature, in fact Hawking claims that the divergence of the stress energy tensor at the chronology horizon (i.e. the boundary of the *chronology violating set*, the latter being the region over which CTCs pass) would be the principal candidate for a mechanism preventing the formation of CTCs.

Despite some work aimed at proving the chronology protection conjecture its present status remains quite unclear with some papers supporting it and other papers suggesting its failure [26, 27, 13, 14, 11].

Apart from the technical motivations, the principal reason behind the rejection of spacetimes presenting chronology violations remains mostly a philosophical one. A closed timelike curve represents an observer which is forced to live an infinite number of times the same history (the grandfather paradox).

It is simply unacceptable that a human being, or any other entity presenting some form of free will, be stuck into a cycle in which always the same decisions are taken. Whatever a closed timelike curve might represent there seems to be consensus that it cannot represent the concept of "observer" to which we are used in physics.

Nevertheless, if the usual notion of "observer" can not be represented by a CTC worldline, a God may indeed be represented by such worldline. Indeed, we have seen that God has an eternal will (point 4) thus faced with the same conditions he would pass through the same decisions. It cannot change direction because he confirms the correctness of the previous decision each time he is facing it.

Now, we have to expand some more on the consideration that God may be modeled by a CTC. First recall that the chronology violating set  $\mathcal{C}$  is made of all the points  $p \in M$  such that  $p \ll p$ . This set splits into equivalence classes  $[p]$  by means of the equivalence relation  $p \sim q$  if  $p \ll q \ll p$ . In other words  $p$  and  $q$  belong to the same

equivalence class if there is a closed timelike curve passing through both  $p$  and  $q$ . Moreover, in this case the timelike curve is entirely contained in  $[p]$ . It is possible to prove that the sets  $[p]$  are all open in the manifold topology.

If  $p$  and  $q$  belong to the same chronology violating class then they have the same chronological role, in fact as  $p \ll q$  and  $q \ll p$  it is not possible to say which one comes before. They are in a sense ‘simultaneous’. Indeed,  $p$  can be connected to  $q$  also by a lightlike causal curve and the same holds in the other direction, thus it is indeed possible to move from  $p$  to  $q$  and then from  $q$  to  $p$  in zero proper time. In particular any timelike curve passing through  $[p]$  would not cross events that follow ‘one after the other’ but rather almost equivalent events, actually chronologically undistinguishable. This picture fits well with point 6, that is with St. Augustine conclusion that “Your years are one day, and your day is not daily, but today; because your today yields no tomorrow, nor it follows yesterday. Your day is the eternity [.]” All that suggests to regard God not as a single CTC, in fact given one one would get an infinite number of them in the same chronology violating class, but rather as a chronology violating class  $[p]$  itself. This class  $[p]$  has also to satisfy point 1, which we convert into the mathematical statement  $M = I^+([p])$ , namely any point of  $M$  is chronologically preceded by a point of God.

Thus we are led to the following definition

**Definition 3.1.** On a spacetime  $(M, g)$ , *God* is a chronology violating class  $[p]$  such that  $M = I^+([p])$ .

I will write this concept of God in italics in order to distinguish this technical notion from the God of the previous sections that has inspired it.

Note that given a *God*, then any point of *God* generates  $M$  in the sense that  $p \in \textit{God} \Rightarrow I^+(p) = M$ , and thus itself  $p \ll p$ . In suggestive terms, any portion of *God* creates itself and the whole world.

Provided *God* exists it is unique, as the following theorem proves

**Theorem 3.2.** (*Uniqueness of God*) *There is at most one chronology violating class  $[p]$  such that  $M = I^+([p])$ .*

*Proof.* Indeed, suppose  $M = I^+([q]) = I^+([p])$  then  $q \in M = I^+([p]) = I^+(p)$ , and with the roles of  $p$  and  $q$  interchanged we get  $p \in I^+(q)$ , thus  $p \sim q$  and hence  $[p] = [q]$ .  $\square$

Since to any chronology violating class  $[r]$  not satisfying  $M = I^+([r])$  we can still apply the arguments relating it to points 4 and 6, we give the following definition

**Definition 3.3.** A *minor God* is a chronology violating class which is not a *God*.

Now, the chronology protection conjecture in its original formulation may be rephrased as follows “there are no *minor Gods*”, in fact the chronology protection conjecture, roughly speaking, states that chronology violating regions can not form but does not state that they cannot exist since the beginning of the Universe. I must say, however, that any mechanism accomplishing the chronology protection would probably exclude, once applied to the backward direction, also any chronology violating region. Probably the issue as to whether there could be a mechanism that removes

*minor Gods* while keeping a *God* could be answered only by showing the details of the chronology protection mechanism.

Let us assume for simplicity that there are no *minor Gods* and let us show in which way the definition of *God* satisfies point 5. Recall that a *time function* is a continuous function  $t : M \rightarrow \mathbb{R}$  such that  $x < y \Rightarrow t(x) < t(y)$ , namely a function that increases over every causal curve. For instance any observer in Minkowski spacetime has its own time function.

Clearly, no time function can exist in the presence of a CTC, because if  $p \ll q \ll p$  then  $t(p) < t(q) < t(p)$ , which is impossible. Indeed, the presence of a time function is equivalent to *stable causality* (i.e. causality is stable under sufficiently small perturbations of the metric) which is a much stronger causality property than chronology. Given one time function one has that a multitude of time functions exist.

Nevertheless, although  $M$  does not admit a time function, the spacetime  $M \setminus \bar{C}$  with the induced metric may indeed admit a time function and hence many of them. In other words, the part of spacetime not containing *God* (or better its closure) may admit time functions. In this sense *God* precedes the region of the Universe where time makes sense, but in a causal rather than a temporal way as those time functions are not defined in the region of *God*. This is exactly St. Augustine's conclusion summarized by point 5.

The nice fact is that not only  $M \setminus \bar{C}$  may admit a time function, but that it *must* admit a time function, provided null geodesic completeness and other reasonable physical conditions are satisfied. For more details on these conditions see [18, 9].

**Theorem 3.4.** *Let  $(M, g)$  be a spacetime that admits no minor Gods but possibly a God  $[p]$ . Assume that the spacetime is null geodesically complete and satisfies the null convergence condition and the null genericity condition on the null geodesics intersecting  $M \setminus \overline{[p]}$ . Then the spacetime  $M \setminus \overline{[p]}$  is stably causal and hence admits a time function.*

(The proof is omitted.)

The fact that the assumption of null geodesic completeness may be actually compatible with the singularity theorems has been discussed in [18].

In conclusions we have given a definition of *God* that satisfies some technical properties which represent pretty well points 2-6.

The figure 1 summarizes the picture of a spacetime admitting a *God*. There are in fact solutions of the Einstein equations admitting a similar causal structure. The most important is the Taub-NUT metric, which so far has not been considered as a serious candidate for a cosmological solution. Here I would like to suggest that not the metric structure but at least the causal structure of the Taub-NUT solution could indeed be similar to that of our Universe. In fact sometimes causal structures like Taub-NUT are dismissed on the ground that they have no 'Big Bag', no initial singularity, a fact which would contradict Hawking's singularity theorem and observations.

This belief is incorrect: Hawking's (1967) singularity theorem states that, given an expanding cosmological flow and some other conditions, there should be some past incomplete timelike geodesic. However, this timelike geodesic may well be totally imprisoned in a compact. In this case it may spiral towards the boundary of the chronology violating set without reaching it. In this picture the 'Big Bang' is replaced

by the boundary of the chronology violating region, exactly that slice that separates *God* from the rest of the Universe. Finally, its hot nature seems to fit well with the said divergence of the stress energy tensor that is expected according to the chronology protection conjecture. In fact there is also the possibility that the matching between the chronology violating set and the rest of the universe be accomplished up to a singular scale transformation. In this case the causal structure would be perfectly meaningful as a whole but the metric would not as it could not be continued through the boundary. For more details on these extension techniques see [15].

I conclude that it is possible to conceive a reasonable Universe whose causal structure has features analogous to Taub-NUT (Misner) and that then, after an initial phase, has the light cones tilted to match an expanding FLRW Universe. Spacetimes presenting some of these elements are for instance the  $\lambda$ -Taub-NUT spacetimes.

Similar models have already appeared in the literature. An important article that anticipated some ideas considered in this work is [7]. However, while in that article the authors focused on the problem of quantum field theory in spacetime with CTCs, here I shall consider mainly the problem of homogeneity and entropy and its relation with causality. In particular, I will introduce the idea of the rigidity at the boundary of the chronology violating region (see next section).

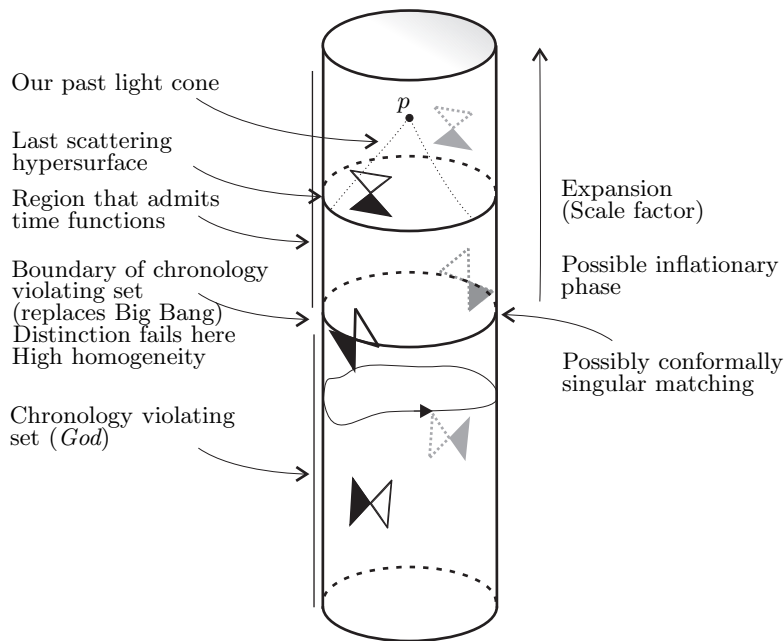


Figure 1: A Universe with  $S^1$  section which gives an idea of the cosmological picture presented in this work. The region that admits time functions is causally preceded by the chronology violating set (*God*) as in St. Augustine's conclusions.

## 4 The homogeneity and entropy problems

The cosmic microwave background (CMB) formed when, after a sufficient expansion of the Universe, the density of matter decreased to a level that light decoupled from it (the mean free path of light became infinite). The set of events of departure of those photons form an ideal last scattering hypersurface. Today we observe just a portion of that hypersurface, namely the intersection of it with our past light cone. Since we observe that the CMB radiation has the same spectra (temperature) independently of the direction of observation, there is the problem of justifying such homogeneity (or isotropy) given the fact that the regions that emitted that radiation were so far apart that, according to the FLRW scenario, they didn't have any past point in common.

It is often claimed that inflation solves this problem. The idea is that if a patch of space expands so much, in the initial phase of the Universe, to include the whole surface we see today, then it should be natural to observe homogeneity. This argument works only if homogeneity is assumed at a different scale, actually at a much smaller scale, prior to inflation, namely if the initial patch is considered homogeneous.

This criticism has been moved to inflation by several authors, as rather than solving the problem of homogeneity, inflation seems to replace a type homogeneity assumption with another [2, 5, 3, 22]. R. Penrose argues that inflation may well prove to be correct but not for the initial arguments moved in its favor [22].

The assumption that there is a chronology violating region generating the whole Universe, that is a *God*, explains instead rather easily the homogeneity of the CMB radiation. Indeed, the explanation has nothing to do with the expansion of the Universe (namely to the conformal scale factor) but rather to its causal structure. In our model any point  $r$  in the last scattering hypersurface contains, in its own past, the chronology violating region of *God*, namely  $[p] \subset I^-(r)$  and in fact its boundary. Thus the chronological pasts of the points in the last scattering hypersurface share many points on spacetime, and thus it is reasonable that they have similar temperatures.

However, it would be incorrect to think that the points of the last scattering hypersurface have the same temperature because of thermalization. Instead, the Universe is already at a very homogeneous state at the boundary of the chronology violating region. Indeed, some mathematical results, connected with the concept of compactly generated Cauchy horizon and imprisoned curves [12, 17], suggest that this boundary must be generated by lightlike geodesics whose closure is exactly the boundary (as it happens in figure 1). Given any two points on the boundary  $p, q$  one would have  $q \in \overline{I^+(p)}$  and  $p \in \overline{I^+(q)}$ , thus in practice they could be considered as causally related. As they can communicate among them on the boundary, this boundary is expected to attain an homogeneous temperature prior to any subsequent expansion.

This mechanism is welcome, indeed R. Penrose [21, 22] has pointed out that the thermalization mechanism can not be considered as a satisfactory explanation for homogeneity as it conflicts with the so called entropy problem to which we shall return in a moment.

Of course this mechanism may be followed by that of inflation, but we point out that it does not seem to be necessary. Indeed, the main accomplishment of inflation seems to be its ability to predict the correct density inhomogeneities over

the homogeneous background. Hollands and Wald [10] have recently argued that not only inflation does not satisfactorily solve the homogeneity problem but also that the desired scale free spectra of the perturbations can be obtained even in absence of inflation. They therefore claim that the main problem is that of homogeneity/isotropy as they could not find any dynamical mechanism for it. We argued that such a mechanism exists, the solution lies in assuming the existence of a chronology violating region from which the Universe develops: a *God* in our terminology.

Let us come to the entropy problem. This difficulty of standard cosmology arises when considering the huge difference between the entropy of the Universe today with that at the time of the Big Bang. R. Penrose by taking into account also the gravitational entropy, has argued that the Universe at its beginning had probably to be thermalized, to account for the homogeneity problem, but nevertheless it had to be special as the calculation of the entropy shows that it was much smaller than today. In his view the Universe could increase in entropy despite its initial thermalization because in the beginning the gravitational degrees of freedom were almost frozen.

He also notes that when matter is left to the action of gravity it tends to clump, passing from an homogeneous state to an inhomogeneous one. The Weyl tensor increases because of this clumping, and therefore this tensor may quantify in some sense the amount of entropy contained in the gravitational degrees of freedoms. Thus he ends suggesting that in the beginning of the universe the Weyl tensor had to be very small, and possibly zero. This is Penrose's Weyl tensor hypothesis [21, 6].

The picture of the beginning of the Universe presented in this work is likely to satisfy the Penrose's Weyl tensor hypothesis. Indeed, as I mentioned, the boundary of the chronology violating region would be generated by lightlike geodesics (which are moreover achronal). Now, there is a *rigidity result* [1] that at least for asymptotically simple spacetimes states that in the neighborhood of an achronal lightlike geodesic the spacetime is isometric to that of Minkowski (Galloway's null splitting theorem [4]). I expect that analogous results should hold for the case considered in this work, that is, I expect the spacetime metric near the boundary of the chronology violating region to be isometric to some highly symmetric spacetime. This rigidity would clearly fix the Weyl tensor and thus send to zero the degrees of freedom contained in it.

Note that in this case the null genericity condition would not hold for geodesics lying on the boundary of the chronology violating region. Fortunately we do not need it in theorem 3.4, hence its consequences are consistent with the rigidity of the boundary.

## 5 Conclusions

In this work I have presented a picture for the beginning of the Universe which seems to be able to solve the homogeneity and entropy problems. The main idea is that the Big Bang has to be replaced with a null hypersurface such that all the points on it have the same chronological future (i.e. future distinction is violated). As a consequence they (almost) causally communicate between them and so homogeneity and thermalization hold there. Moreover, the points in the last scattering (spacelike) hypersurface have chronological pasts that contain one and hence all points of this

null hypersurface, a fact which clarifies the observed temperature homogeneity.

If proved necessary, the just mentioned beginning of the Universe may be followed by a period of inflation, so that it is indeed possible to join the good accomplishments of inflation with the solution of the homogeneity and entropy problems given by the above idea.

By a stability argument, the spacetime once continued through the null hypersurface must develop closed timelike curves. Indeed, a spacetime in which the cones tilt in the opposite sense as in figure 37 of [9] would have a null hypersurface (and hence a failure of distinction) that disappears under a small perturbation of the metric.

With the aim of solving the homogeneity and entropy problem one is therefore naturally led to the idea of a chronology violating region from which the whole Universe has developed [7].

I showed that this picture for a Universe fits pretty well with some conclusions reached by St. Augustine while he was answering some questions raised by the Manichæans. To appreciate the correspondence it is necessary to identify God with the chronology violating set that precedes the whole Universe.

I must say that I was developing the physical content of this work before discovering St. Augustine thought in the *Confessions*. Nevertheless, I was so puzzled by the correspondence that decided to present them in conjunction so as to stress the similarities. While doing so I discovered some unexpected results like theorem 3.4 which I missed in previous analysis of similar problems, a fact which to my mind confirmed the correspondence.

One may ask how it happened that St. Augustine went so close to the model of Universe presented in these pages, given that he certainly ignored general relativity. My own opinion is that while thinking about a subject there are many ways of coming to trivial or incorrect conclusions, whereas only a few paths can lead to correct or at least interestingly structured thoughts. It is therefore not an accident that St. Augustine deep reflections on time, creation and God can find today a correspondence in general relativity. Suffice to consider that the latter is the most advanced theory we have ever had on the dynamics of time.

## Acknowledgments

Although I had been thinking about the content of this essay for a while, I have written it quite rapidly and thus I may have missed some relevant references. To the authors of the potentially missed works go my apologies. This work has been partially supported by GNFM of INDAM and by FQXi.

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