Causation, existence, and creation in space-times with non-trivial topology

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Abstract. The Kalam Cosmological Argument is perhaps the most solid and widely discussed argument for a caused creation of the universe. The usual objections to the argument mainly focus on the second premise. In this paper we discuss the dependency of the first premise on the topological structure of the space-time manifold adopted for the underlying cosmological model. It is shown that in chronology-violating space-times the first premise is also violated. The chronology-violation, in turn, requires a massive violation of the so-called energy conditions which could have observational effects that are briefly discussed here. Hence, astronomical observations could be relevant for the validity of the metaphysical argument. In this sense, it is possible to talk of “observational theology”.

1. Introduction

The so-called Kalam Cosmological Argument (e.g. Craig 1979) is a version of the classical cosmological argument based on some medieval Islamic arguments against the infinitude of the past. In modern syllogistic form it can be formulated as follows:

1. Whatever begins to exist has a cause of its existence.
2. The universe began to exist.
3. Therefore, the universe has a cause of its existence.

It has been argued that the first premise is a fundamental metaphysical principle which cannot be intelligibly denied and that the second premise is supported by modern cosmology, in such a way that the conclusion of the argument is true (Craig 1979, Craig & Smith 1993). These contentions have been discussed in recent years by several philosophers, notably Adolf Grünbaum, who argued that the Big Bang model does not support the second premise (e.g. Grünbaum 1989, 1990, 1991, 2000, and some replies in Craig 1991 and 1992). The first premise, on the contrary, has not
been considered controversial except from the point of view of quantum mechanics (see the discussions in Craig & Smith 1993).

In this paper we shall argue that the validity of the first premise depends on the topology of space-time manifold adopted for the cosmological model. Multiple connected space-times can be compatible with objects that obey all physical laws but violate the first premise of the Kalam Cosmological Argument. Some semantic comments are in order first to clarify the meaning of the expression “to begin to exist”.

2. A semantical note

Craig (1992) attributes to Grünbaum the implicit use of the following definition:

“$x$ begins to exist”=def. “$x$ exists at time $t$ and there are instants of time immediately prior to $t$ at which $x$ does not exist”.

This definition is objected because it is difficult to accept that the existence of $x$ at $t$ can entail the existence of temporal instants prior to $t$. Admittedly, in the context of a relational theory of space-time (e.g. Perez-Bergliaffa, Romero & Vucetich 1998) the requirement of the existence of moments prior to $t$ is nothing else than the requirement of the existence of objects other than $x$ before $x$. Such a definition, then, is not adequate to the discussion of the origin of the system formed by all things, i.e. the universe. Craig, in turn, proposes:

“$x$ begins to exist”=def. “$x$ exists at time $t$ and there are no instants of time immediately prior to $t$ at which $x$ exists”.

This allows for a beginning of time itself and is apparently apt for a discussion on the beginning of the universe. But it has the problem of demanding a sharp edge for the existence of $x$. Anything created by an evolutionary process lasting a finite time interval is excluded. Let us consider, for example, the Mankind. It certainly exists now and it certainly did not exist 50 million years ago, but can we point out an instant $t$ at which it did existed and an immediately prior instant at which it did not?. Not only biological counterexamples are possible, but we can think also in most physical systems, like a star or a molecular cloud, which are formed by a slow transition from a previous state.

In order to remove this problem we propose:

“$x$ begins to exist”=def. “$x$ exists at time $t$ and there is a time interval $\Delta t \geq 0$ such that there are no instants of time immediately prior to $t - \Delta t$ at which $x$ exists”.

For $\Delta t = 0$ we recover Craig’s definition. In what follows we shall understand “to begin to exist” in the sense of this latter definition.

3. Chronology-violating space-times and self-existent objects

A relativistic space-time is represented by a four-dimensional manifold $M$ equipped with a Lorentzian metric $g_{ab}$. The General Theory of Relativity requires the manifold to be continuous and differentiable but not specific constraints are imposed on the details of its topology. Usually, simply connected manifolds are considered, but multiply connected ones cannot be ruled out only on a priori grounds.

In recent years there has been a sustained interest in multiple connected space-times, also called wormhole space-times, originated in the fact that close timelike curves (CTCs) naturally appear in them (e.g. Morris, Thorne & Yurtsever 1988, Thorne 1992). These curves represent the world lines of any physical system in a temporally orientable space-time that, moving always in the future direction, ends arriving back at some point of its own past. Any space-time with CTCs is called a chronology-violating space-time. Objections to the formation of CTCs in the real universe had been formulated by a number of scientists, most notably by Hawking (1992), but in the absence of a theory of quantum gravity the possibility of wormholes in space-time cannot be ruled out (see the discussions and references in Earman 1995a, Romero & Torres 2001, and Nahin 1999).

One of the most strange implications of chronology-violating space-times is the possibility of an ontology with self-existent objects. These are physical systems “trapped” in CTCs. Romero & Torres (2001), who have discussed these systems in depth, give the following toy-example to illustrate the nature of such objects:

Suppose that, in a space-time where CTCs exist, a time traveler takes a ride on a time machine carrying a book with her. She goes back to the past, forgets the book in -what will be- her laboratory, and returns to the future. The book remains then hidden until the time traveler finds it just before starting her time trip, carrying the book with her.

The book in question is a self-existent object: it exists at a given $t$, there exists $\Delta t \geq 0$ such that the object does not exist at $t - \Delta t$, but, however, there is not an external cause of its existence. The self-existent object is just a feature of space-time itself, it is not either created or destroyed in space-time. Such objects clearly violate the first premise of the Kalam Cosmological Argument.

It is very important to emphasize that, despite that the self-existent objects have not a cause of their existence, they do not violate causality. In fact, since their space-time history is a continuous closed curve, their
physical state at every time $t$ is casually linked to a previous state. In this way, these objects are not causally created, but they have a finite existence in the sense that they exist during a finite time interval, and their existence does not violate strict causality.

Romero & Torres (2001) have argued against an ontology of self-existent objects invoking a full Principle of Self-Consistency for all laws of nature. This principle, which is used to dissolve the so-called “paradoxes” of time travel (Earman 1995b, Nahin 1999), can be stated as:

*The laws of nature are such that any local solution of their equations that represents a feature of the real universe must be extendible to a global solution.*

Romero and Torres suggest that this principle is a *metanomological* statement (see Bunge 1961) that enforces the harmony between local and global affairs in space-time. By including thermodynamics in the consistency analysis of the motion of macroscopic systems through wormhole space-times, they have shown that non-interacting self-existent objects are not possible in the real universe because energy degradation along the CTC results in non-consistent histories.

Notwithstanding these objections, the development of consistent histories remains an open possibility for isolated systems where entropy cannot be defined (e.g. single particles) and for interacting systems where their energy degradation is exactly compensated by external work made upon them (Lossev & Novikov 1992). Hence, if CTCs actually occur in the universe, there seems to be no form to avoid the possibility of at least some types of self-existent objects.

Very recently, J. Richard Gott III and Li-Xin Li (1998) have even proposed that the universe itself could be a self-existent object. Form a philosophical point of view, this would be a violation of both premises of the Kalam Cosmological Argument with a single counterexample. As far as it can be seen, the work by Gott and Li is consistent with the Big Bang paradigm. They only require the existence of a multiply connected space-time with a CTC region beyond the original inflationary state.

A key point for the validity of the first premise of the Kalam Cosmological Argument is that the space-time in the real universe must be described by a simply connected manifold, with no CTCs. Otherwise, the presence of objects that have “began to exist” without external cause but notwithstanding are subject to causality cannot be excluded. We have, then, two possibilities in order to explore the validity of the first premise in the context of its dependency on the underlying topology of space-time:

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1Formally, CTCs are possible even in simply connected space-times, but these kind of solutions of Einstein field equations, like the classical Gödel (1949) rotating universe, are thought to be not applicable to the real world.
1) we can try to prove, from basic physical laws, that CTCs cannot be 
formed in the real universe (i.e. we can try to find out a mechanism to en-
force chronology protection), or 2) we can inquire about the observational 
signatures of wormhole structures in space-time and try to test through 
observations the hypothesis that natural wormholes actually do exist. The 
first option requires a full theory of Quantum Gravity, something that 
is beyond our present knowledge. The second approach is being already 
explored by some scientists.

4. Observational signatures of WEC-violating matter

Macroscopic and static wormhole structures as those necessary to allow the 
formation of CTCs require that the average null energy condition (ANEC) 
be violated in the wormhole throat. This condition is part of the so-called 
energy conditions of Einstein gravity, which are very general hypothesis 
designed to provide as much information as possible on a wide variety of 
physical systems without specifying a particular equation of state. These 
conditions are not proved from basic principles, they are just conjectures, 
which can be very useful in some contexts. However, many violating sys-
tems are known, including the universe itself (see Visser 1996).

The energy conditions violated by traversable wormhole can be put in 
terms of the stress-energy tensor of the matter threading the wormhole as 
$\rho + p \geq 0$, where $\rho$ is the energy density and $p$ is the total pressure. This 
implies also a violation of the so-called weak energy condition $WEC$ ($\rho \geq 
0 \land \rho + p \geq 0$; see Visser 1996 for details, also Morris and Thorne 1988).
Plainly stated, all this means that the matter threading the wormhole must 
exert gravitational repulsion in order to stay stable against collapse. If 
natural wormholes exist in the universe (e.g. if the original topology after 
the Big-Bang was multiply connected), then there should be observable 
signatures of the interactions between matter with negative energy density 
with the normal matter.

At astronomical level the most important observational consequence 
of the existence of natural wormholes is gravitational lensing of background 
sources (Cramer et al. 1995, Torres et al. 1998; Eiroa et al. 2001, Safonova 
et al. 2001). There are very specific features produced by chromaticity 
effects in lensing of extended sources that could be used to differentiate 
events produced by wormholes from those of other objects (Eiroa et al. 
2001). In the wormhole microlensing case there are two intensity peaks 
during each event separated by an umbra region. On the contrary, in the 
normal case there is a single, time-symmetric peak. In addition, in the 
wormhole case it can be shown that there is a spectral break that is not 
observed in the usual case (Eiroa et al. 2001 for details).

Also, the macrolensing effects upon a background field of galaxies pro-
duced by large-scale violations of the energy conditions are observationally 
distinguishable from the normal macrolensing by either dark or luminous
matter concentrations (see Safonova et al. 2001 for complete numerical simulations of macrolensed galaxy fields). In particular, it can be shown that for positive mass we see concentric arcs, whereas for negative energy densities we have filamentary features projected from the center.

The above examples are enough to illustrate the kind of observational effects that can be expected in an universe with multiple connected topology. Whether such space-time wormholes actually exist in our universe is something that has to be found yet.

The mere existence of a multiple connected topology for space-time does not warrant, by itself, the violation of the first premise of the Kalam Cosmological Argument. But it makes possible the formation of CTCs and non-cronal situations in that space-time, hence opening the possibility of an ontology with self-existent objects. This implies that the universality of the premise can be objected even at a macroscopic level, without resorting to quantum considerations.

5. Conclusions: Theology meets experiment

The first premise of the Kalam Cosmological Argument, namely that “whatever that begins to exist has a cause of its existence”, is not a self-evident, universally valid statement as it is usually accepted. We have shown that the truth value of the premise is dependent on some basic characteristics of the space-time manifold that represents the real universe. In particular, multiple connected space-times can accommodate objects that exist by themselves, without external cause, but also without any local violation of causality. These objects “begin to exist” in accordance to even the most restrictive definitions given in Section 2.

Since the connectivity of space-time can be probed through astronomical observations (see Anchordoqui et al. 1999 for an example of these observational studies), the validity of the Kalam Cosmological Argument can be tested by the scientific method. Not only the second premise, which uses to be discussed in the light of the Big Bang cosmology, but also the first premise of the argument is susceptible to experimental test. It is in this more extended sense that in the Kalam Cosmological Argument we can say that theology meets experiment.

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Chronology violation and the Cosmological Argument

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