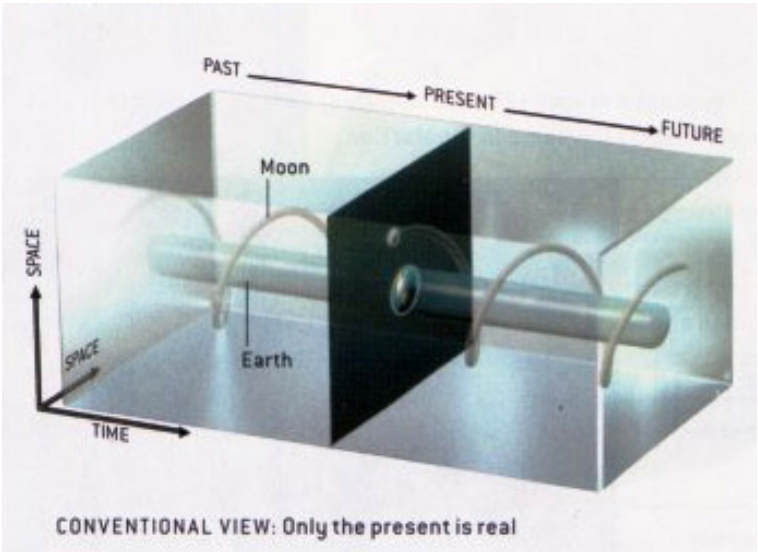
The 'Arrow' or 'Passage' of Time

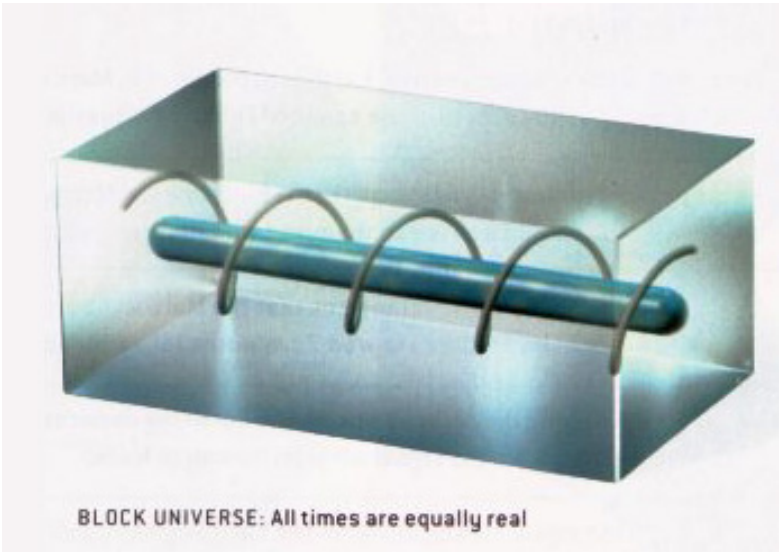
Looking for Good Questions

Huw Price

Seven Pines, May 2016

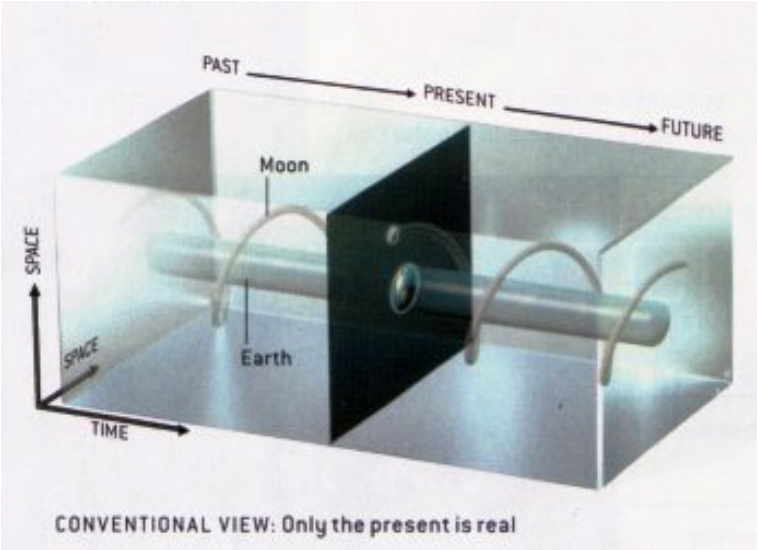
Two views of time





[Images: Scientific American/Bryan Christie Design]

The dynamic or 'passage' view



CONVENTIONAL VIEW: Only the present is real

This view treats one or more of these three **independent** elements as objectively real (even if missing from current physics):

1. A distinguished present moment.
2. An objective 'flow' of time ('becoming').
3. An objective direction of time.

This is said to be a minority view among physicists, but it has had – and still has – some distinguished champions.

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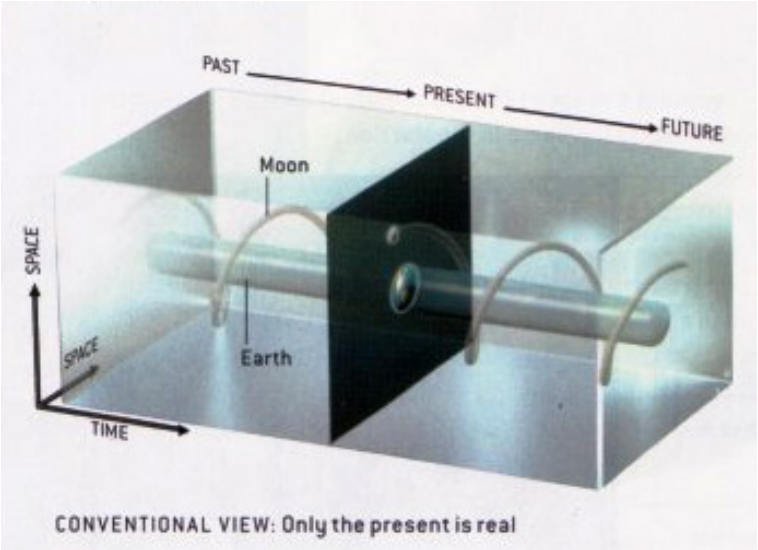

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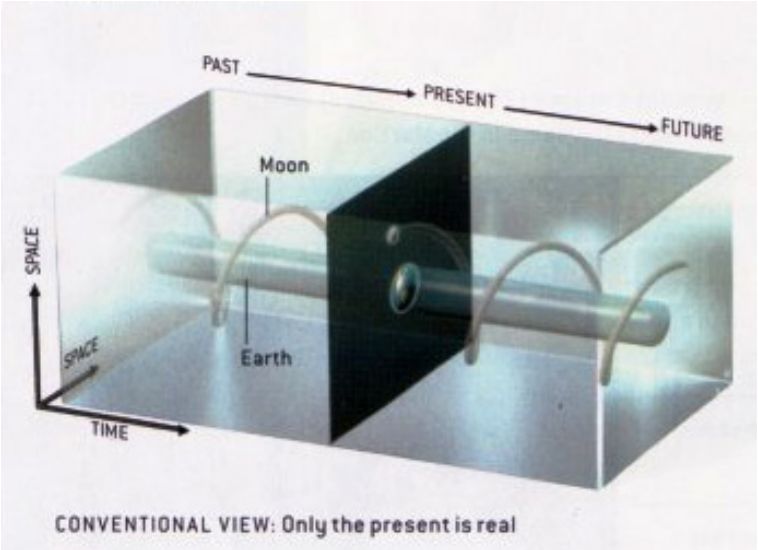

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- Regards time as simply one dimension in a 4D 'block'.
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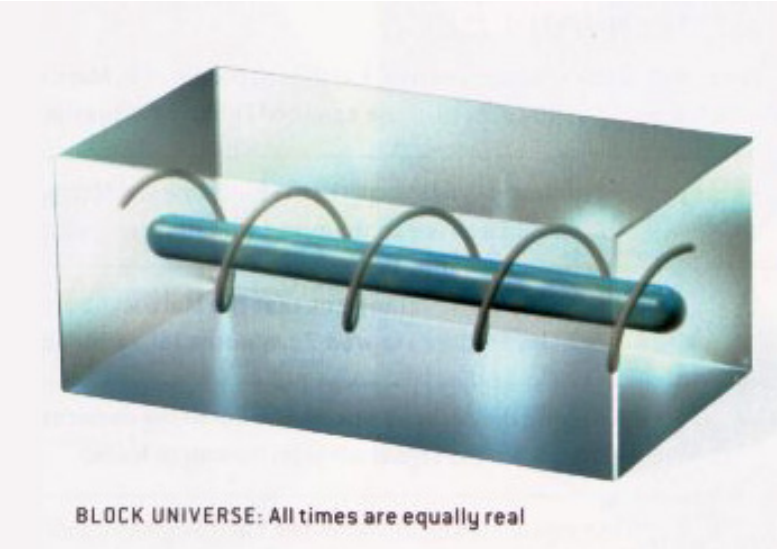
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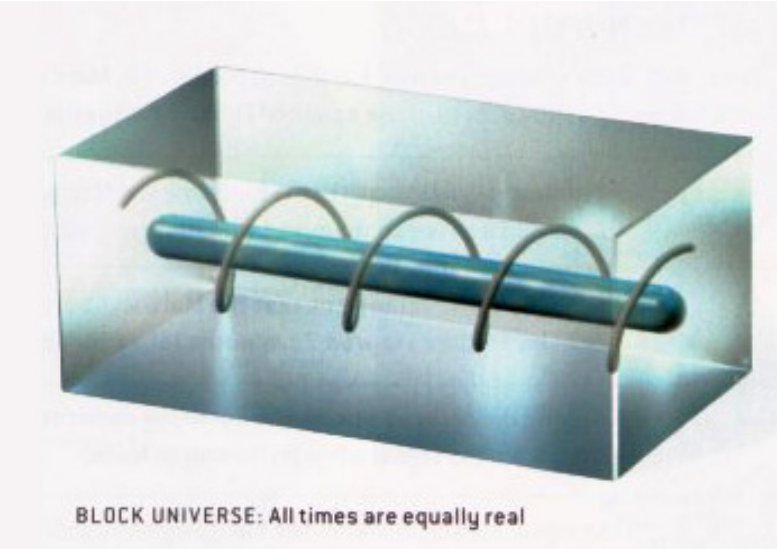
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"Hmmm … no motion in this picture!"

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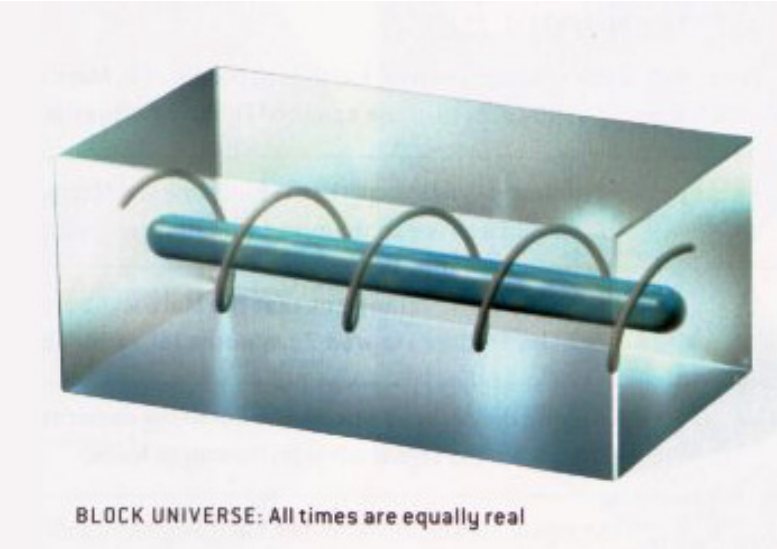
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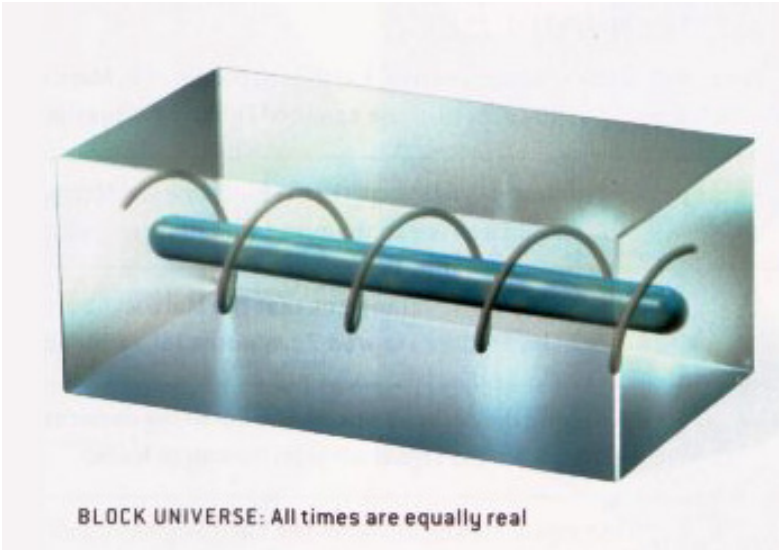
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1. Einstein: No privileged present

Einstein & Besso.

"For we convinced physicists, the distinction between past, present, and future is only an illusion, albeit a persistent one."

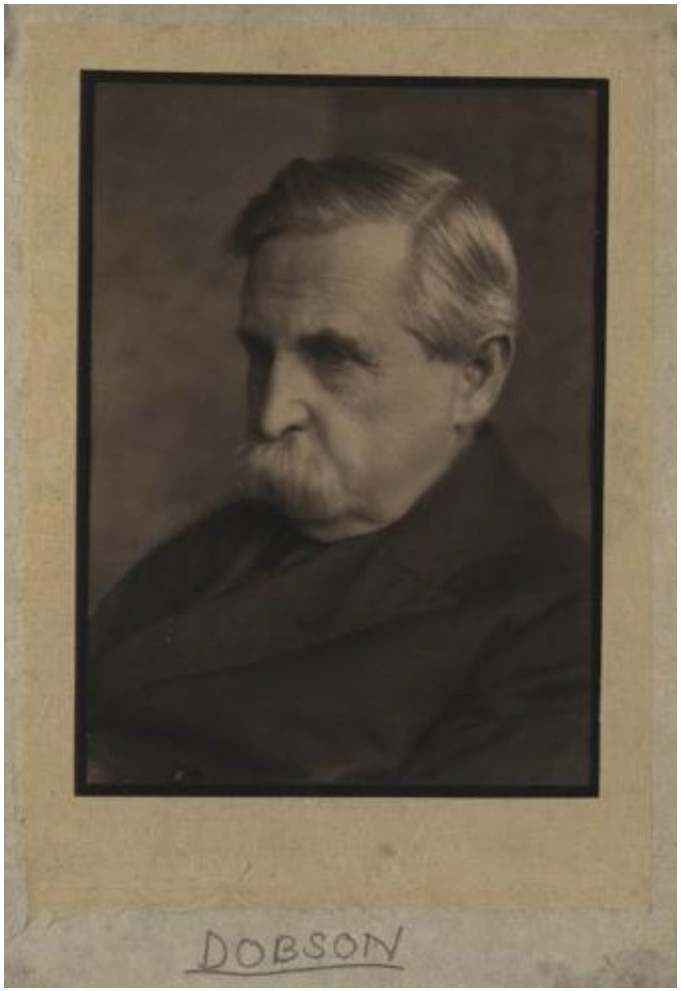
– Einstein, *Letter to the family of Michele Besso,* 1955.

2. Weyl: No objective passage

"The objective world simply is, it does not happen. Only to the gaze of my consciousness, crawling upward along the life line of my body, does a section of this world come to life as a fleeting image in space which continuously changes in time."

– Hermann Weyl, *Philosophy of Mathematics and Natural Science,* 1949.

A word from the poets



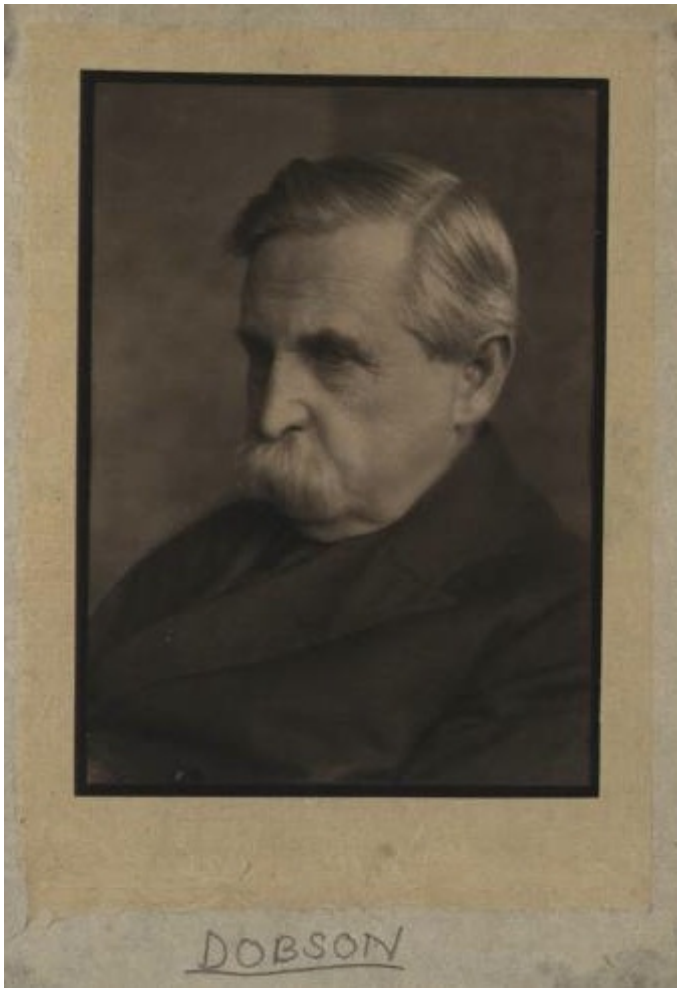
A word from the poets

TIME goes, you say? Ah no!
Alas, Time stays, we go.

...

Ours is the eyes' deceit
Of men whose flying feet
Lead through some landscape low;
We pass, and think we see
The earth's fixed surface flee:—
Alas, Time stays,—we go!

– Austin Dobson, 'The Paradox of Time', 1875.



3. Boltzmann: No objective direction

"[I]n the universe, which is in thermal equilibrium throughout and therefore dead, there will occur here and there relatively small regions of the same size as our galaxy … which … fluctuate noticably from thermal equilibrium, and indeed the state probability in such cases will be equally likely to increase or decrease."

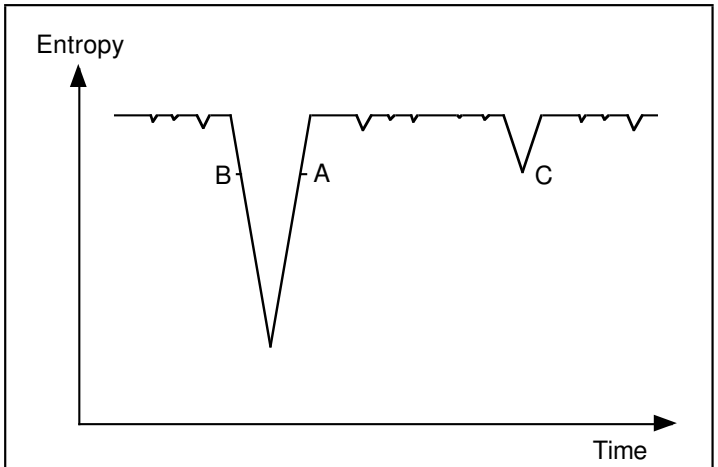


Figure 1. Boltzmann's entropy curve.

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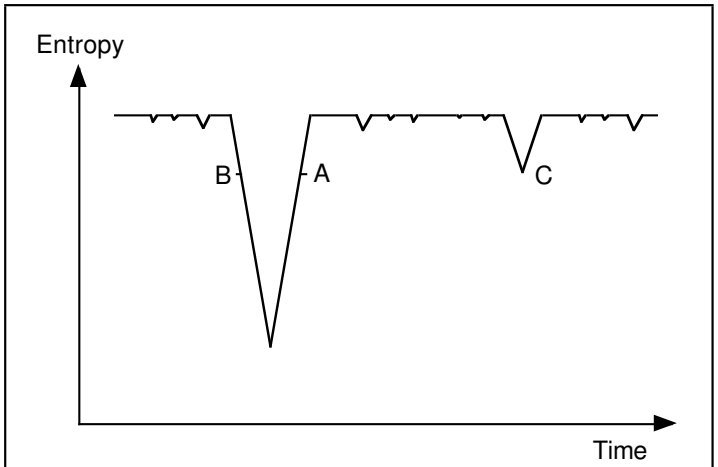

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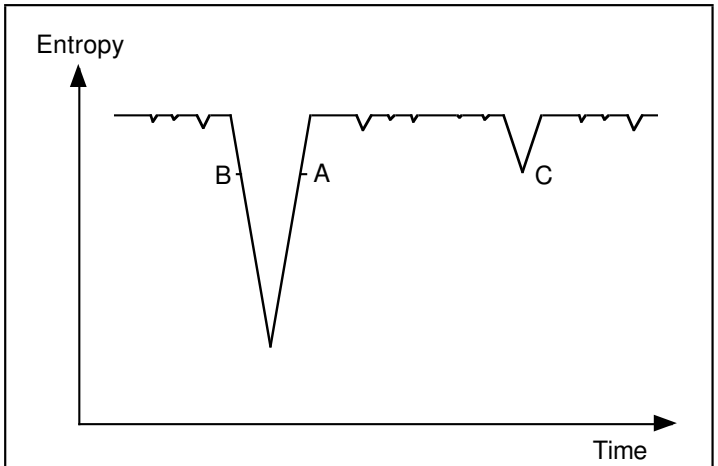
"For the universe, the two directions of time are indistinguishable, just as in space there is no up and down. However, just as at a particular place on the earth's surface we call 'down' the direction toward the center of the earth, so will a living being in a particular time interval of such a single world distinguish the direction of time toward the less probable state from the opposite direction (the former toward the past, the latter toward the future)."

– *Lectures on Gas Theory,* 1896–98.



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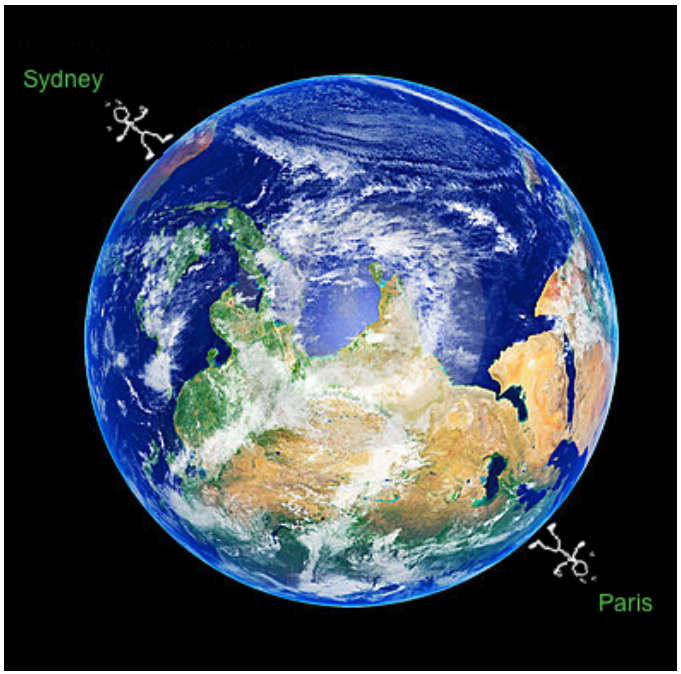
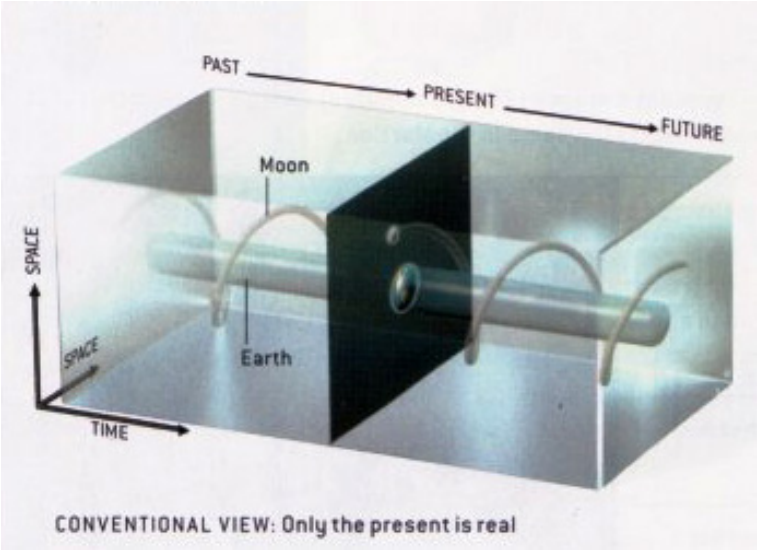


Does physics need an objective present?



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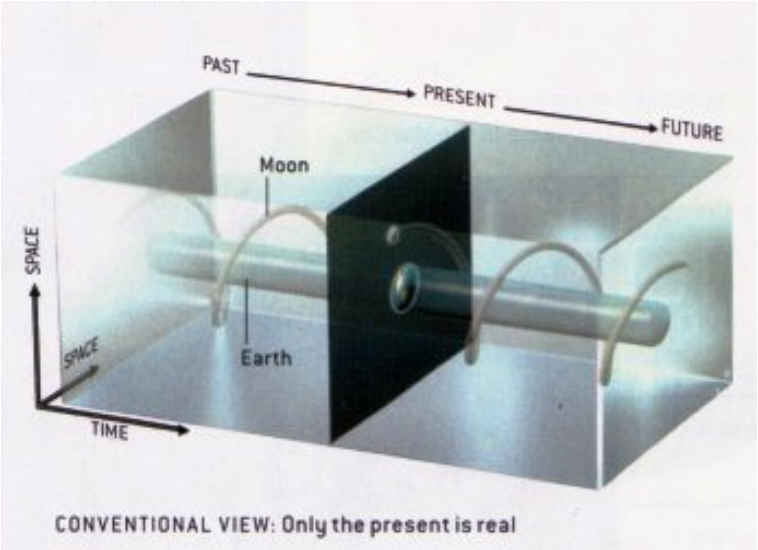

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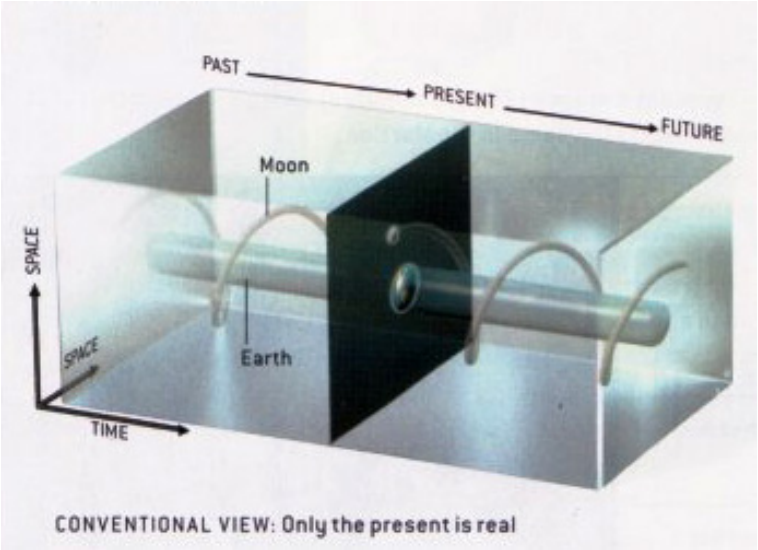

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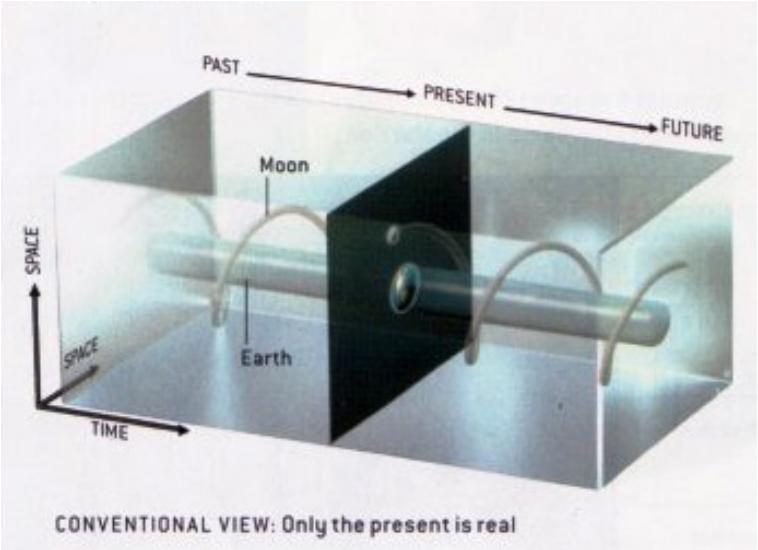

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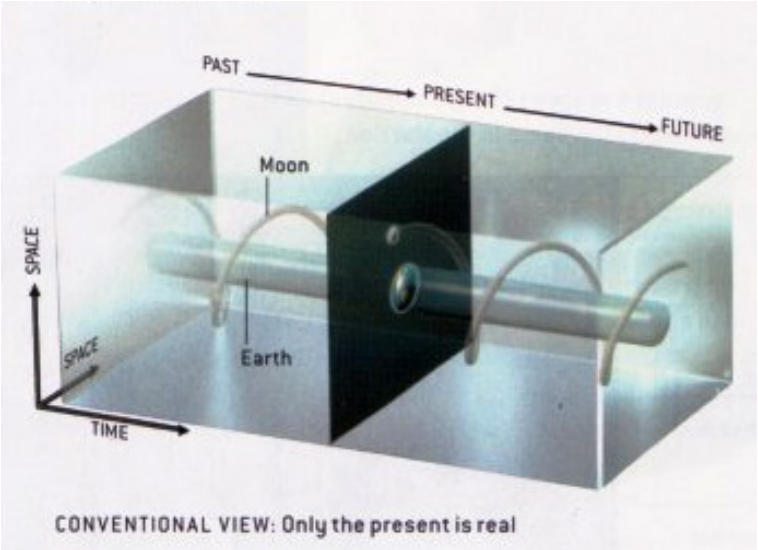

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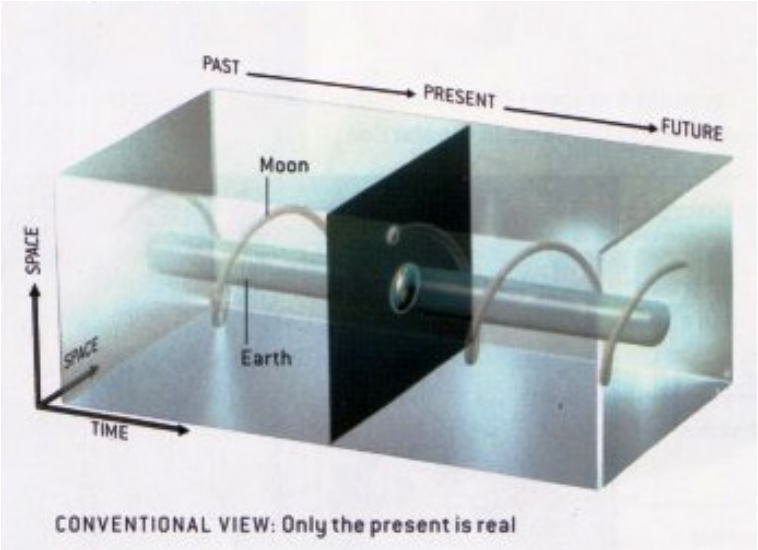

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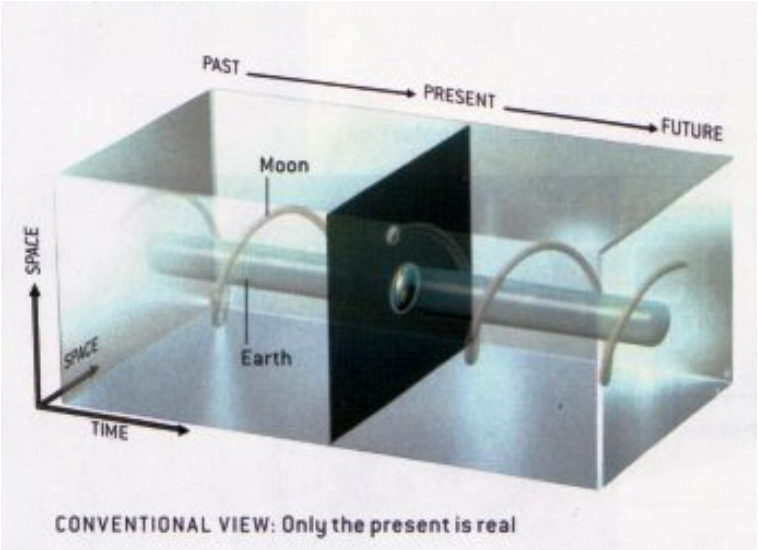

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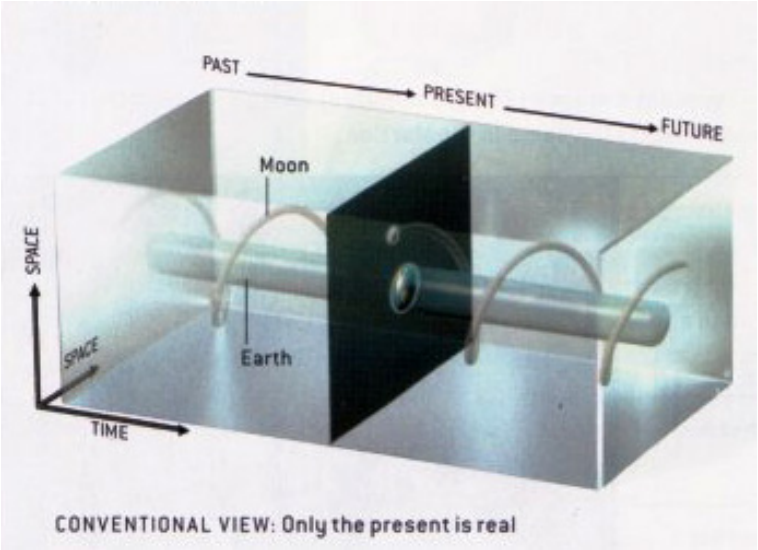

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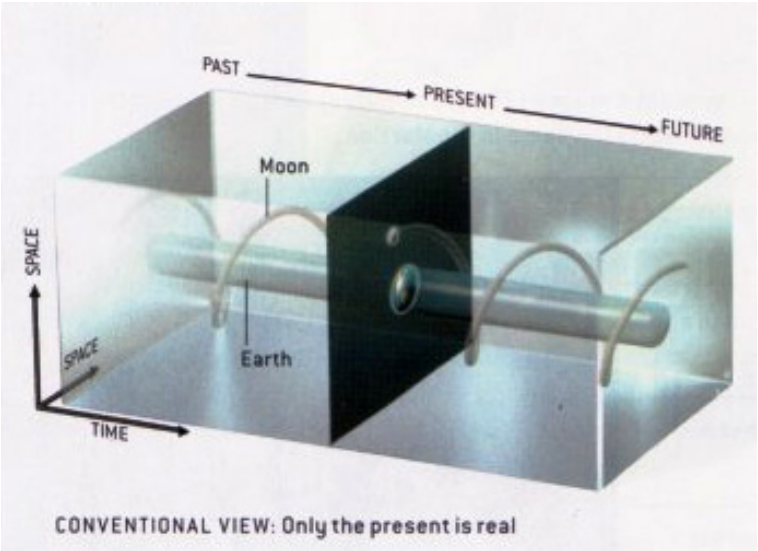

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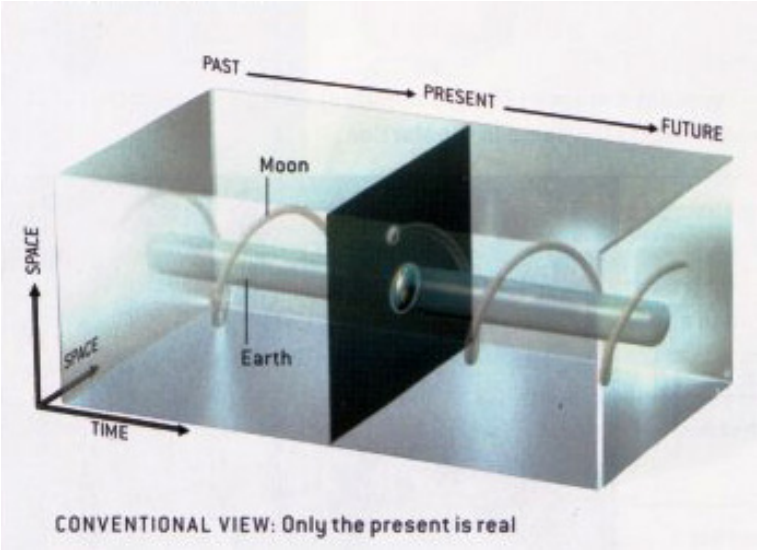

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Putting it slightly differently

- Someone who thinks that an objective present moment is missing from a 'physics of passage' has a problem with their story about how time passed last week.
- Presumably they think that a full history of last week would mention the fact that time was passing last week.
- But that history doesn't (and **can't**, on pain of absurdity) pick out one moment last week as **the** present moment.
- **Conclusion:** If there is 'a new physics of passage', it doesn't need to single out one moment as 'special'.

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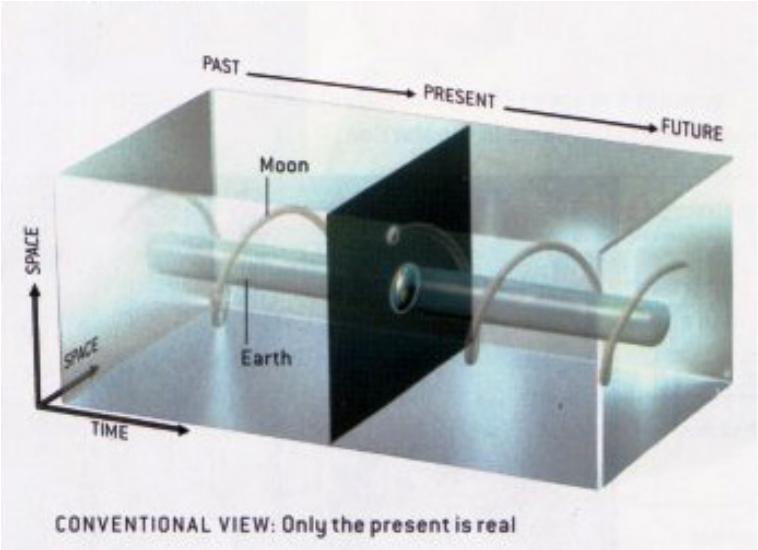

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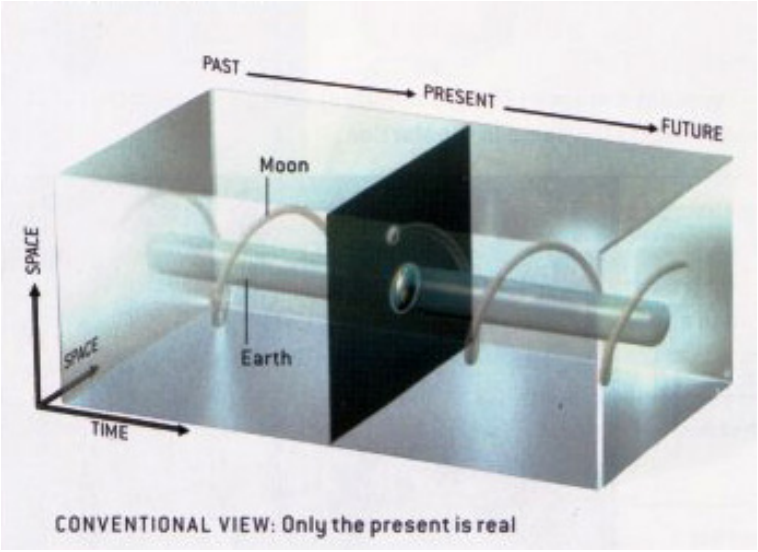

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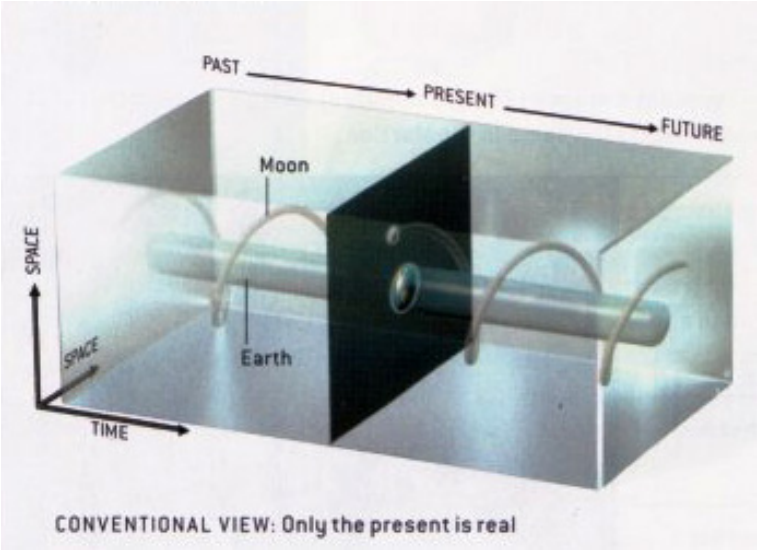

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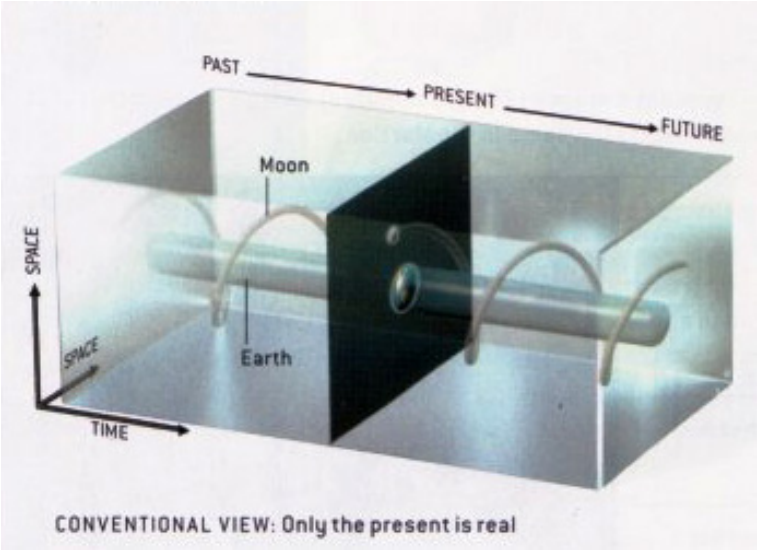

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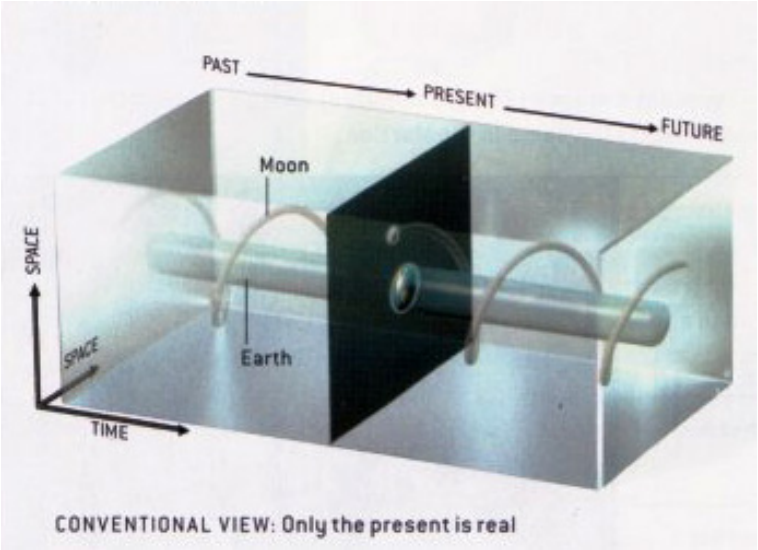

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What would it **take** to make these different worlds?

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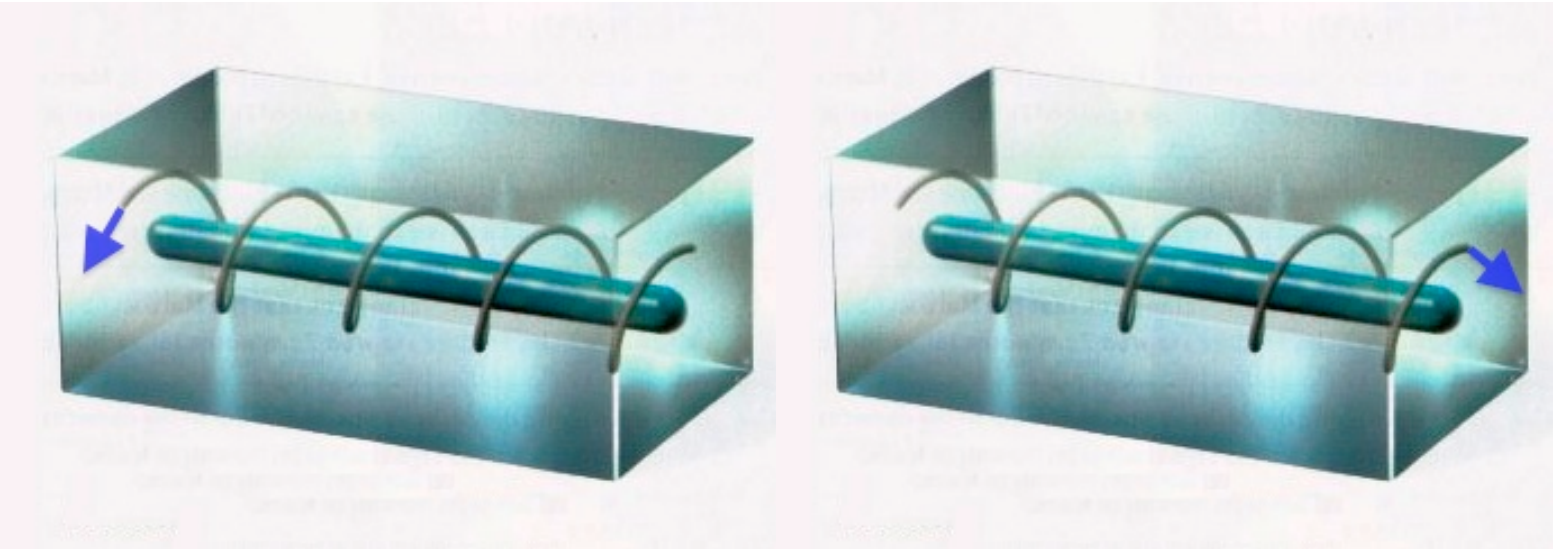

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How many worlds?

Did God need to make a choice?

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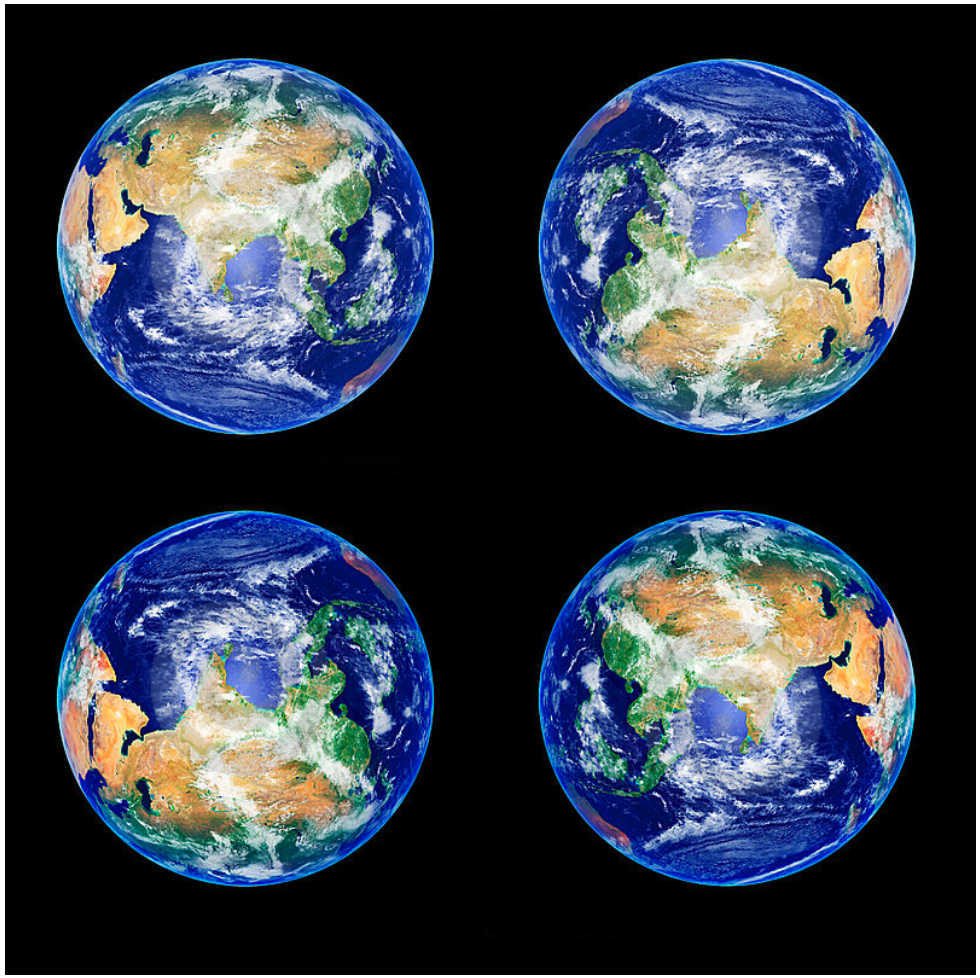

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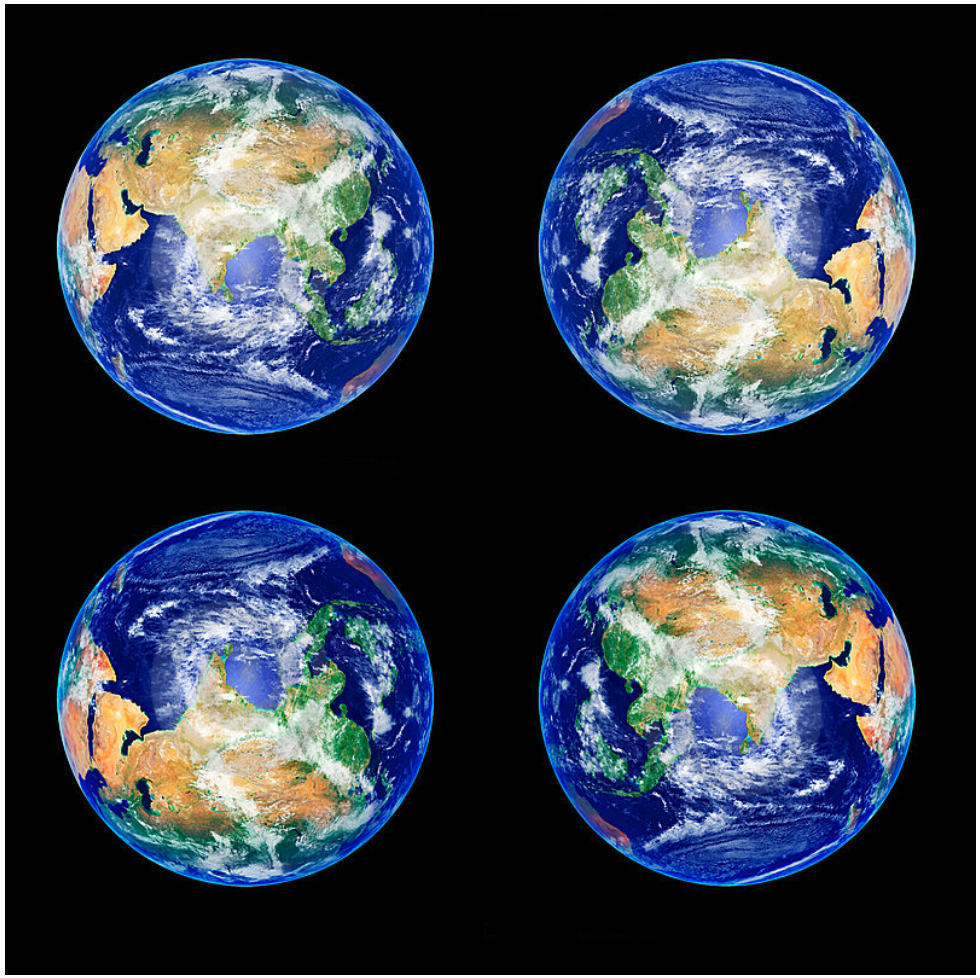

Are these **different** worlds, or **different views** of the **same** world?

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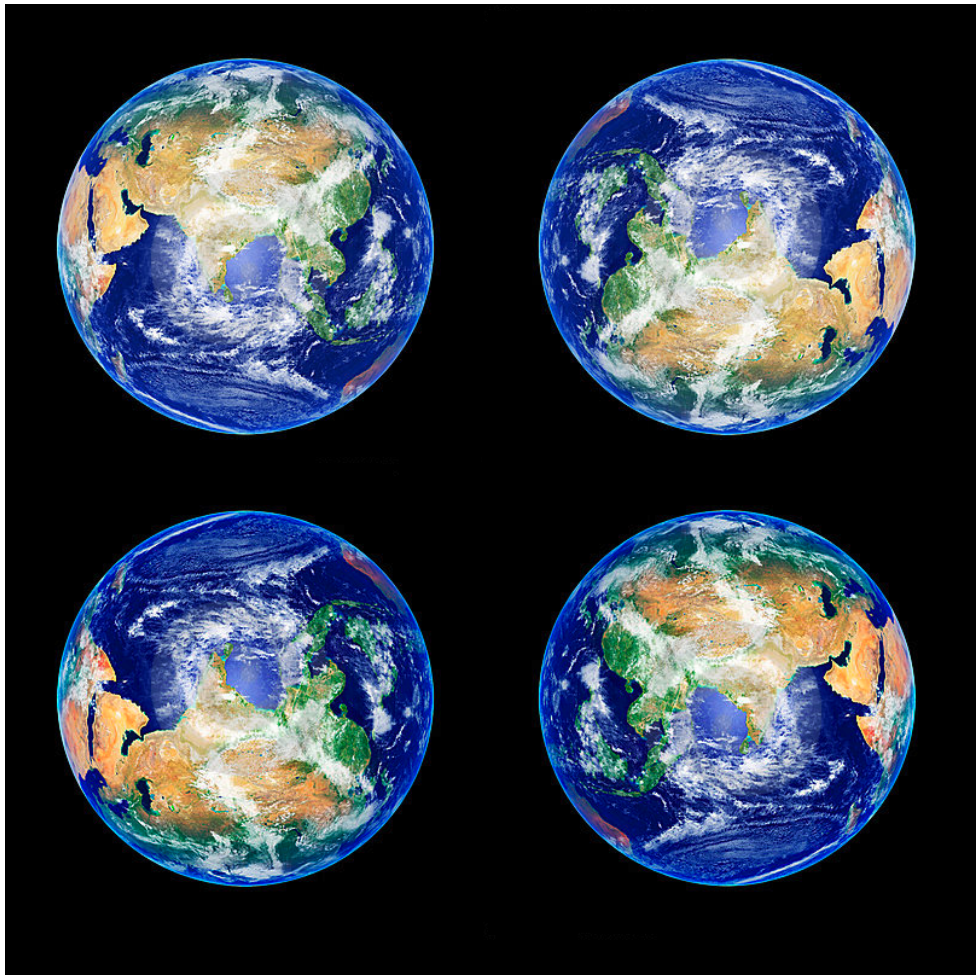

NB: Spatial asymmetry doesn't answer the question!

Similarly for time

What would it take to make these **different** worlds?

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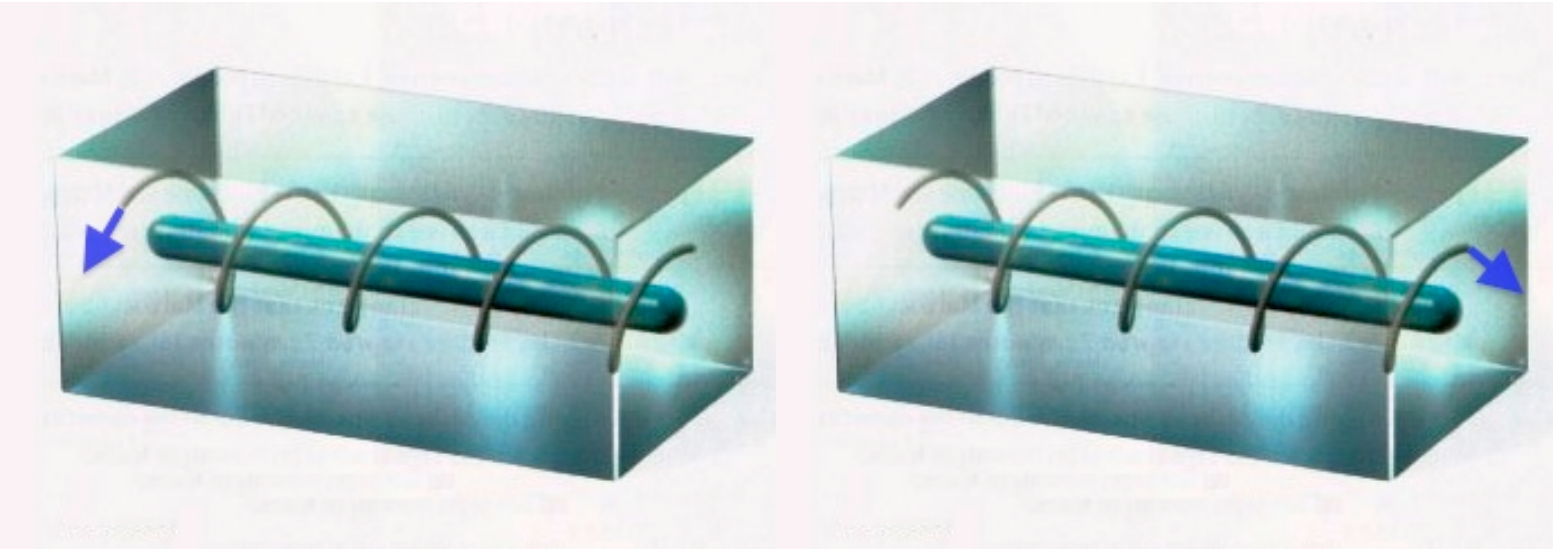

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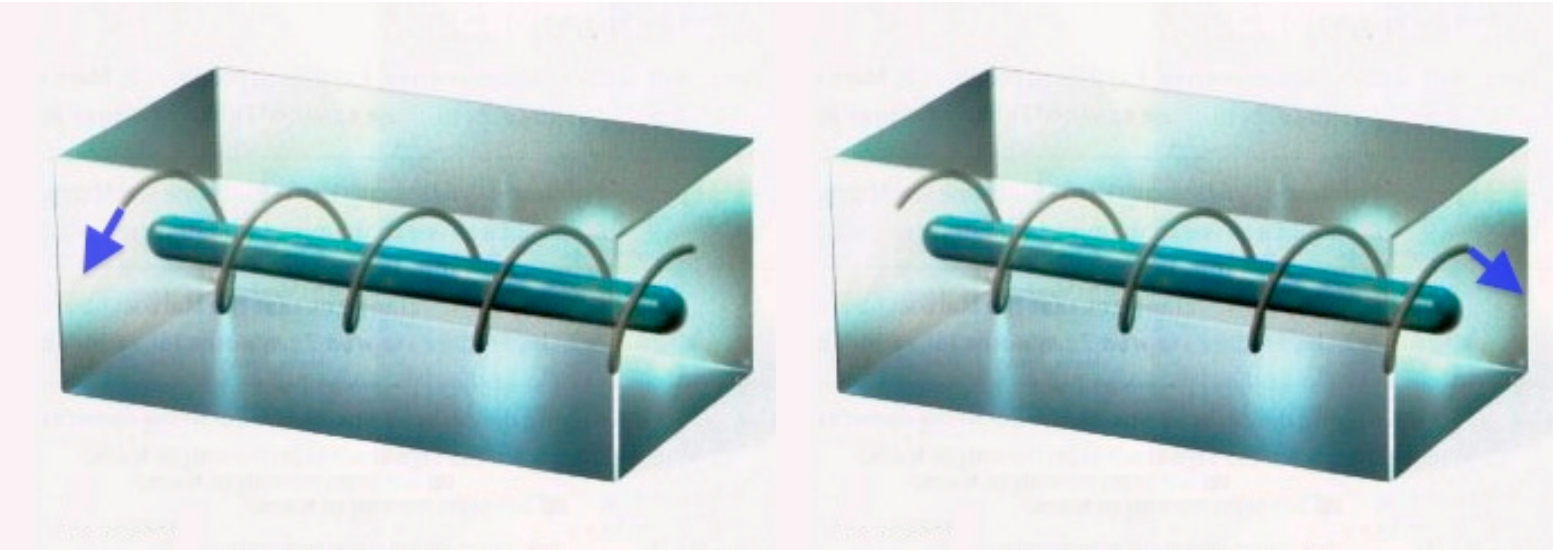
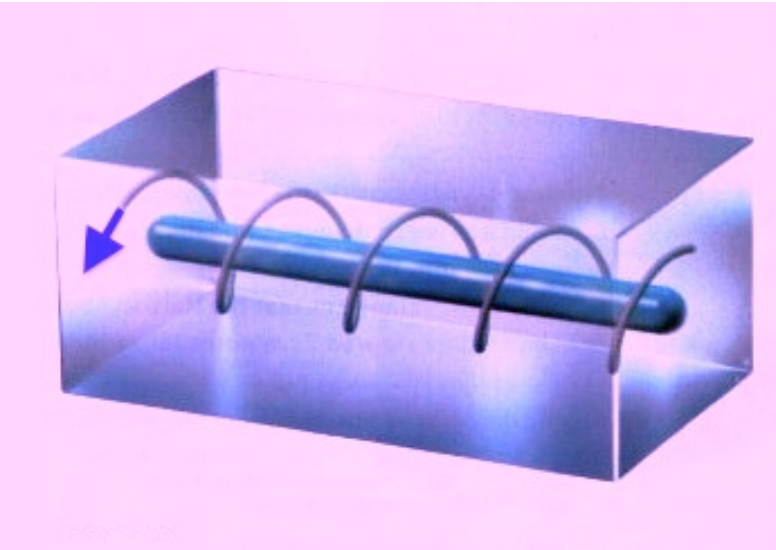
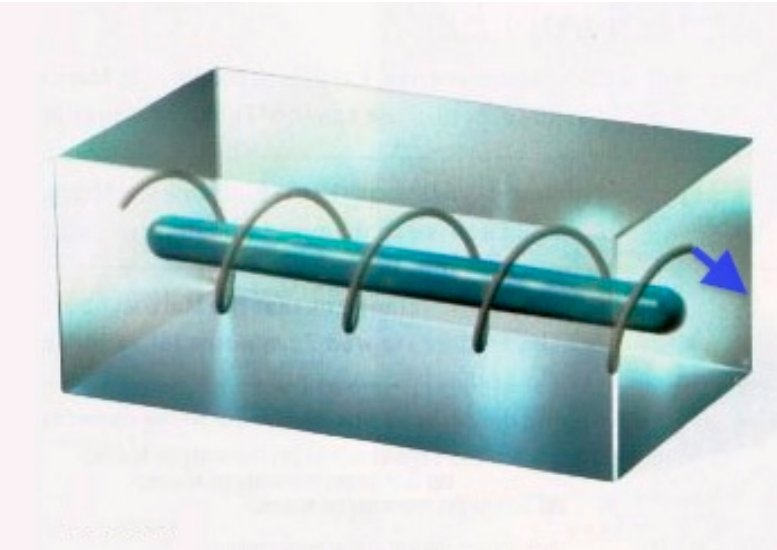


NB1: Time-asymmetry isn't enough!

Similarly for time





NB2: It needs to be the right sort of difference … but what would that be?

Does time have a 'rate'? A dialogue

- Parm: If time passes, how fast does it pass?
- Hera: At one hour per hour (like, DUH!)
- Parm: Isn't it a problem that no other answer makes sense? Doesn't it suggest it wasn't a question about anything we could *discover*?
- Hera: No, it's a feature, not a fault – it *is* 'just obvious' that time passes!
- Parm: Unlike space?
- Hera: Yes! (And like, DUH, again!)
- Parm: Doesn't space extend west (say) at one metre per metre? In other words, if you move a metre west you've travelled a metre to the west, right?
- Hera: (Face palm) Sure, but I don't think this conversation is 'going anywhere'! (Get it?)
- Parm: But then what's the difference between time and space? This notion of 'rate of change' is so trivial that it applies to both, each in its own terms.

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– D. C. Williams, 'The Myth of Passage'.

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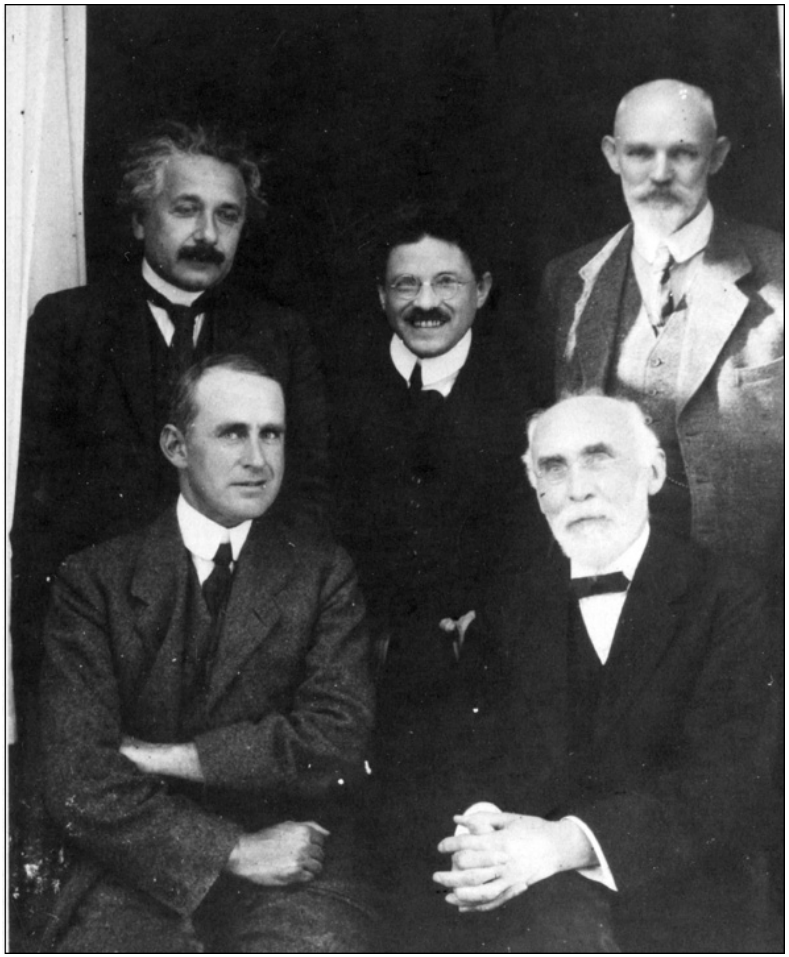
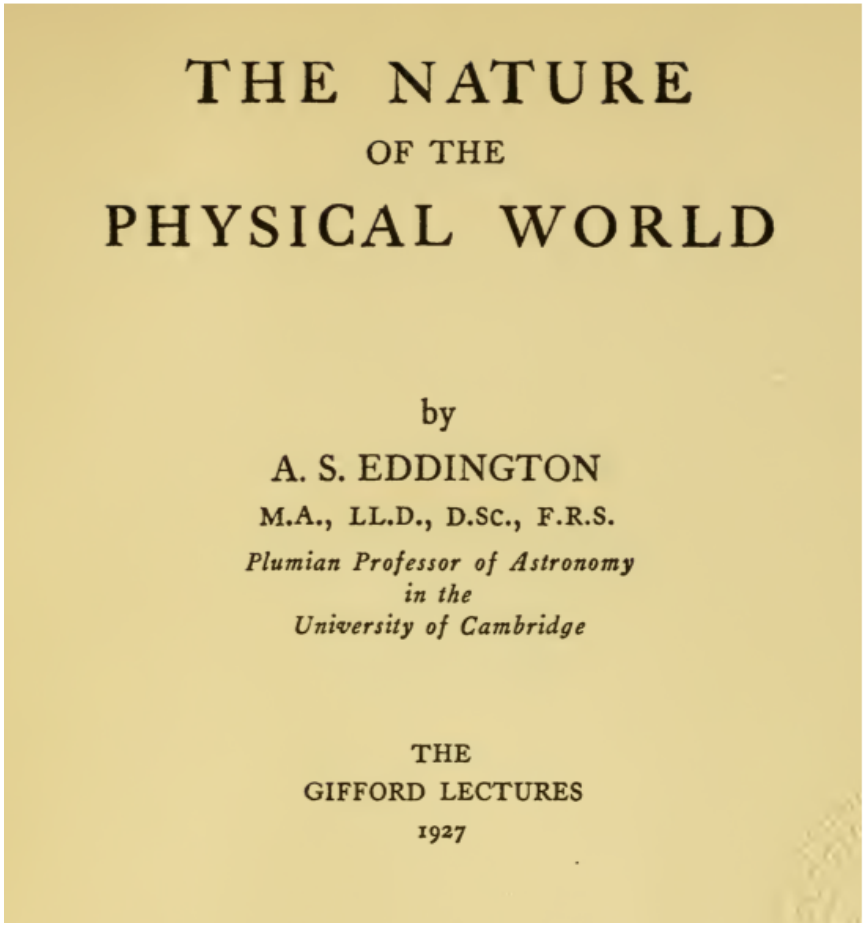
"His universe expanded into popularity" – TIME, 1934



Eddington (lower left) with Einstein, Ehrenfest, Lorentz and de Sitter. [Emilio Segrè Archives]

The origins of 'Time's Arrow'



THE NATURE
OF THE
PHYSICAL WORLD

by
A. S. EDDINGTON
M.A., LL.D., D.Sc., F.R.S.
Plumian Professor of Astronomy
in the
University of Cambridge

THE
GIFFORD LECTURES
1927

The origins of 'Time's Arrow'

68 THE RUNNING-DOWN OF THE UNIVERSE

Time's Arrow. The great thing about time is that it goes on. But this is an aspect of it which the physicist sometimes seems inclined to neglect. In the four-dimensional world considered in the last chapter the events past and future lie spread out before us as in a map. The events are there in their proper spatial and temporal relation; but there is no indication that they undergo what has been described as "the formality of taking place", and the question of their doing or undoing does not arise. We see in the map the path from past to future or from future to past; but there is no signboard to indicate that it is a one-way street. Something must be added to the geometrical conceptions comprised in Minkowski's world before it becomes a complete picture of the world as we know it.

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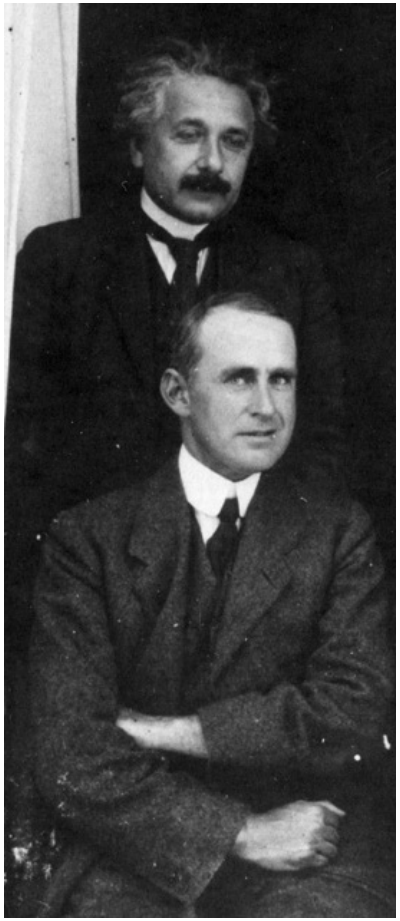
"[T]he second law of thermodynamics … opens up a new province of knowledge, the study of organization; and it is in connection with organization that **time-flow and a distinction between doing and undoing appear for the first time.**"

A 'private door' onto a one-way street?



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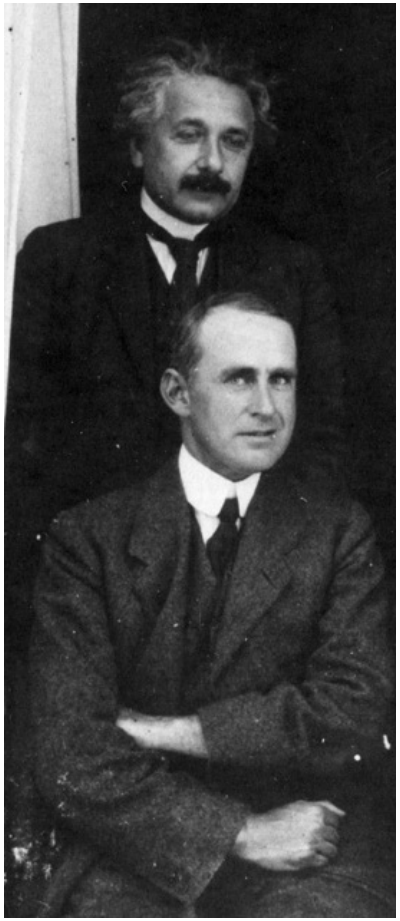

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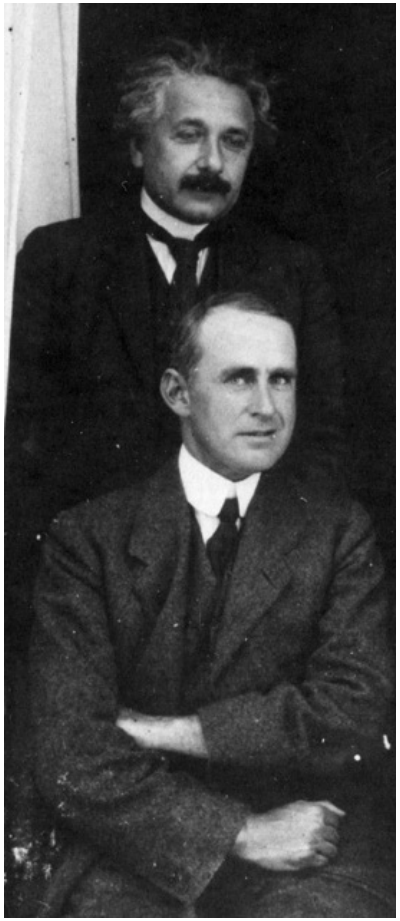

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No doubt some will reply that they are content; to these I would say—Then **show your good faith by reversing the dynamic quality of time** (which you may freely do if it has no importance in Nature), and, just for a change, give us a picture of the universe passing from the more random to the less random state …"

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"If you are an astronomer, tell how waves of light hurry in from the depths of space and condense on to stars; how the complex solar system unwinds itself into the evenness of a nebula. …

If you genuinely believe that a contra-evolutionary theory is just as true and as significant as an evolutionary theory, **surely it is time that a protest should be made against the entirely one-sided version currently taught.**" (1928: 91–92)

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Meeting Eddington's Challenge

First step:

1. Remember Boltzmann on 'up' and 'down'.
2. Suppose someone challenged the view that 'up' isn't objective, by saying "Just try living your life upside-down!"
3. **Answer:** We can't do it **around here**, but we can if we move somewhere else.

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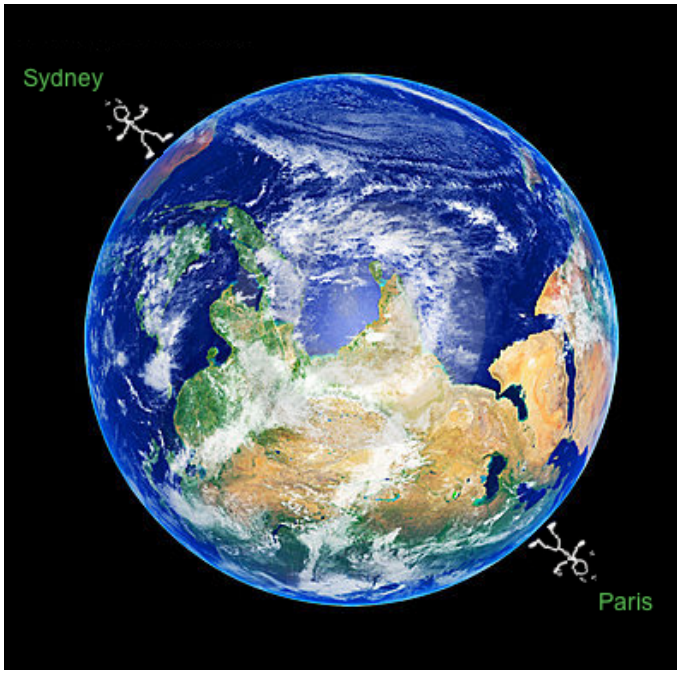

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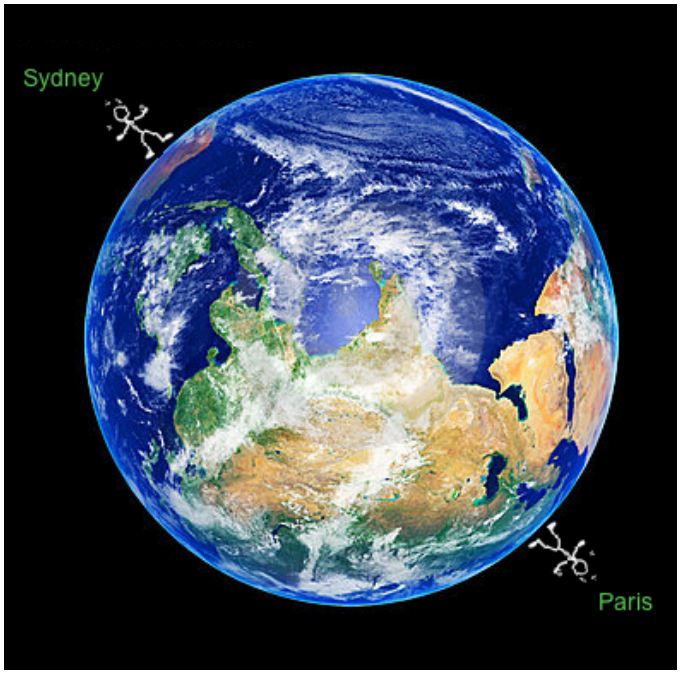

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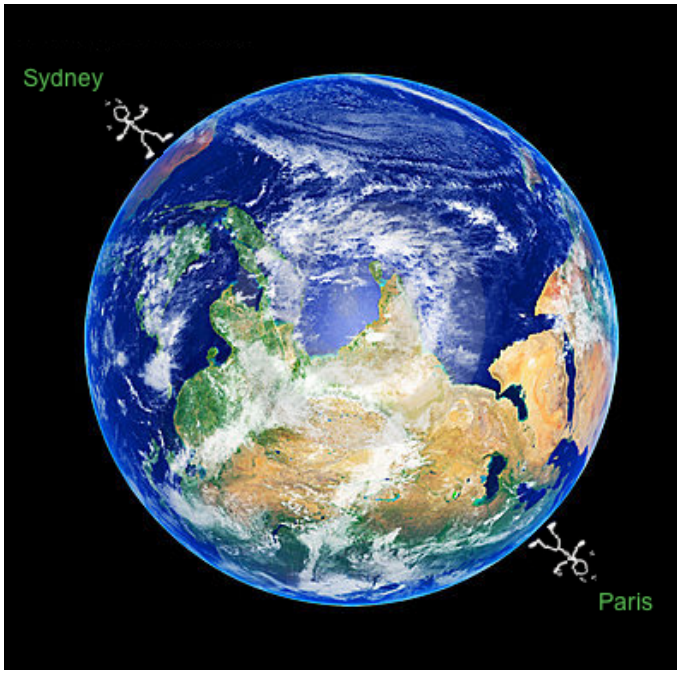

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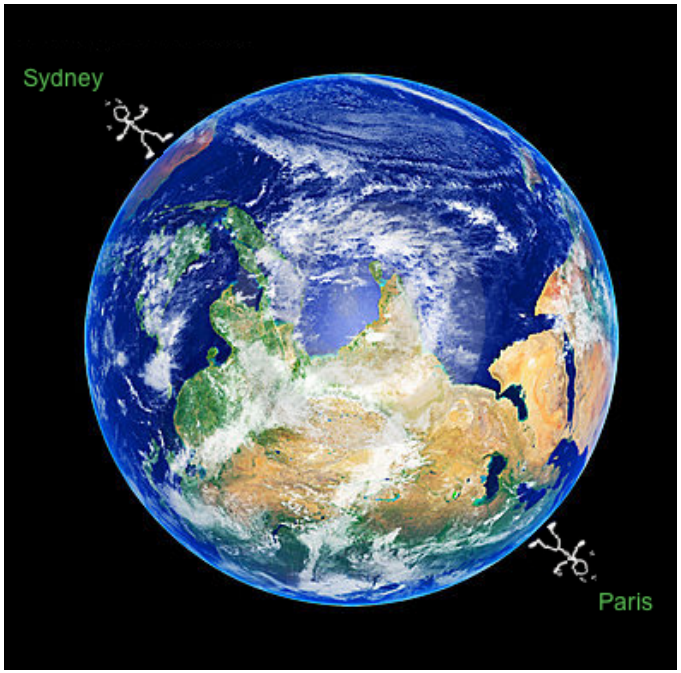

Applying this to the direction of time

Distinguish three cases:

1. Around here.
2. The very big.
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Around here

In our region (**very** broadly construed):

- Physics is dominated by special initial conditions.
- Here, Eddington is right: 'randomness' only works in one direction.
- The real puzzle is why it doesn't work towards the 'past' – and the answer seems to lie in cosmology.

"We are thus driven to admit anti-chance; and apparently the best thing we can do with it is to sweep it up into a heap at the beginning of time." (Eddington, 1931)

But this leaves two other scales to consider:

- 'Above' and 'below' the anomaly.

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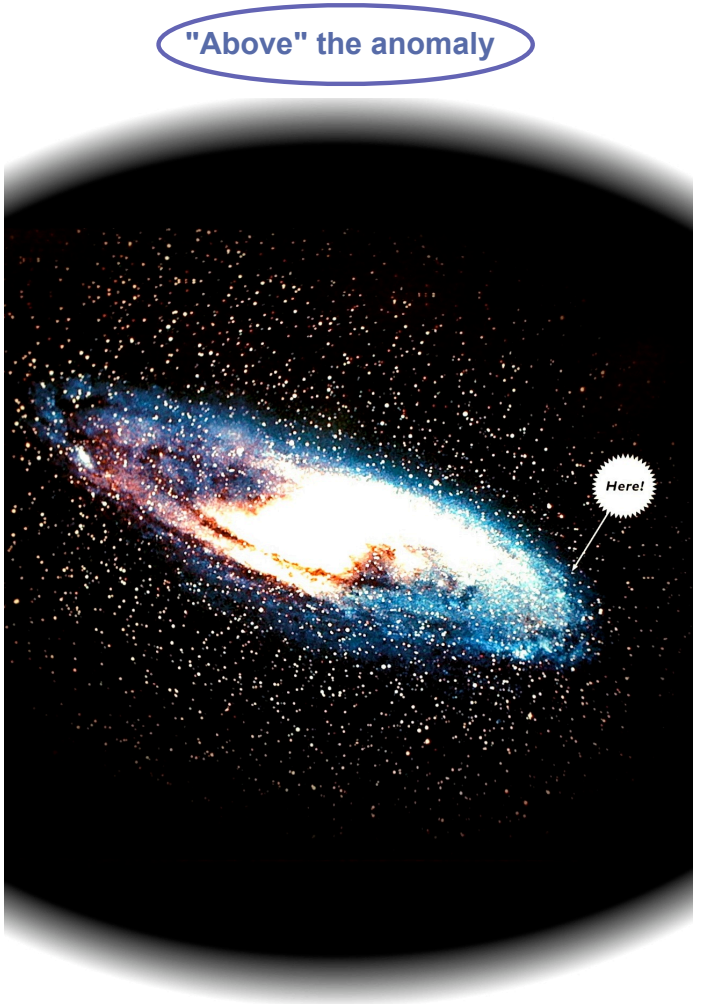

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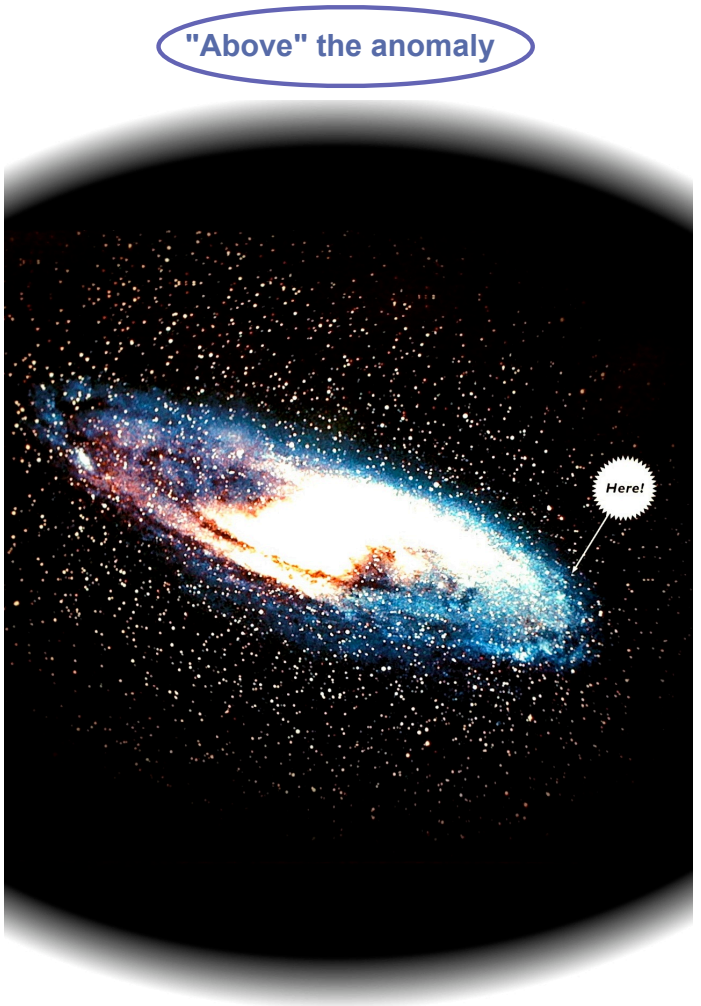

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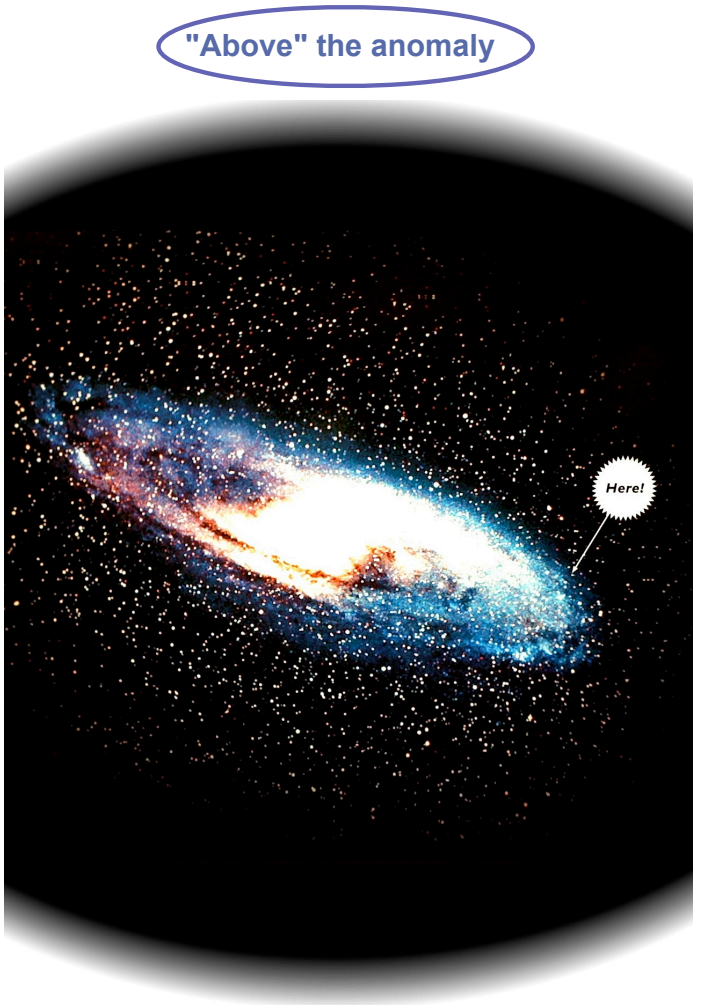

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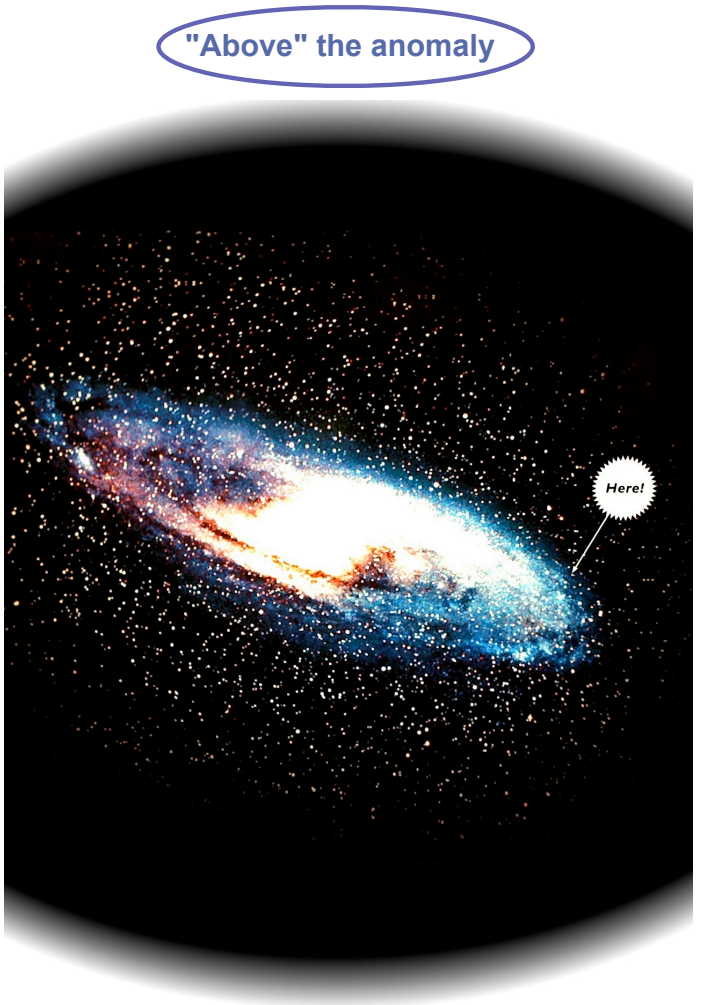

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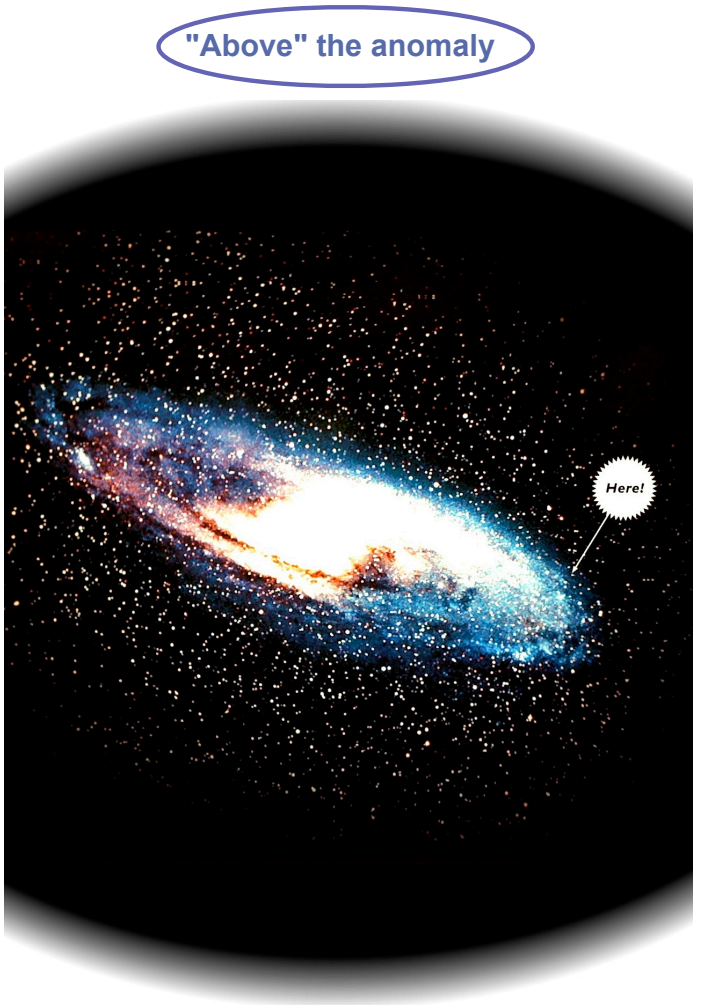

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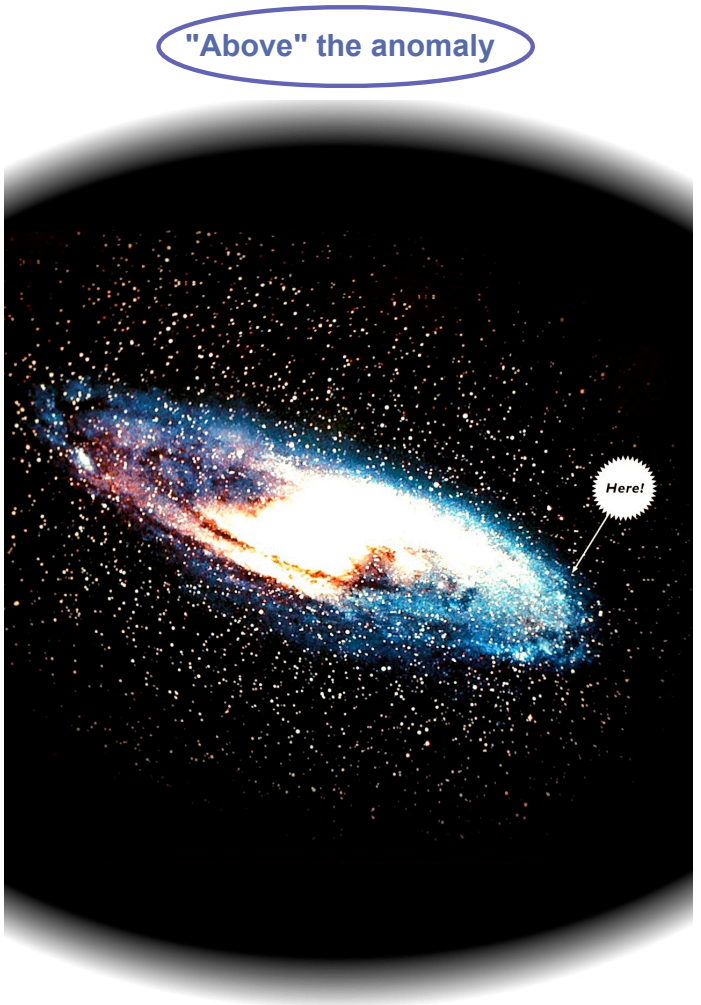

Above the anomaly: an example

"The ultra-large-scale structure of the universe: Starting from a generic state, it can be evolved both forward and backward in time, as it approaches an empty de Sitter configuration. Eventually, fluctuations lead to the onset of inflation in the far past and far future of the starting slice. The arrow of time is reversed in these two regimes."

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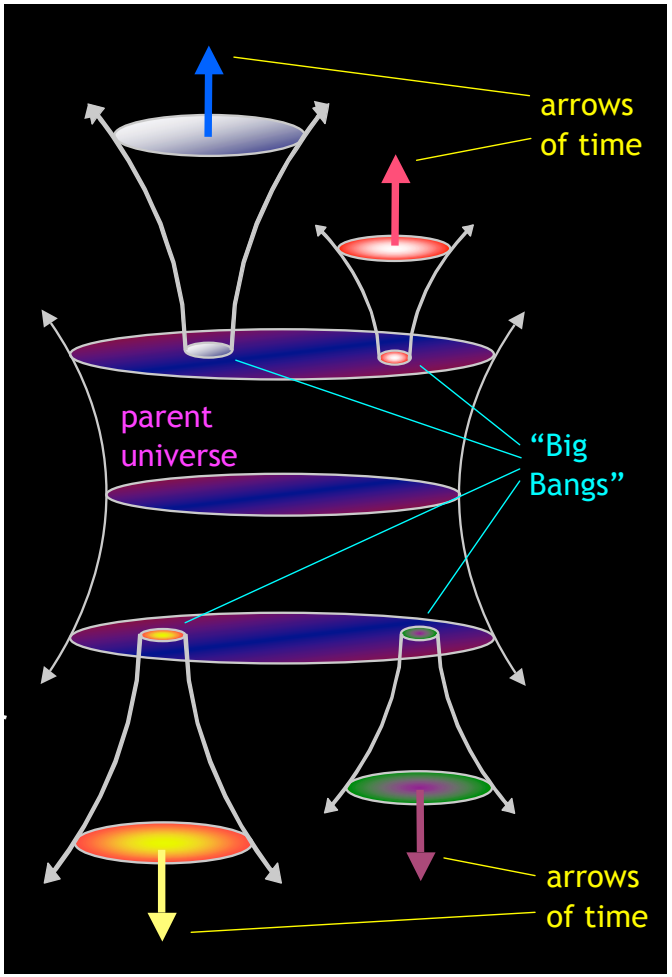

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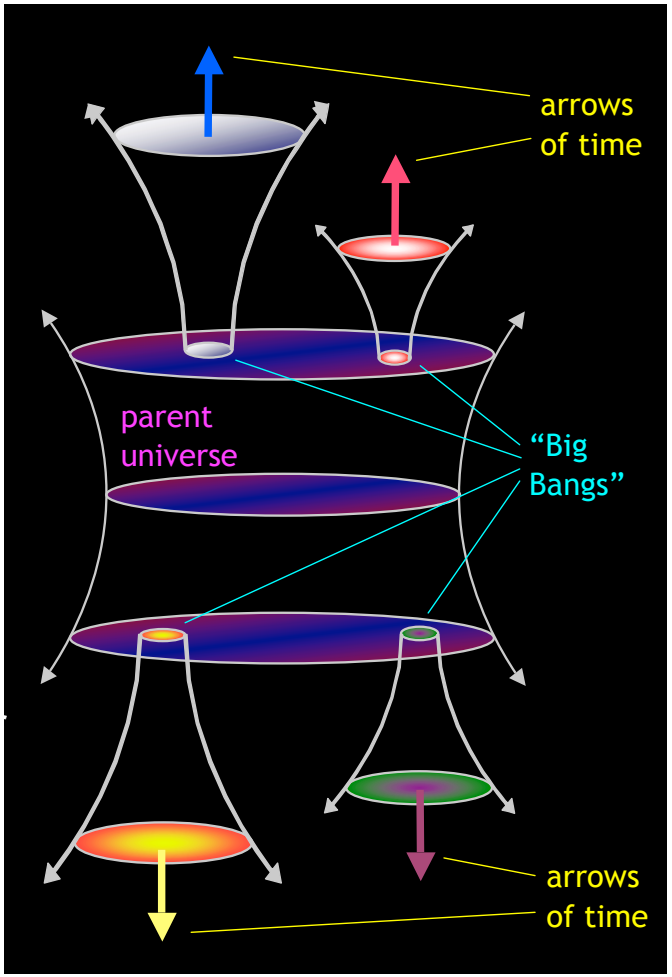

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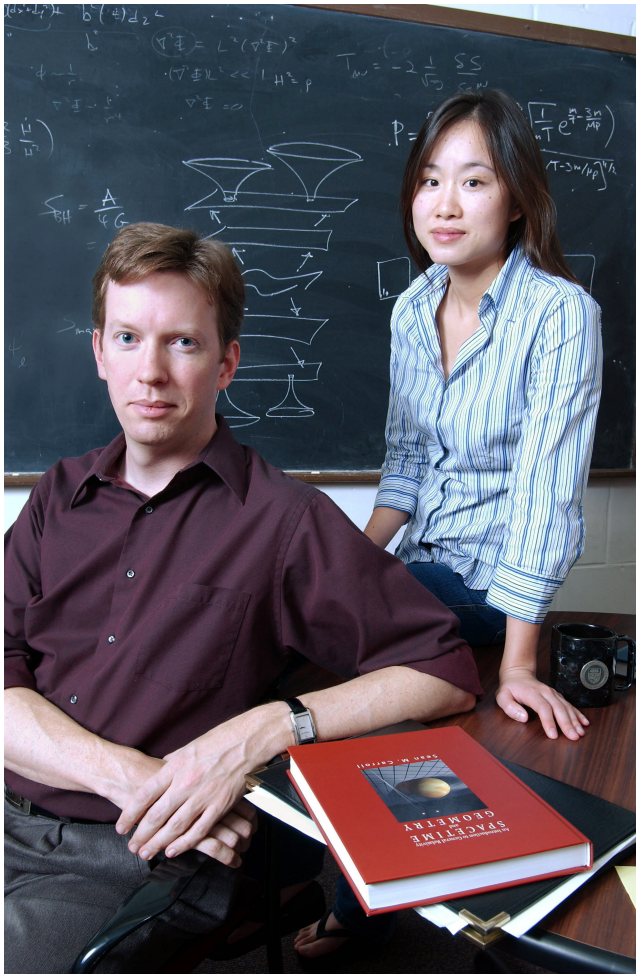

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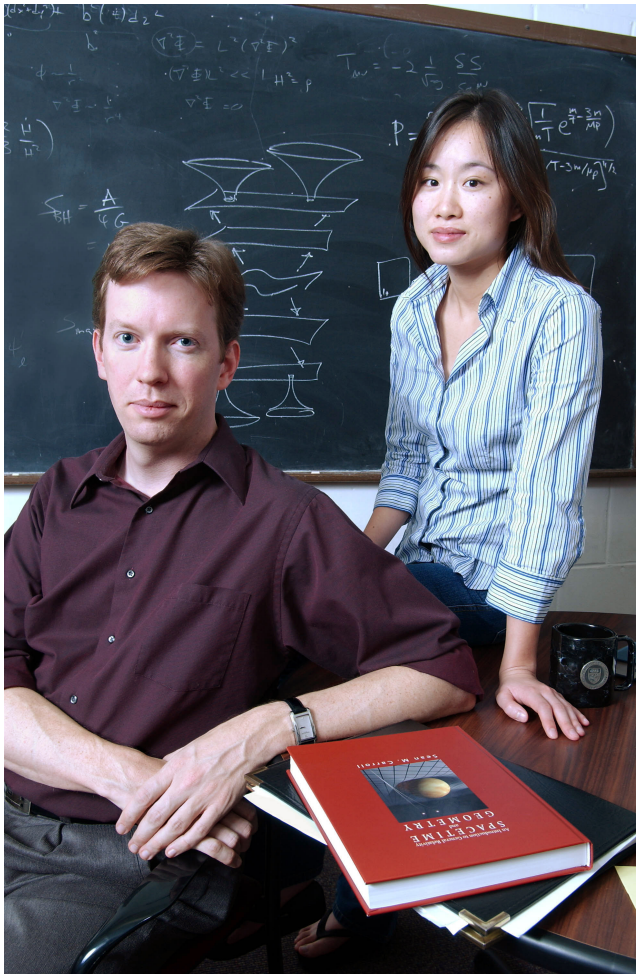

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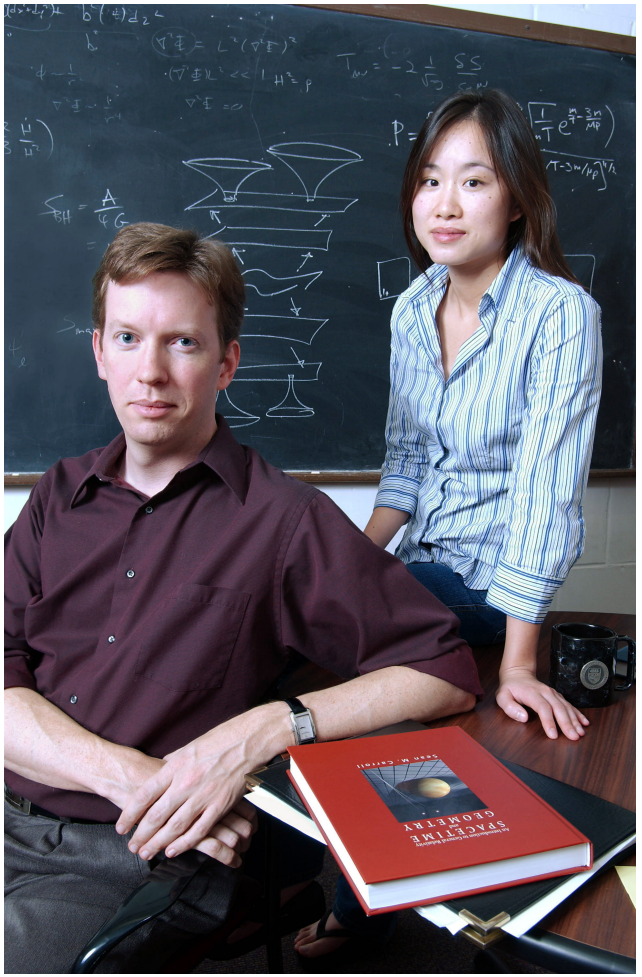

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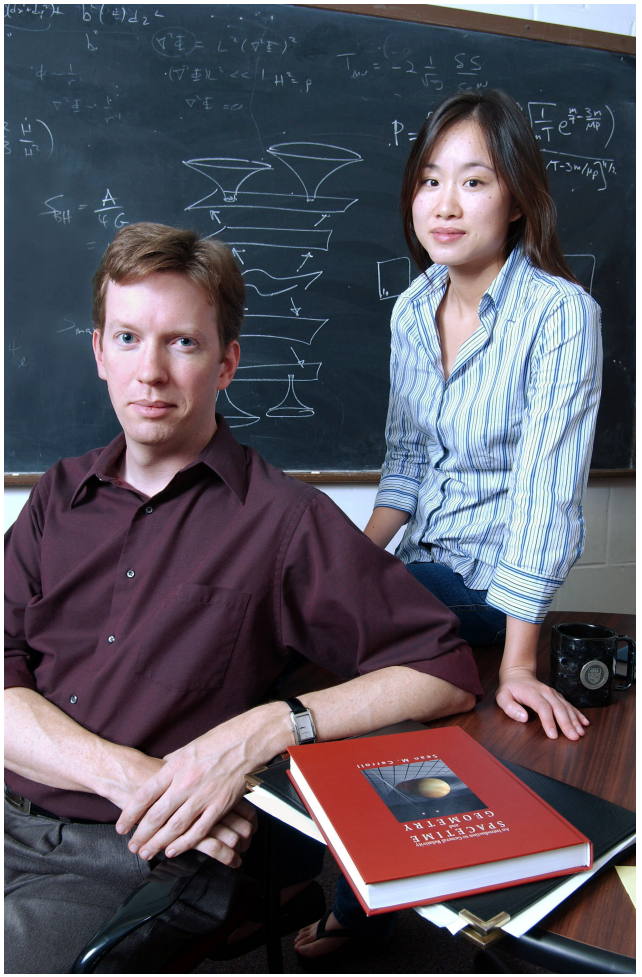

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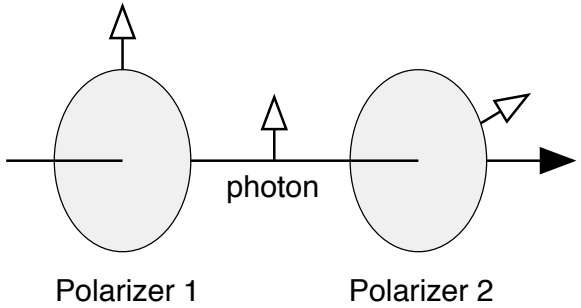

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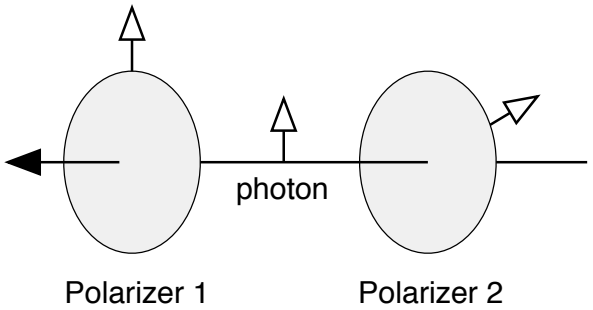

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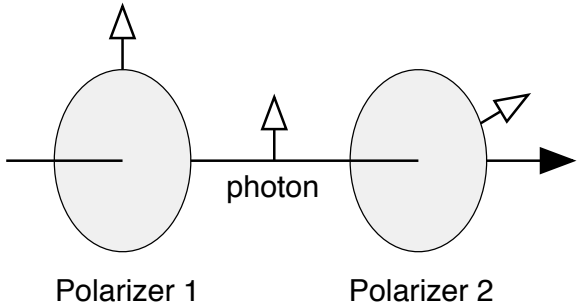

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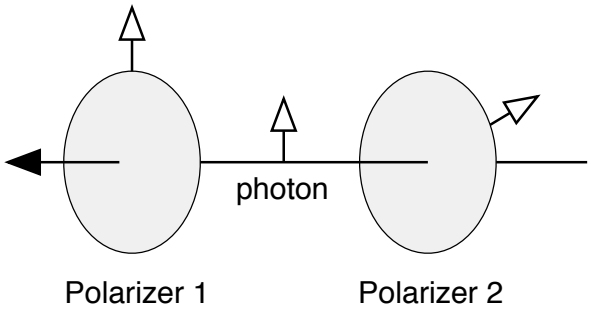

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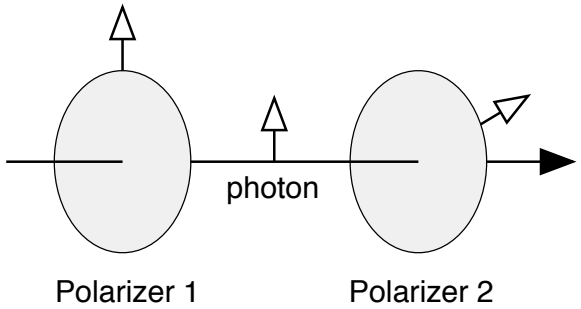

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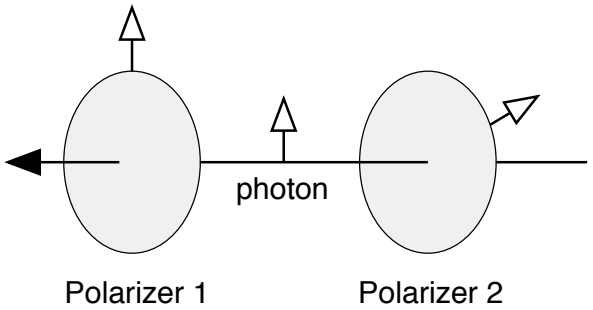

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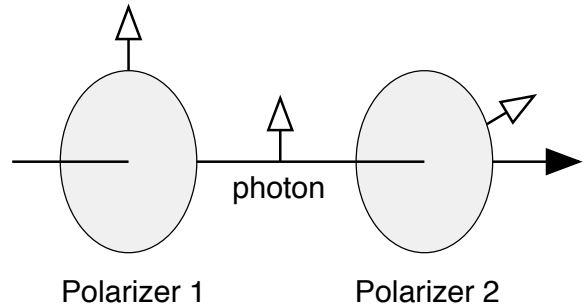

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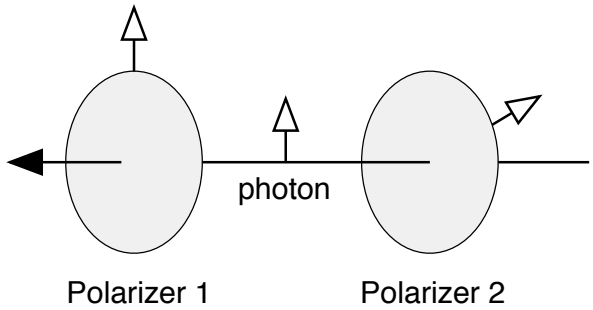

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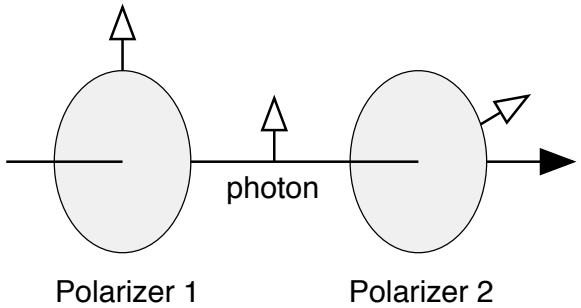

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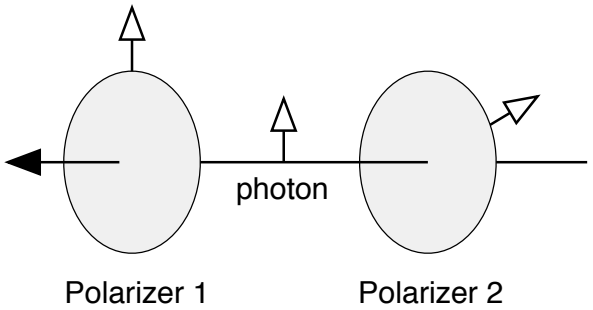

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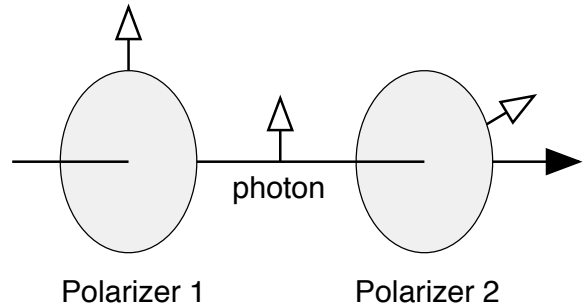

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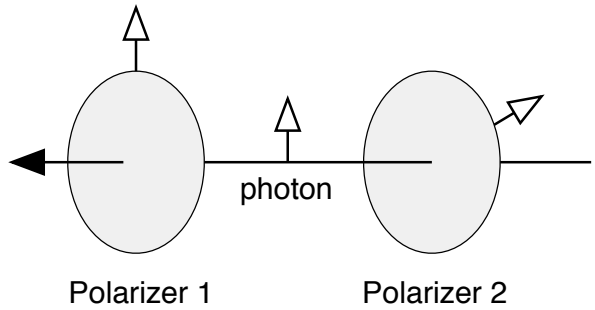
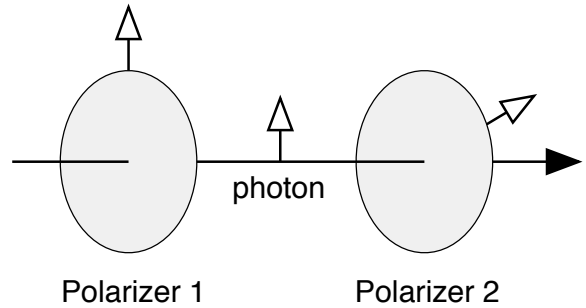


Disallowed

A puzzle about QM

- But most people assume that the same should be true of any plausible HV theory, underlying QM. (It is assumed by all 'No Hidden Variable' theorems.)
- Could this be an 'unjustified extrapolation' of the familiar time-asymmetry?
- If so, we've been missing something big, by not facing up to Eddington's Challenge.
- (See, e.g., **arXiv:1001.5057**, **1002.0906**, **1508.01140**.)



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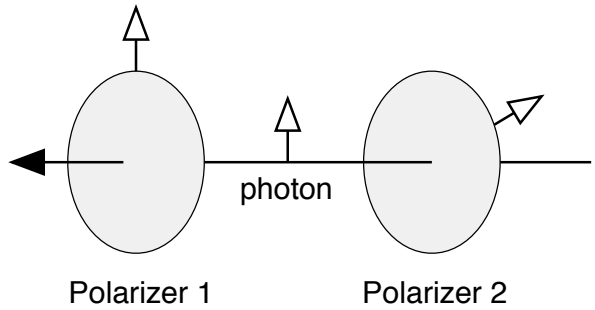

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Why this matters

- Distinguishing 'objective' from 'subjective' – i.e., **what's in the world**, from **what comes from us** – is one of the defining projects both of physics and philosophy.
- In the case of time, the distinction itself is still in flux: we haven't agreed on what's objective, and what comes from us (or from special features of our neighbourhood).
- (Three key ingredients: direction, 'flow', and the status of the 'now'.)
- **My view:** Physics is in transition – (mostly) committed to the view that these are not objective, but not yet comfortable with the consequences of that.
- Eddington may have made the wrong call – his map of the terrain certainly needs some attention – but he saw what was at stake, with a clarity that has rarely been matched.

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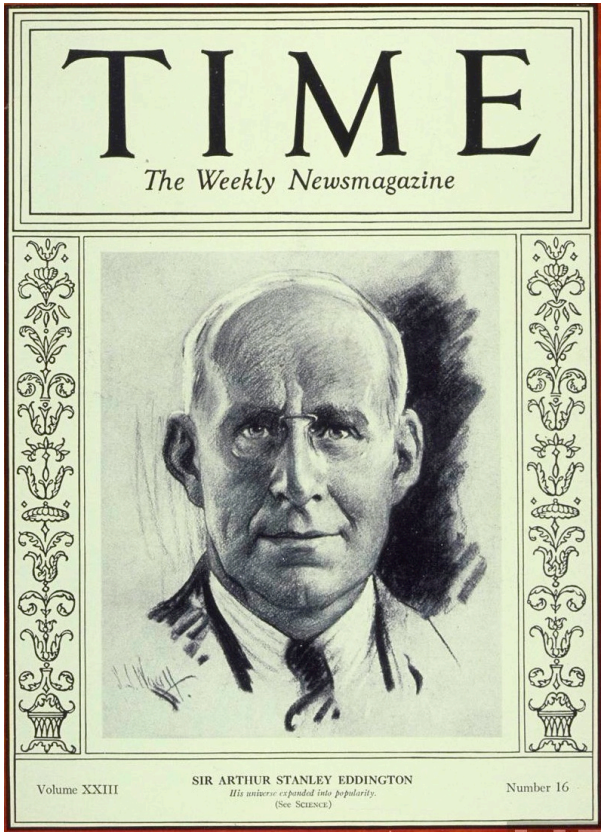

"One of mankind's most reassuring cosmic thinkers … he discoursed on his cosmic subject with a wit and clarity rare among scientists."

– TIME, December 4, 1944.