

Title: Causality and Becoming

Date: Jun 30, 2016 10:00 AM

URL: <http://pirsa.org/16060118>

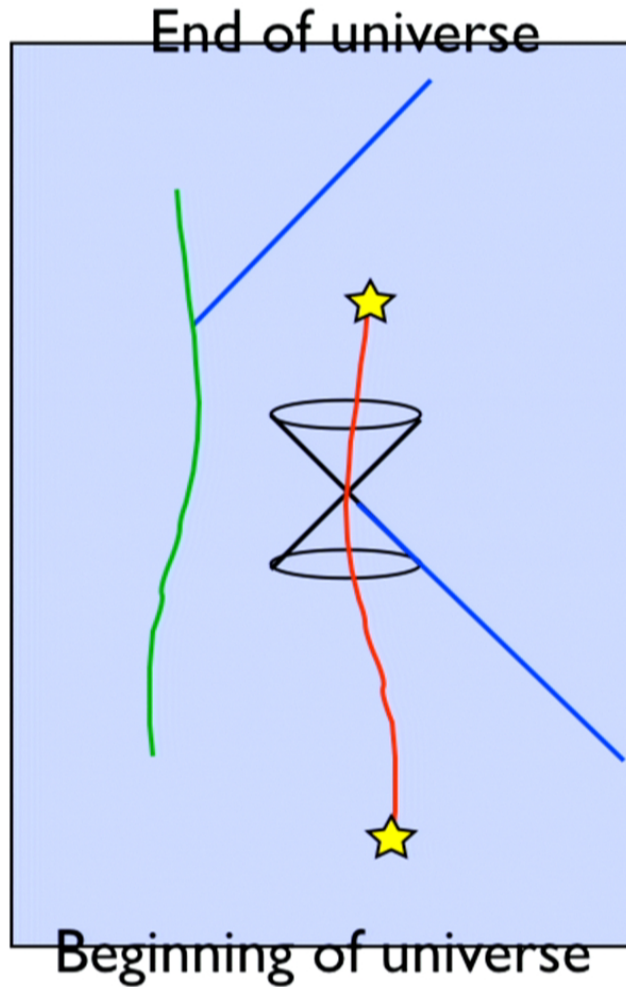
Abstract:

In pre-relativistic physics, time was lost by being “spatialised” as (merely) a fourth dimension.

In General Relativity, physical time is proper time and elapses **locally** along worldlines. GR undoes the spatialisation of time because temporal order is a **partial order not a linear order**.

There is no global Now in GR & the physical world is a spacetime. This has suggested a “block universe” view to many physicists and philosophers.

The Physical world as a block

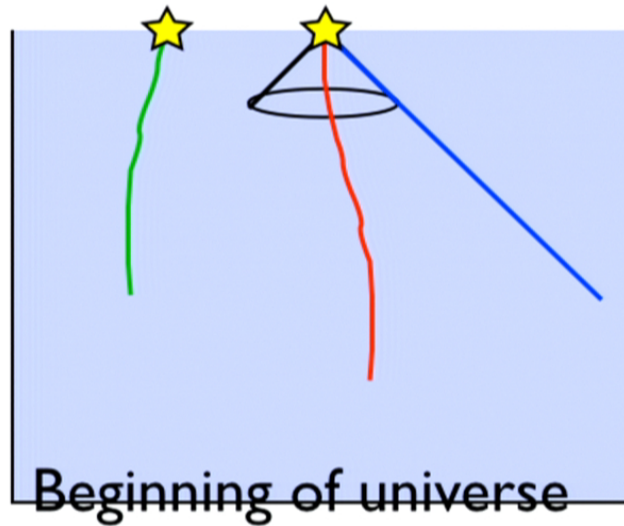


A la recherche du temps perdu

To do justice to the temporal nature of our perception whilst maintaining the spacetime nature of the physical world in General Relativity, a “growing block” seems to be called for (**Broad**):

This requires a physical process of “becoming”

Unveiling
is a
synchronised
becoming



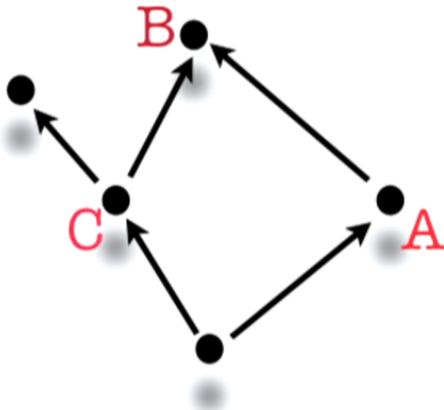
The process of becoming **cannot** be such an unveiling of the block because that would introduce a physical, global time. Is it possible to realise becoming within physics **without** a global time, what R. Sorkin calls “asynchronous becoming”?

This goal can act as a **heuristic** in the quest to create new physics: quantum gravity.

Causal sets: the marriage of causal order and atomicity

It is widely expected that spacetime will not be well-described by a differentiable Lorentzian manifold close to the Planck scale. Spacetime atomicity is perhaps the simplest way to realise this expectation.

Causal set theory is an approach to quantum gravity based on the hypothesis that spacetime is fundamentally discrete or atomic and takes the form of a transitive, directed, acyclic graph or “discrete order” or “causet”



'tHooft; Myrheim;
Bombelli, Lee, Meyer, Sorkin

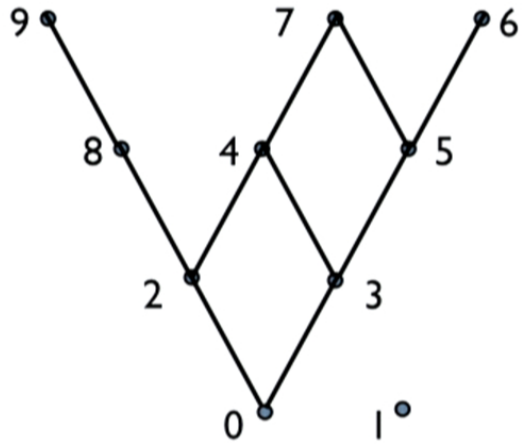
The elements are the atoms of spacetime. At macroscopic scales, the order relation gives rise to the spacetime causal order and the number of elements gives the 4-d spacetime volume.

Dynamical emergence of GR

- Let us assume “kinematical emergence” of continuum spacetime from causal sets: a causal set **can** contain all the geometrical information of a Lorentzian spacetime on scales larger than the discreteness scale.
- To claim that GR emerges from quantum gravity, such causal sets, approximate-able by solutions of the Einstein equations, must arise **dynamically** in the fundamental theory.
- Causal sets are inimical to a Hamiltonian approach so we take the Path Integral as the basis for a Quantum Causal Set Dynamics.
- Attitude: Path Integral Quantum Theory is a species of generalised stochastic process. Quantum Mechanics is a generalisation of Brownian motion.
- Therefore, as a warm up for **quantum** causal set theory, we try to construct **classical stochastic** models for causal sets. Here, the notion of **Becoming** played a heuristic role in the discovery of an interesting class of models: Classical Sequential Growth

Classical sequential growth models (Rideout&Sorkin)

A random process of continual **births** of new spacetime atoms



The same causal set (with different labels) can be grown in other ways.

Asynchronous becoming

- The physical order in which spacetime atoms are born is their order in the resulting causal set, a partial order: there's no global time.
- The “present” is **not** any particular collection of spacetime atoms, the present is the birth process itself
- There is no “god’s eye view” of the physical world: the birth process is objective but the “world that exists now” is subjective and is the causet to the past of a particular spacetime atom being born.

“[The model] provides an objective correlate of our subjective perception of “time passing” in the unceasing cascade of birth-events” **Sorkin**

This aspect of time — that we experience it passing — seems not to be captured in GR in the Block Universe picture. So, if the birth of space-time atoms survives as a process in full quantum gravity, the passage of time will not be “emergent” but fundamental.

The Parable of the Sceptical Newtonian!

17th Century Scientist: There is a physical force of weight on you -- look at celestial mechanics, etc. The Newtonian theory perfectly accounts for all that data

17th Century Sceptic: But I don't experience this gravitational force of weight whereas I do experience other forces of comparable magnitude.

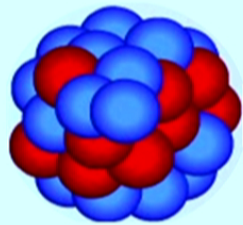
Scientist : The force of weight exists. So your lack of experience of lack of force must be due to neurology, psychology, the way the mind and body work to produce experience.

Sceptic: Maybe. But maybe this is telling us to look for a theory in which there is no force of weight.

Note I: The lack of experience of a force of weight did not contradict Newtonian gravity, it was **not even a fact** within it. The 17th Century Scientist held an unassailable position!

Note II: The lack of experience of a force of weight is evidence from a regime far from that in which **full GR** is required (strong gravity).

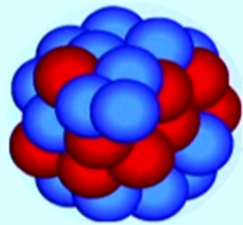
“Nothing happens until emission”





An absorber, even very far away and operating much later, takes an integral part in the process by merely **non-absorbing!**

WRONG!



Decay and the uncertainty principle

- decaying state is a system with uncertainty of lifetime (i.e. mean life τ) that is bound to the uncertainty of total energy given by:

$$\Delta E \Delta t \geq \frac{\hbar}{2}$$

- uncertainty in energy of an excited state is reflected in the line shape of the radiation emitted in decay to the ground state.

➔ probability of measuring energy E given by *Lorentzian* distribution:

$$P(E) = \frac{1}{(E - E_0)^2 + \Gamma^2/4}$$

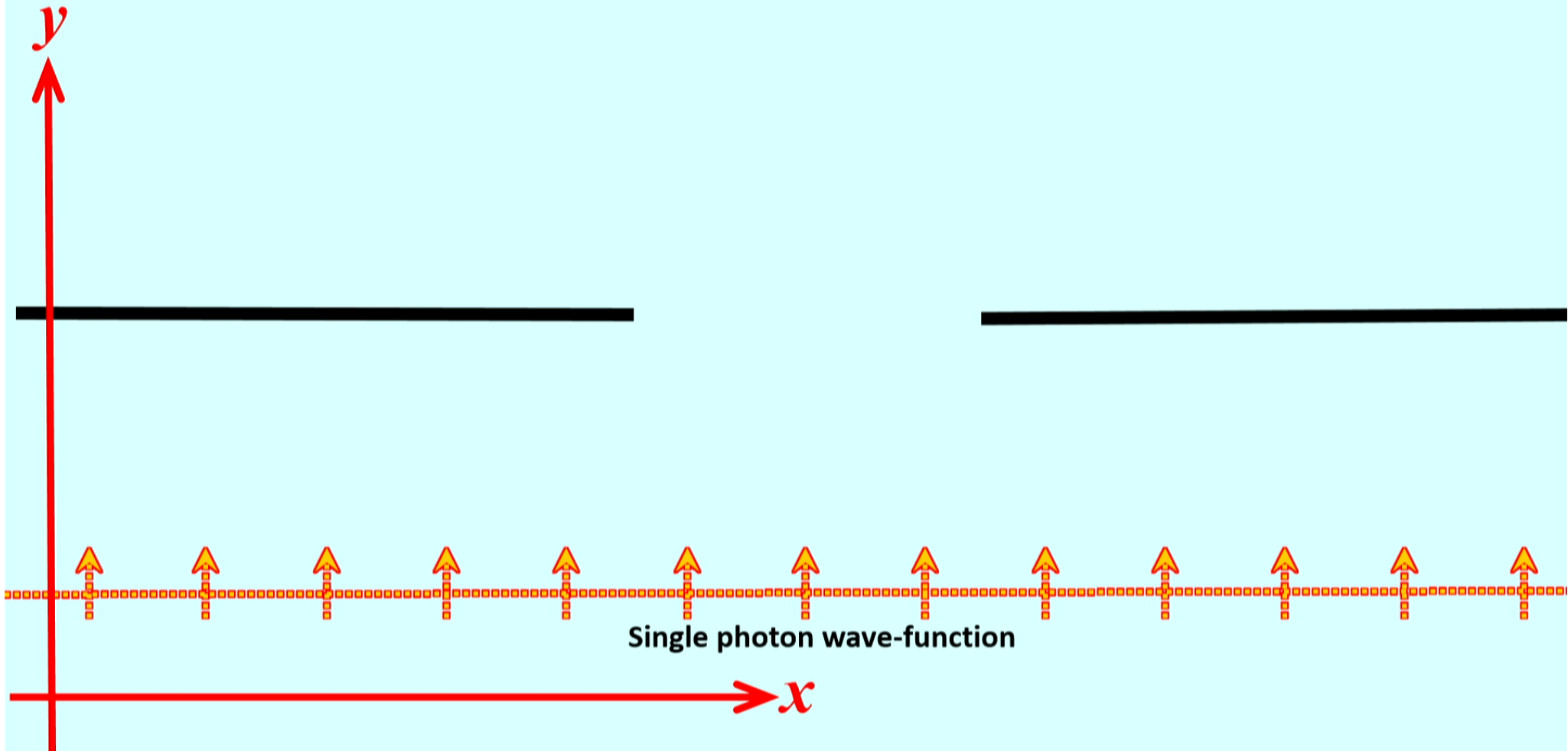
E_0 is the central energy
 Γ is full width in half height (FWHM)

- because Γ is FWHM then $\frac{\Gamma}{2} = \Delta E$ and thus $\Gamma = \hbar\omega = \frac{\hbar}{\tau}$

Conclusion

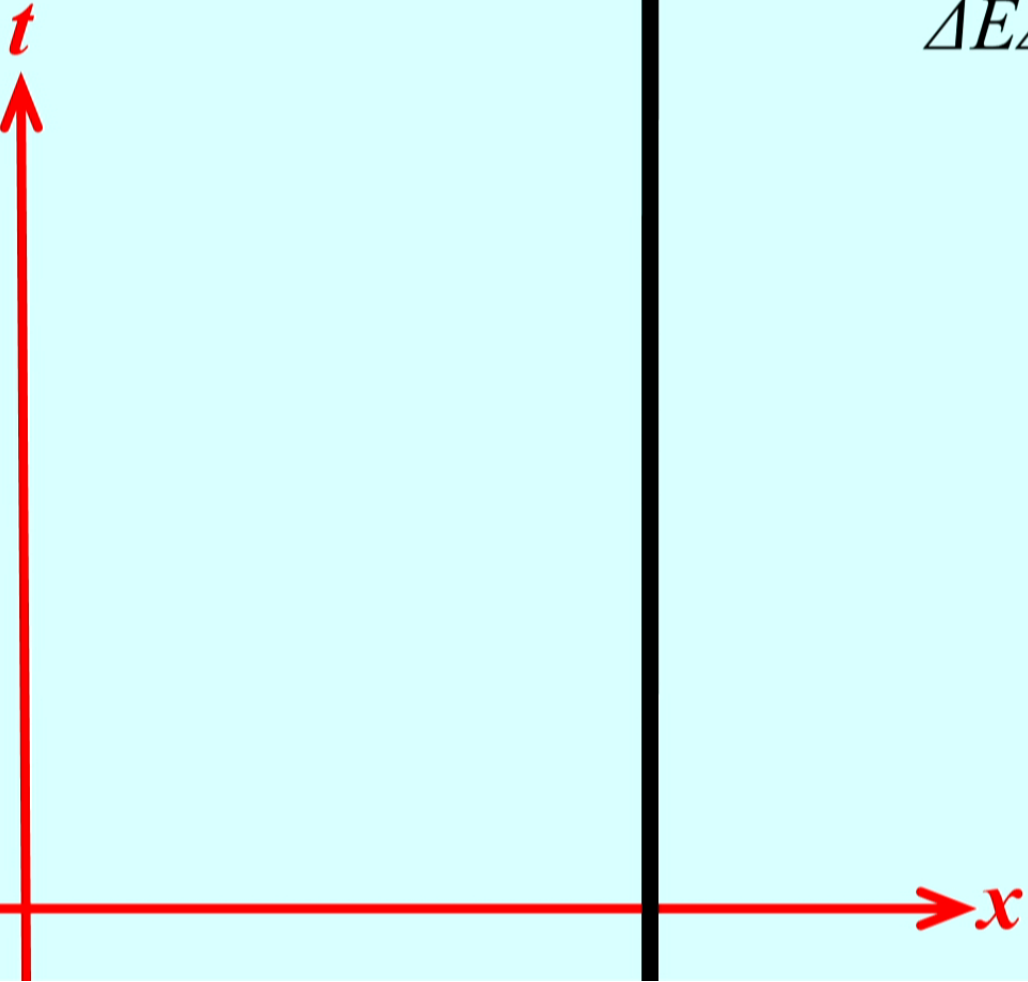
In every emission which is subject to the time/energy uncertainty, the source is constantly being measured, *with observable consequences*, even though no particle seems to be emitted.

Spatial IFM

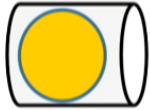


Temporal IFM

$$\Delta E \Delta t \geq \frac{\hbar}{2}$$



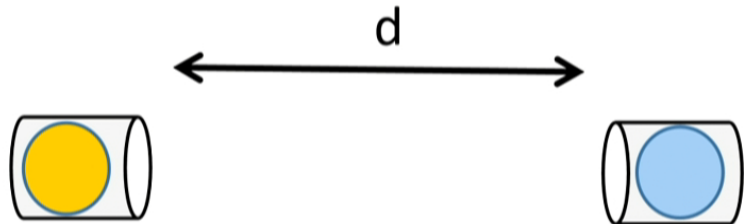
The Quantum Liar Paradox version 2



1. Prepare 1 excited & 1 ground atom

More precisely, the state in Version 2, stage 2 is $\frac{1}{\sqrt{2+\delta}} [\sqrt{1+\varepsilon} |A_1\rangle |A_2^*\rangle + \sqrt{1-\varepsilon} |A_1^*\rangle |A_2\rangle + \sqrt{\delta} |A_1\rangle |A_2\rangle]$
where $\varepsilon, \delta \ll 1$.

The Quantum Liar Paradox version 2



1. Prepare 1 excited & 1 ground atom

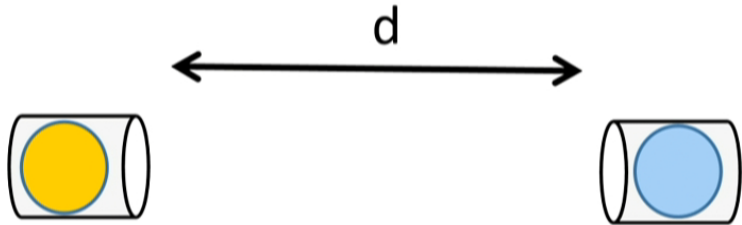


2. Close the left cavity after time τ
and the right after time $\tau + d/c$. You get:

$$\frac{1}{\sqrt{2}} (|A_1\rangle|A_2^*\rangle + |A_1^*\rangle|A_2\rangle)$$

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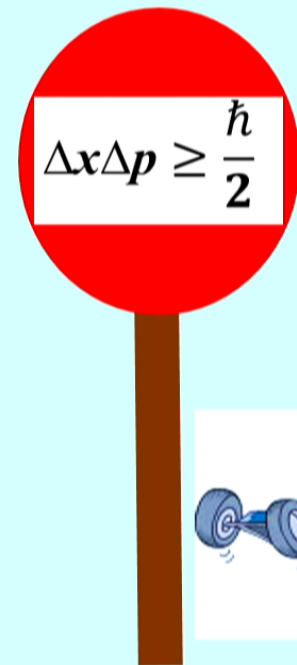
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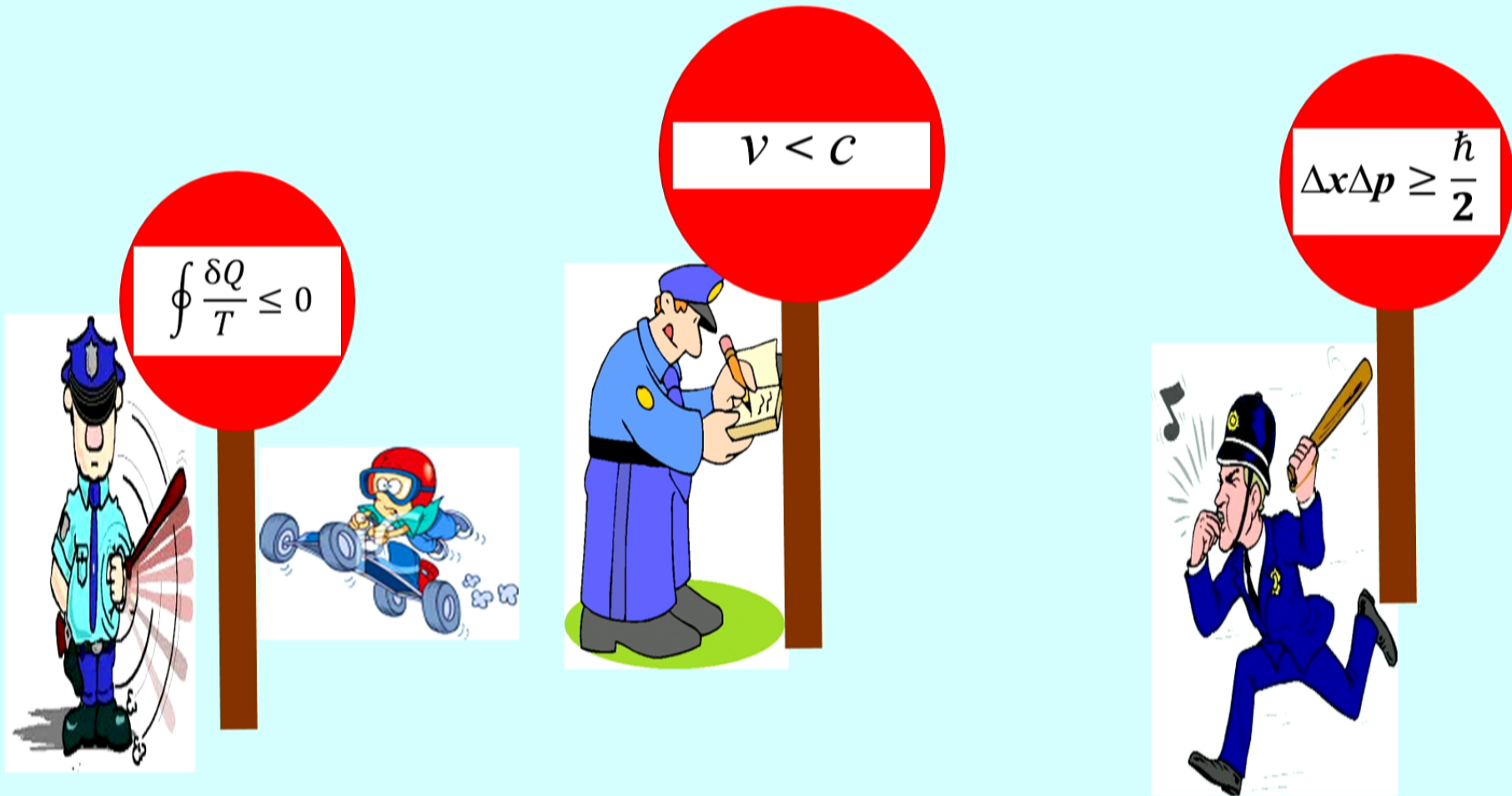


3. Measure for excited/ground.
Whence the entanglement?

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A.C. Elitzur (1992) Locality and indeterminism preserve the second law, *Physics Letters A* **167**, 335.



Time: The Naïve View



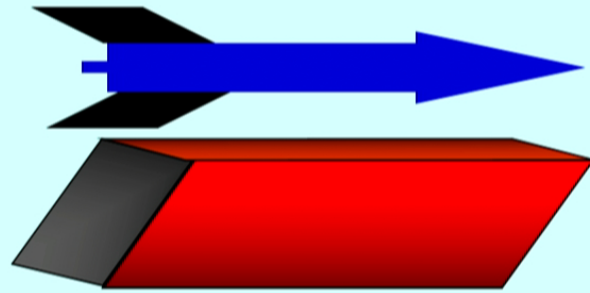
Time: The Relativistic View



Time: The Relativistic View



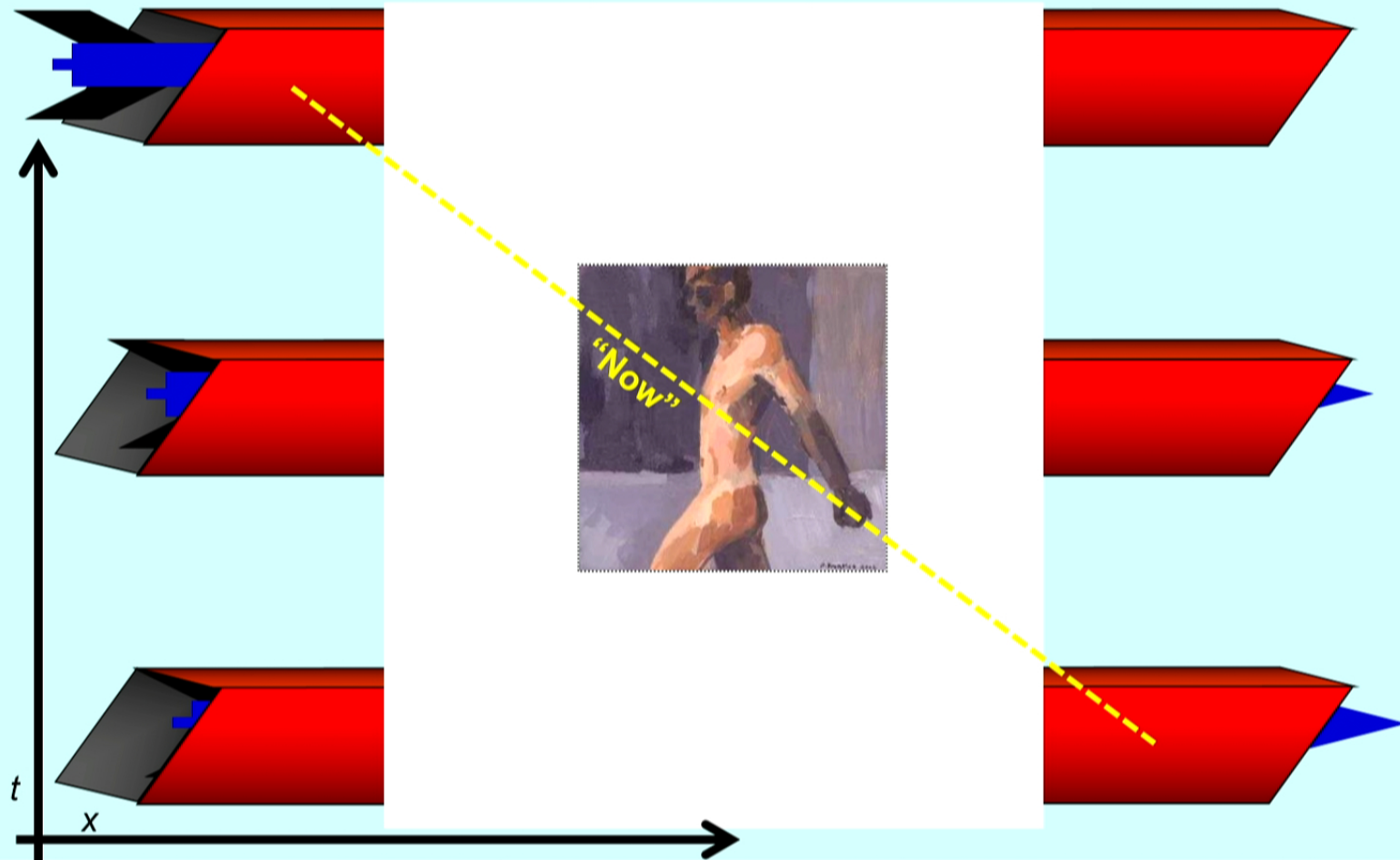
The Pole and the Barn Paradox



The Pole and the Barn Paradox



The Lorentz-Fitzgerald Contraction: A Straightforward Consequence of the “Coexistence” of Past and Future States





New York World-Telegram

The and Sun

ALL Sport FINAL Bid and Asked Prices Complete Markets

VOL. 122—NO. 190—

NEW YORK, MONDAY, APRIL 18, 1955.

FIVE CENTS

DR. EINSTEIN IS DEAD AT 76

Kindergarten Tots to Get Free Vaccine

City Adds 64,000 To First Program

Some 64,000 kindergarten children will get free Salk vaccine shots this spring as a result of a sudden shift today in Board of Education policy.

In spite of the confused picture on supply, the city said it would now include kindergarten children in the top priority. This includes children from ages 5 to 6 from kindergarten to the fourth grade.

The previous set up announced over the weekend said the first, second, third and fourth grade children had to be taken care of first. Kindergarten children were to be placed in a second priority.

Will Be Vaccine. The new policy was spelled out by Dr. Frank J. O'Brien, associate superintendent in charge of child welfare, and Dr. H. H. Goldberger, director of the city's health education.

"There will be enough vaccine for all children in the kindergarten to the fourth grade between now and the summer," said Dr. Goldberger.

"It really makes no difference whether a child is immunized next Monday or next month, as long as he gets the

Baseball

NATIONAL LEAGUE. R. H. E.

Pirates	7	0	0	1	0	0	2	—	3	9	0	
Giants	2	0	1	8	0	0	1	0	—	12	15	1

Markert, Grunwald, Pace, Pepper and Shepard; Little, Grimm and Westrum.

Cubs	1	0	0	0	0	0	0	—	1	6	0
Braves	0	0	0	0	0	0	2	—	2	6	1

Hacker and Chitt; Buhl, Johnson and Crandall.

RODGERS at PHILADELPHIA, night.

YANKEES at BALTIMORE, night.

Results at Jamaica

(Charts and Other Race Results in Sports Section.)

1—Head Me (Woodhouse)..... 4.20 2.80 2.20
 2—Gay Scot (Atkinson)..... — 5.70 3.50
 3—Main Speaker (Broussard)..... — — 3.20

1—Dark Belle (Higley)..... 6.40 3.60 2.90
 2—Grand Kerry (Bouglie)..... — 9.00 3.10
 3—Good Marrow (Nichols)..... — — 2.60

Daily double (7 and 1) paid \$136.

1—Lomb House (Westrop)..... 11.80 7.90 4.90
 2—Putney (Valenzuela)..... — 7.10 3.70
 3—Canaris (Roland)..... — — 2.40

1—Maritime Job (Mikkonen)..... 11.50 5.20 3.10
 2—Worry Masana (Atkinson)..... — 4.50 2.90
 3—Teusling (Stoval)..... — — 2.50

1—Old Trick (Roland)..... 9.00 5.10 2.50
 2—Mr. Paul (Gleason)..... — 15.70 6.30
 3—Blackway (Valenzuela)..... — — 2.70

1—Smogger (LeBlanc)..... 63.50 26.40 13.10
 2—1 Balute (Atkinson)..... — 2.90 1.40
 3—Canadiana (Westrop)..... — — 6.20

1—Brazil First (Shuk)..... 6.60 4.30 3.20
 2—Ron Clark (Lester)..... — 10.10 6.80
 3—Trisong (Woodhouse)..... — — 3.60

1—Dan Giddings (Gargeme)..... 16.40 6.70 4.70
 2—Dead Duck (Roland)..... — 2.90 1.60
 3—Lotus Ester (Mikkonen)..... — — 4.00

Reds Blasted As Bandung Talks Begin

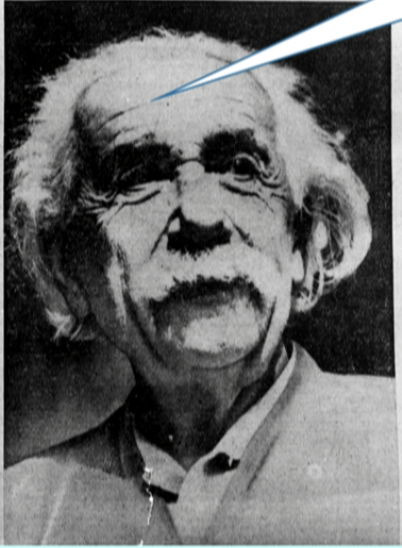
Free Vietnam, Iraq Open Fire

By GENE SYMONDS, United Press Staff Writer, BANDUNG, Indonesia, April 18.—Iraq and Free Viet Nam strongly condemned communism today at the opening session of the 29-nation Asian-African conference.

Red China's Premier Chou En-lai, one of the most prominent delegates, lambled through it all. The attacks on communism were virtually the only jarring notes in the opening day of the week-long session designed to consolidate the 2,500,000,000 peoples of Africa and Asia against colonialism and to unify them in a common economic and cultural force for world peace.

Leaders of the conference called by India, Burma, Indonesia, Ceylon and Pakistan have appealed to speakers to avoid such controversial subjects as Red China's claim on Formosa or any other that might disturb the peace and calm of the conference.

Hope Kapholok.



Burst Artery Proves Fatal To Physicist

Father of Atom Age Passes at Princeton

By EDWARD ELLEN, Staff Writer. Albert Einstein, hailed by some as the greatest genius of all time, died quietly at 1:15 a.m. today in Princeton Hospital in Princeton, N. J., at 76.

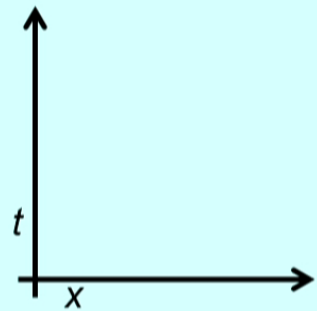
Death was due to a rupture of the aorta, the body's main artery, caused by hardening of the arteries. His death had first been attributed to a gall bladder condition but an autopsy showed differently.

Dr. Einstein, his physicians revealed after his death, made a decision in the field of medicine a few days ago and, typically, it was correct. They had left it up to him whether surgery should be attempted to alleviate his illness. The scientist violently opposed surgery and the autopsy showed today it would not have helped the condition. Dr. Einstein had been right again.

One of his last acts was to work on a message to be delivered April 20 on the eve of the seventh anniversary of the founding of Israel. This was put aside, however, as his condition worsened. Shortly before he died, he breathed a few words in his native German



No I'm not! Only my world-line ends here (4 weeks after that of Michele Besso)!

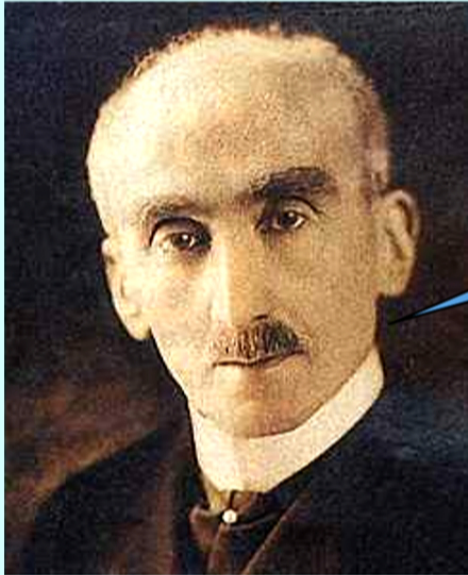


“Time and space are essential forms of any thought
and of any PowerPoint slide.”



The Significance of Non-Particles

- The overwhelming majority of physical interactions in the universe are of the IFM kind, both spatial and temporal
- Hence there is much more entanglement between faraway parts of the universe, mediated by non-photons and other non-particles
- Which has many bearings worth considering on thermodynamics, Mach's principle, etc.



Never spatialize time!

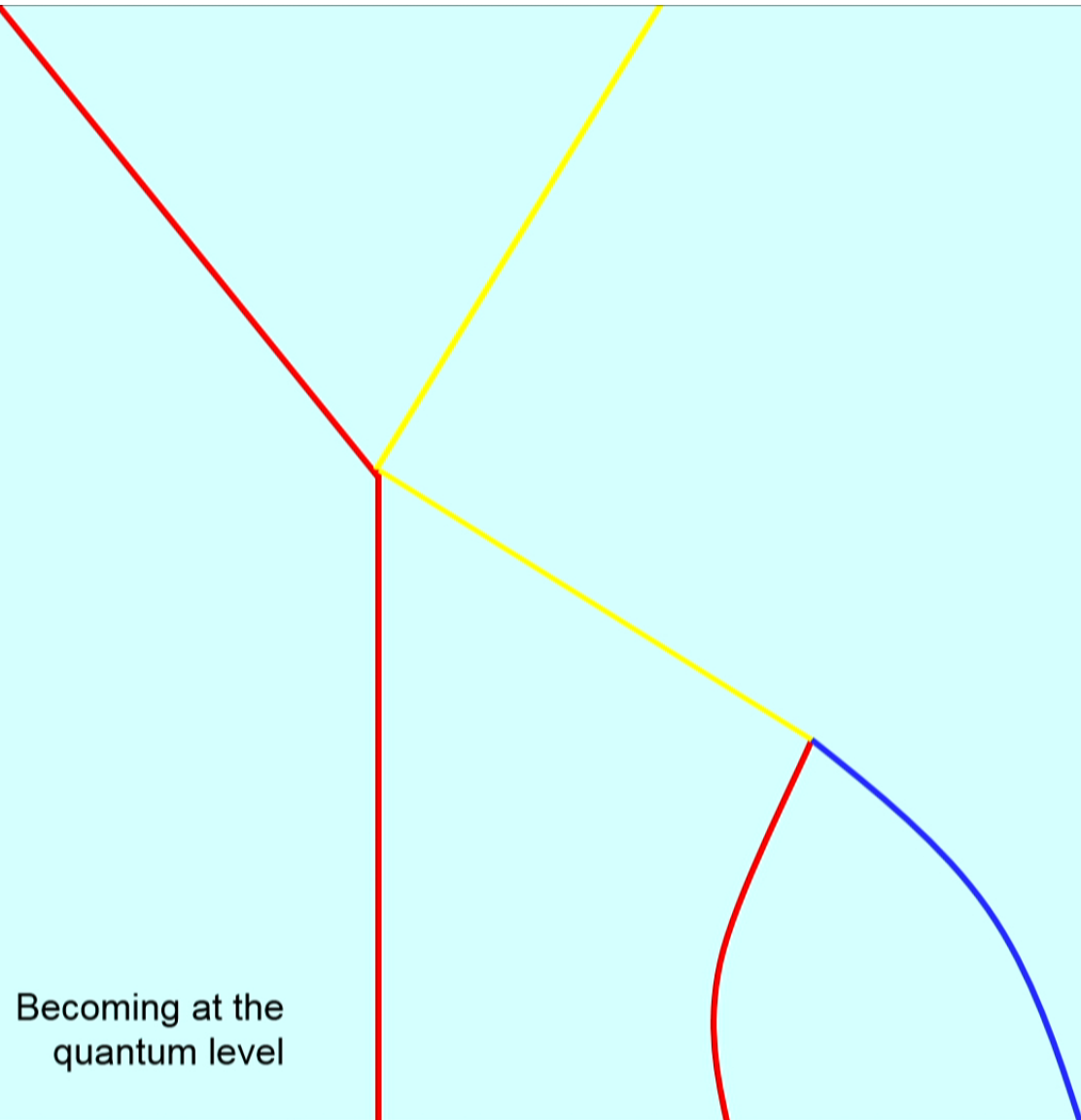


Naïve Becoming

Let's Go Quantum:

Quantum interaction takes place beyond the “Now,”
hence outside of spacetime.

“Collapse” gives rise not only to the particle in its
location, but to all the points in empty space
where it *could* have been.



Becoming at the
quantum level

If wishes were horses, beggars would ride.
If turnips were watches, I'd wear one by my side.
If "if's" and "and's" were pots and pans,
There'd be no work for tinkers' hands.

Comment on the uniqueness of quantum mechanics

Comment on the uniqueness of

