THE MANY-FACETED ENIGMA OF TIME: A PHYSICIST'S PERSPECTVE

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TIME IS AN ENIGMA IN ALL DOMAINS

Feynman: "We physicists work with time every day but don't ask me what it is. It is too difficult."

Whitehead: "It is impossible to meditate on time without overwhelming emotion at the limitation of human intelligence."

Pinker: "How could consciousness could arise from the physical brain? Beats the heck out of me. I have some prejudices but no idea of how to begin to look for a defensible answer."

St Augustine: "What is time? If no one asks me, I know. If I wish to explain it to one that asketh, I know not."

Time plays crucial role in linking physics to these different fields



Time is necessarily on the border of physics and philosophy with physics elucidating many old philosophical disputes.

Space and time intertwined in neural circuits but time more complicated than space for both neuroscience and physics.

Physics may eventually describe consciousness and clarify questions such as: What is now? Why am I me?

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SIX RECENT BOOKS ON TIME AND PHYSICS





...but these barely mention consciousness!







MEASUREMENT OF TIME

All clocks depends on laws of physics

3000 BC Water clock. 1500 BC Sundials

1300 Mechanical clock. 1450 Portable spring clock. 1657 pendulum clock.

1735 Harrison's sea clock (longitude)

1807 Mass-produced shelf clock. 1854 Miniaturized watches (civil war)

1928 Quartz clock. 1948 Cesium clock. 2015 Strontium clock (accuracy 10⁻¹⁸)



Hemispherical Sundial (Italy, circa A.D. 100)



Pendulum Clock (the Netherlands, 1657)





Shelf Clock (U.S., circa 1816)



A caesium atomic clock from 1975

Time now more accurately measured than space

NATURAL CLOCKS FROM RADIOACTIVE DECAY





NEWTONIAN VIEW

Arena of physical reality is 3D space....and time





Both space and time are absolute

NEWTONIAN MECHANISTIC UNIVERSE

=> future and past implicit in present





Pierre Laplace

"An intellect which at a certain moment would know all the forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies in the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes." How do we reconcile the block universe with our intuitive understanding of time?



Eternalism or Presentism?

EINSTEIN VIEW

Arena of physical reality is 4D spacetime







Time is 4th dimension

Worldline

TIME IN SPECIAL RELATIVITY



Time different from space: $ds^2 < 0$ gives causal connection

- Always move forward in time
- No absolute present (only here-now)
- Moving clocks run slow and rulers shrink



The twin who accelerates and decelerates is younger

Cosmic ray muon decays in 2 $\times 10^{-6}$ s => travel only 600m. But appears to decay in 0.06 s at 0.9994c => reaches ground.

TIME IN GENERAL RELATIVITY

Spacetime is curved by gravity => many individual times



Clocks run slow in gravity field, objects falling to where time is slowed.

Time experienced depends on space-time path Longest duration for freely-falling observer



TIMEWARPS



Living in bungalow for year => microsec younger than at top of skyscraper



Head ages more than feet by 300 nanosec in 80 years



Clock on plane going around world eastward (westward) records 40 nanosecs less (273 nanosec more) than clock on Earth



BLACK HOLES

Light-cones tilt inwards => light cannot escape when region falls within event horizon radius

 $R_{EH} = 2GM/c^2 = 3(M/M_O)km$



Time stops at edge of black hole, so astronaut freezes at horizon for external observer but crosses it in own experience and sees whole future of Universe while falling to central singularity.



Astronaut can travel arbitrarily far into our future by hovering close to BH but not falling inside it.

TIME TRAVEL

Easy to the future through time dilation and gravity effect. Travel to past needs tachyons or closed timelike curves or wormholes.



CTCs arise in rotating universe (Godel) or for rotating cylinder (Tipler)

Can travel to past through WH to any time *after* it was created. WHs may have been created in early Universe but need negative energy to hold mouth open.

Hawking: Chronology Protection Theorem

ENIGMAS OF QUANTUM THEORY Sheehan & Cyrus



Two-slit experiment



Entangelment



Schrodinger's Cat



Uncertainty Principle

INTERPRETATIONS OF QUANTUM THEORY





Copenhagen

Pilot wave



Many Worlds



Transactional

TIME IN QUANTUM THEORY

Time fuzzy in GR but space fuzzy in QT and time more Newtonian.

Page & Wootters (1983): Entanglement generates time.

Connes & Rovelli (1994): Time emerges from irreversible interaction between micro quantum objects and macro objects that make measurements. But order of measurements ambiguous in quantum world.

QM limited to isolated systems => clock and observer outside system => need deeper theory extendable to whole Universe

Orchestrated Objective Reduction Does consciousness collapse wave function? Penrose & Hameroff (1996): consciousness requires non-computable quantum processes involving neurons (microtubules)

The human brain is packed with cells called neurons that connect via networks of axons and dendrites. These pass signals across minute spaces called synaptic gaps. The classical view says thought is born from these connections between neurons. Microtubule Orch-OR, on the other hand, suggests that consciousness originates from quantum interactions in the microtubules inside each cell.

ARROWS OF TIME

- Cause and effect (punch)
- Life and death (leaves)
- Cosmic expansion (big bang)
- Radiation (retarded)
- Quantum collapse (micro)
- Psychological (memory)





But laws of fundamental physics are time-reversible (CP-violation?)

Arrow of time (past/future asymmetry) different from flow of time.

All arrows arise from Second Law of Thermodynamics



All past/future distinctions arise because our environment is very far from equilibrium, and entropy is increasing.





Development of complexity => Universe not in thermal equilibrium

ARTHUR EDDINGTON



"If your pet theory of the Universes is in disagreement with Maxwell's theory, so much the worse for Maxwell's theory. If it is found to be contradicted by observations - well, these experimentalists do bungle things sometimes. But if your theory is found to be against the Second Law of Thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation." To understand the evolution of entropy, we need to supplement Boltzmann by the Past Hypothesis:

The observable universe began in a low-entropy state that could evolve into our current state via increasing entropy.

Nobody knows why this should be true, but it is.



TIME AND THE BIG BANG?

Aristotle: no beginning of time. St Augustine: God created time with Universe.

Does time disappear at Big Bang singularity?

Hartle-Hawking: time imaginary near big bang => no boundary proposal





Nothing outside Universe => no time in quantum cosmology

 $ds^2 = -c^2 dt^2 + d\underline{r}^2$ $ds^2 = c^2 dt^2 + d\underline{r}^2$ BIG BOUNCE => earlier collapsing phase => cyclic model





TIME IN QUANTUM GRAVITY

Space granular not continuous on Planck scale => spacetime foam $(10^{-33}$ cm, 10^{-43} s)

Time emergent in macroworld but not at Planck scale?



Are space and time or neither fundamental or irrelevant to Quantum Gravity?

QG approaches

Canonical QG => no time (Wheeler- de Witt) Causal Set Theory => passage of time for localized observer (Sorkin) String Theory => like QT (space fuzzy) Loop Quantum Gravity => like GR (time fuzzy)

Time is real and key to understanding QG (Smolin). Laws emerge and evolve with Universe. Must extend physics to whole Universe and beyond its parts.

Previous history of physics has progressively diminished role of time (Barbour)





But mind is fundamental not incidental to universe

anthropic principle
 quantum theory
 psi
 time

"My position [on consciousness] demands a major revolution in physics.... [T]here is something very fundamental missing from current science. Our understanding at this time is not adequate and we're going to have to move to new regions of science...."



~ SIR ROGER PENROSE mathematical physicist

Gravitational collapse of quantum superposition => AoT



Detectable by Gran Sasso experiment in 2020?



But we need radical revision of what is meant by these terms

WHAT IS THE NATURE OF REALITY?

Link between philosophy of mind and philosophy of time

Percepts associated with external (physical) reality in standard view



PERCEPTUAL FIELDS

There exists 3D space in which are localized both physical objects and sensors through which we observe objects. Each observer has only partial information about this space but there exists a 3D configuration which gives 2D projections concordant with those presented. Reality is 3D structure which consistently reconciles our perceptions of it.



REALITY STRUCTURE

MODIFIED MODEL OF REALITY

Relativity theory implies that physical world is 4D, with the objects and observers being represented by world-lines and perceptual fields being 3D. Physical reality is 4D structure which consistently reconciles our perceptions of it.



World of things (persistence in time) => world of events (limited duration)

SPACETIME OUTLOOK TREE



Phenomenal space is part of spacetime. Object and brain are just two ends of 4-dimensional chain.

MEMORY SPACE

Mainstream View. Memories of physical events are contained in brain.

Alternative View. Memories arise from access of consciousness to parts of spacetime connected to brain by nexus of signalling worldlines.



Tag not trace!

Memory is re-experiencing of past

Proust *Remembrance of things past* => reality is memory

HIGHER DIMENSIONS IN PHYSICS

Physics gives sequence of paradigms with increasing dimensionality with increasing remoteness from common sense reality



Extended 5th dimension => 4D brane in higher-dimensional bulk Brane cosmology => brane moves through the bulk Could higher dimensional space accommodate mind?

TIME AND MIND: THREE PROBLEMS



- Flow of time
- Precognition
- Specious present

Talks by Bertolami, Canales, Mossbridge, Bem, Wittmann

CONSCIOUSNESS AND THE FLOW OF TIME



Einstein "block universe" does not describe flow of time

Most philosophers infer time is unreal or just feature of mind (McTaggart, Smart, Putnam, Price)

Current physics => passage of time gives no extra information.

But what if Final Theory can accommodate mind?



Weyl: No objective passage

Hermann Weyl (1949) The objective world *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 changes in time.

Einstein: No privileged present



Einstein's letter to family of Michele Besso (1955)

"Now he has departed from this strange world a little ahead of me. That means nothing. People like us, who believe in physics, know that the distinction between past, present and future is only stubbornly persistent illusion"

NEED EXTRA DIMENSION FOR MENTAL TIME



Extra dimension (t₂) can describe time flow Access possible futures (past) => precognition (memory) Brane cosmology: 4D <u>brane</u> moving through 5D <u>bulk</u> Other two-time models: Weinstein, Bars, Aharanov et al.



Each instant of time a new Universe

Y. Aharanov, S. Popescu and J. Tollaksen

We present an alternative view of quantum evolution in which each moment of time is viewed as a new "universe" and time evolution is given by correlatons between them.

Three-time models: Pavsic, Mignami, Recami, Cole, Pilotti

Even ordinary perception requires 5D reality structure



Phenomenal space and physical space are slices of 5D space

SPECIOUS PRESENT

William James (1890) "The prototype of all conceived times is the Specious Present, the short duration of which we are immediately and incessantly sensible."

the 'specious present'



Consciousness occurs in 'time slices' lasting only milliseconds, study suggests

Michael H. Herzog, Thomas Kammer, Frank Scharnowski

2ms audio, 10ms tactile, 20ms vision

VARIATIONS IN SPECIOUS PRESENT

DecreaseIncreaseTrapeze artistBalance artistCrisisFever

Do brain processes explain these variations? More dramatic changes in transpersonal states Tea time NDE life review Time

"In the description of mystical experiences produced through the stages of Samadhi characterised by Patanjali, it's as though the meditator is adjusting the focal length of his mind and encountering systematically different world" (Ed Kelly)

SP zero!

SP infinite!



Wittmann talk





Why should consciousness only exist on human scale?



Jonathan Schooler, Bridging the Objective/Subjective Divide





What defines an individual moment?

- Capacity for temporal discrimination
- Possibility that different conscious entities may move in objective time relative to subjective time in different size steps.
 - negative correlation between vertebrate size and the flicker fusion rate. (Healy et al, 2013)
 - consciousness of smaller animals may move through subjective time relative to physical time at a faster rate than larger animals.





Could time branch into a second objective dimension of time?



- Many worlds theory of physics (Everett)
 - observation of quantum events associated with splitting universe

Alternative

- Observer windows rotate in second dimension of objective time
- Possibly enables consciousness to select alternative futures thereby providing room for free will

In T. Metzinger & J. M. Windt (Eds). Open MIND: 34 (2015)

SPECULATIVE PROPOSAL

Hierarchy of extra dimensions compactified on different scales => hierarchy of SPs



Thouless and Wiesner (1947): focus of mind is usually brain but psi-gamma (receptive) and psi-kappa (expressive) act on surrounding <u>penumbra</u> in space and time

Hypothesis: specious present gives scale of penumbra

ESP needs increase in SP, PK needs decrease in SP



Flow of time and personal identity require specious present
Separate identity only exists in lower dimensional space.
Hierarchy of dim'ns => hierarchy of SPs => hierarchy of selves



