Some critical notes on time in the multiverse
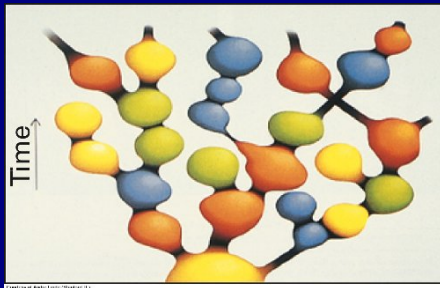
Henrik Zinkernagel

Department of Philosophy
University of Granada
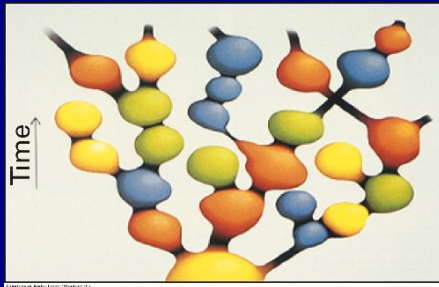Spain

zink@ugr.es

Based on joint work with Svend E. Rugh

Could our universe be just a patch in a much older (and larger) structure?
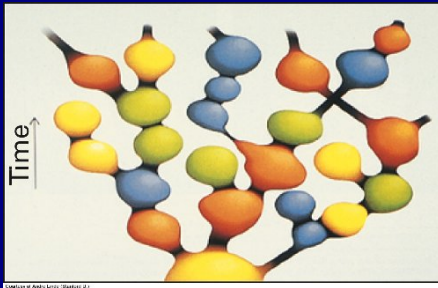
Could our universe be just a patch in a much older (and larger) structure?
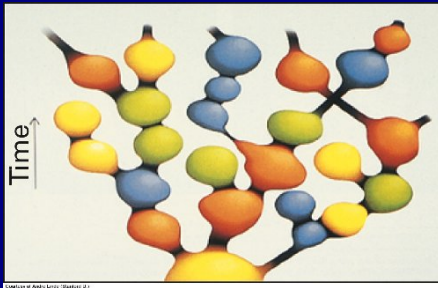

The answer will depend on what time is supposed to be in this picture.

Could our universe be just a patch in a much older (and larger) structure?

The answer will depend on what time is supposed to be in this picture.

There seems to be two ways to establish the possibility of older patches:

Could our universe be just a patch in a much older (and larger) structure?

The answer will depend on what time is supposed to be in this picture.

There seems to be two ways to establish the possibility of older patches:

1. Define some sort of a 'supercosmic' time for the multiverse which gives a definite time ordering of the patches (as in the picture).

Could our universe be just a patch in a much older (and larger) structure?

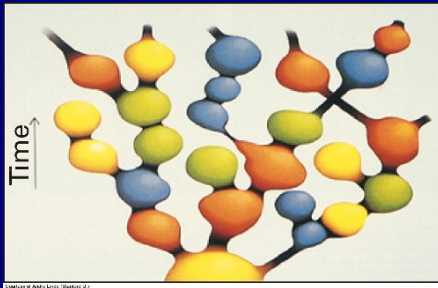The answer will depend on what time is supposed to be in this picture.

There seems to be two ways to establish the possibility of older patches:

1. Define some sort of a 'supercosmic' time for the multiverse which gives a definite time ordering of the patches (as in the picture).

2. If this cannot be done, then try to extrapolate our 'local' cosmic time concept back through our 'local' Big Bang.

To evaluate these possibilities we need to know:

To evaluate these possibilities we need to know:

How is a supercosmic time to be defined?

To evaluate these possibilities we need to know:

How is a supercosmic time to be defined?

How is (ordinary) cosmic time defined?

To evaluate these possibilities we need to know:

How is a supercosmic time to be defined?

How is (ordinary) cosmic time defined?

Indeed, what *is* time?

Two philosophical views on time

Two philosophical views on time

Newton: Absolute time

Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external (1687)

Leibniz: Relational time

Space and matter differ, as time and motion. However, these things, though different, are inseparable ($\sim$ 1716).

Two philosophical views on time

Newton: Absolute time

Leibniz: Relational time

Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external (1687)

Space and matter differ, as time and motion. However, these things, though different, are inseparable ($\sim$ 1716).

But does Newton's absolute time make sense?

Two philosophical views on time

Newton: Absolute time

Leibniz: Relational time

Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external (1687)

Space and matter differ, as time and motion. However, these things, though different, are inseparable (~ 1716).

But does Newton's absolute time make sense?

- Flows without relation to anything external? How fast does it flow?

Two philosophical views on time

Newton: Absolute time

Leibniz: Relational time

Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external (1687)

Space and matter differ, as time and motion. However, these things, though different, are inseparable (~ 1716).

But does Newton's absolute time make sense?

- Flows without relation to anything external? How fast does it flow?

In the end, Newton might have agreed that time is implicitly defined by the laws of nature, that absolute time is what an ideal clock (a physical process governed by these laws) would measure, and that time is - in this sense - inseparable from motion.

How is cosmic time defined?

In general, no global time in general relativity, but the FLRW line element, with a global time parameter, can be derived if two assumptions are made:
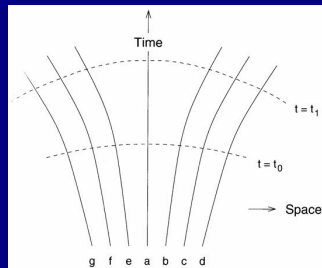
How is cosmic time defined?

In general, no global time in general relativity, but the FLRW line element, with a global time parameter, can be derived if two assumptions are made:

1. The Weyl postulate. The world lines of fundamental particles (e.g. galaxies) form a bundle of non-intersecting geodesics orthogonal to a series of spacelike hypersurfaces. This series of hypersurfaces allows for a common cosmic time. ($g_{0i} = 0$; $ds^2 = c^2 dt^2 - g_{ij}(x,t) dx^i dx^j$)

How is cosmic time defined?

In general, no global time in general relativity, but the FLRW line element, with a global time parameter, can be derived if two assumptions are made:
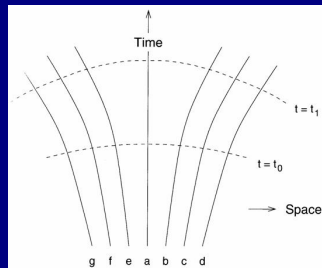
1. The Weyl postulate. The world lines of fundamental particles (e.g. galaxies) form a bundle of non-intersecting geodesics orthogonal to a series of spacelike hypersurfaces. This series of hypersurfaces allows for a common cosmic time. ($g_{0i} = 0$; $ds^2 = c^2 dt^2 - g_{ij}(x, t) dx^i dx^j$)

If two galaxy world lines did intersect, our coordinate system would break down.

Narlikar (2002)

How is cosmic time defined?

In general, no global time in general relativity, but the FLRW line element, with a global time parameter, can be derived if two assumptions are made:

1. The Weyl postulate. The world lines of fundamental particles (e.g. galaxies) form a bundle of non-intersecting geodesics orthogonal to a series of spacelike hypersurfaces. This series of hypersurfaces allows for a common cosmic time. ($g_{0i} = 0$; $ds^2 = c^2 dt^2 - g_{ij}(x, t) dx^i dx^j$)

If two galaxy world lines did intersect, our coordinate system would break down.
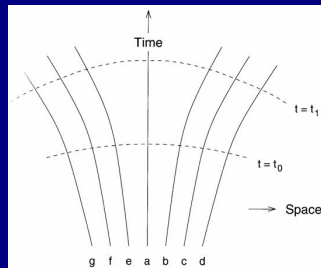
Narlikar (2002)

2. The cosmological principle. The universe is (spatially) homogeneous and isotropic. (FLRW: $ds^2 = c^2 dt^2 - R^2(t) \left\{ \frac{dr^2}{1 - kr^2} + r^2(d\theta^2 + \sin^2\theta d\phi^2) \right\}$)

Cosmic time and the matter content

Both the Weyl postulate and the cosmological principle, which are needed to set up the standard model of cosmology, and define a cosmic time, refer to the physical constituents of the universe. This means

Cosmic time and the matter content

Both the Weyl postulate and the cosmological principle, which are needed to set up the standard model of cosmology, and define a cosmic time, refer to the physical constituents of the universe. This means

1. The definition of cosmic time is related to the behaviour of the material constituents of the universe. This supports a relational conception of time.

Cosmic time and the matter content

Both the Weyl postulate and the cosmological principle, which are needed to set up the standard model of cosmology, and define a cosmic time, refer to the physical constituents of the universe. This means
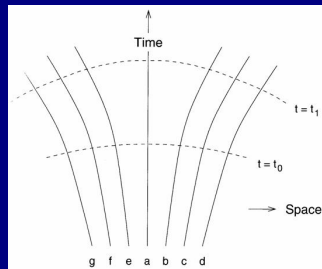
1. The definition of cosmic time is related to the behaviour of the material constituents of the universe. This supports a relational conception of time.

2. The required behaviour of the material constituents of the universe seems to be a classical behaviour.

Cosmic time and the matter content

Both the Weyl postulate and the cosmological principle, which are needed to set up the standard model of cosmology, and define a cosmic time, refer to the physical constituents of the universe. This means

1. The definition of cosmic time is related to the behaviour of the material constituents of the universe. This supports a relational conception of time.
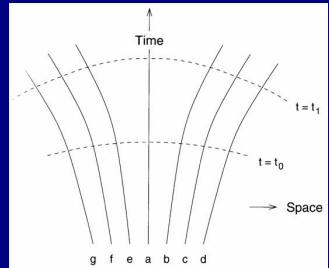
2. The required behaviour of the material constituents of the universe seems to be a classical behaviour.

Could entangled quantum constituents (wavefunctions) produce this picture of non-intersecting geodesics?

Cosmic time and the matter content

Both the Weyl postulate and the cosmological principle, which are needed to set up the standard model of cosmology, and define a cosmic time, refer to the physical constituents of the universe. This means

1. The definition of cosmic time is related to the behaviour of the material constituents of the universe. This supports a relational conception of time.

2. The required behaviour of the material constituents of the universe seems to be a classical behaviour.
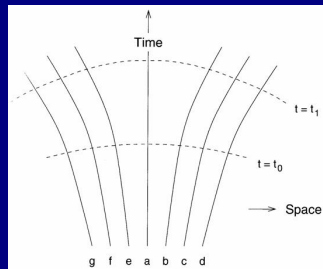

Could entangled quantum constituents (wavefunctions) produce this picture of non-intersecting geodesics?

```
┌─────────────────────┐        ┌─────────────────────────────┐
│    Definition of     │  ⟷    │   Classical and well-behaved │
│    cosmic time       │        │   material constituents      │
└─────────────────────┘        └─────────────────────────────┘
```

Option 1: Can we define a supercosmic time?
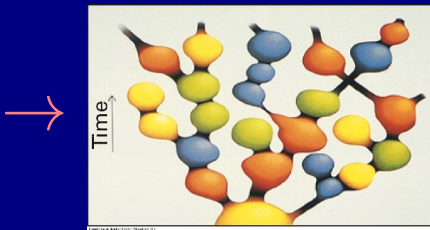
$\longrightarrow$

Option 1: Can we define a supercosmic time?
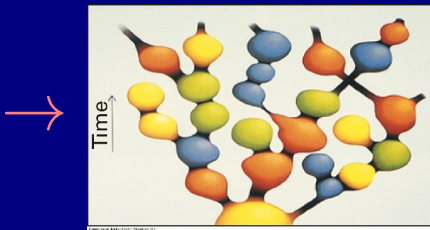
If time is relational, then there is no freely flowing absolute and universal background time parameter → (cosmic and supercosmic) time needs to be grounded in matter behaviour.

Option 1: Can we define a supercosmic time?

If time is relational, then there is no freely flowing absolute and universal background time parameter → (cosmic and supercosmic) time needs to be grounded in matter behaviour.

In particular, in the above picture (and in similar pictures from the string landscape), there does not seem to be a homogeneous multiverse with patches obeying the Weyl postulate - which could physically ground a 'supercosmic' time to order the patches.

Option 2: Can we extrapolate our cosmic time back to an older patch?

As one extrapolates backwards in cosmic history, the prerequisites for setting up the cosmic time (and the cosmological principle) may become problematic:

Option 2: Can we extrapolate our cosmic time back to an older patch?

As one extrapolates backwards in cosmic history, the prerequisites for setting up the cosmic time (and the cosmological principle) may become problematic:

1) Before the electroweak phase transition ($\sim 10^{-11}$ seconds), known physics becomes scale invariant, so one loses any handle on how close we are to the singularity.

Option 2: Can we extrapolate our cosmic time back to an older patch?

As one extrapolates backwards in cosmic history, the prerequisites for setting up the cosmic time (and the cosmological principle) may become problematic:

1) Before the electroweak phase transition ($\sim 10^{-11}$ seconds), known physics becomes scale invariant, so one loses any handle on how close we are to the singularity.
Way out: Postulate some speculative physics scale (but admit that the time scale becomes speculative too) [Rugh and Zinkernagel 2009]

Option 2: Can we extrapolate our cosmic time back to an older patch?

As one extrapolates backwards in cosmic history, the prerequisites for setting up the cosmic time (and the cosmological principle) may become problematic:

1) Before the electroweak phase transition ($\sim 10^{-11}$ seconds), known physics becomes scale invariant, so one loses any handle on how close we are to the singularity.
Way out: Postulate some speculative physics scale (but admit that the time scale becomes speculative too) [Rugh and Zinkernagel 2009]

2) Suppose you are a quantum fundamentalist (= everything is quantum, and even if something looks classical *now*, there were an early time when nothing did). Then, at this early time, it seems that no well-defined and non-intersecting particle trajectories can be found (Weyl postulate?).

Option 2: Can we extrapolate our cosmic time back to an older patch?

As one extrapolates backwards in cosmic history, the prerequisites for setting up the cosmic time (and the cosmological principle) may become problematic:

1) Before the electroweak phase transition ($\sim 10^{-11}$ seconds), known physics becomes scale invariant, so one loses any handle on how close we are to the singularity.
Way out: Postulate some speculative physics scale (but admit that the time scale becomes speculative too) [Rugh and Zinkernagel 2009]

2) Suppose you are a quantum fundamentalist ($=$ everything is quantum, and even if something looks classical *now*, there were an early time when nothing did). Then, at this early time, it seems that no well-defined and non-intersecting particle trajectories can be found (Weyl postulate?).

Certainly most people would agree that, at least, there is no (known) sensible time concept "before" the Planck time (10^{-43} seconds).

So could our universe be just a patch in a much older (and larger) structure?

As mentioned, there seems to be two ways to establish this possibility:
1) supercosmic time to order the patches; or 2) extrapolation of our cosmic time concept back through our Big Bang.

So could our universe be just a patch in a much older (and larger) structure?

As mentioned, there seems to be two ways to establish this possibility: 1) supercosmic time to order the patches; or 2) extrapolation of our cosmic time concept back through our Big Bang.

BUT:

So could our universe be just a patch in a much older (and larger) structure?

As mentioned, there seems to be two ways to establish this possibility: 1) supercosmic time to order the patches; or 2) extrapolation of our cosmic time concept back through our Big Bang.

BUT:

It seems difficult to define a supercosmic time... (if there is no Weyl postulate and no homogeneity in the multiverse).

So could our universe be just a patch in a much older (and larger) structure?

As mentioned, there seems to be two ways to establish this possibility: 1) supercosmic time to order the patches; or 2) extrapolation of our cosmic time concept back through our Big Bang.

BUT:

It seems difficult to define a supercosmic time... (if there is no Weyl postulate and no homogeneity in the multiverse).

It seems difficult to extrapolate our 'local' cosmic time backwards to a pre Big Big epoch... (through the electroweak phase transition?; through a quantum gravity 'epoch'?; through the singularity?).

So could our universe be just a patch in a much older (and larger) structure?

As mentioned, there seems to be two ways to establish this possibility: 1) supercosmic time to order the patches; or 2) extrapolation of our cosmic time concept back through our Big Bang.

BUT:

It seems difficult to define a supercosmic time... (if there is no Weyl postulate and no homogeneity in the multiverse).

It seems difficult to extrapolate our 'local' cosmic time backwards to a pre Big Big epoch... (through the electroweak phase transition?; through a quantum gravity 'epoch'?; through the singularity?).

Finally, it seems to be even more problematic to think of patches 'older' than ours if we consider more radical versions of the multiverse (c.f. Tegmark's level II-IV):

...completely disconnected regions or ...very or fundamentally different laws (time is implicitly defined by laws); ...

A word of clarification

I am not trying to argue that there cannot be an older multiverse.

A word of clarification

I am not trying to argue that there cannot be an older multiverse.

But I do think that one should be clear about what time concept is used...

A word of clarification

I am not trying to argue that there cannot be an older multiverse.

But I do think that one should be clear about what time concept is used...

📄 Rugh, S.E. and Zinkernagel, H.
On the physical basis of cosmic time
Studies in History and Philosophy of Modern Physics 40, 2009,
pp.1-19.

📄 Rugh, S.E. and Zinkernagel, H.
Cosmic time and quantum fundamentalism
In preparation.

📄 Zinkernagel, H.
Did time have a beginning?
International Studies in the Philosophy of Science 22:3, 2008, pp.
237-258.