IS TIME FUZZY?

(TIME DISPERSION IN QUANTUM MECHANICS)

Quantum mechanics: space is fuzzy, particles do not have a well-defined position in space.

Special relativity: time and space are interchangeable.

Therefore, shouldn't time be fuzzy as well?

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Time dispersion in quantum mechanics

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RELATIVITY & THE GPS



- Without including relativistic effects, errors of 11km/day!
- Slowing due to relativistic speed: about -1 part in 10 billion
- Speed up due to blueshift: about +5 parts in 10 billion

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LIFE SPAN OF AN ATOM

- accelerated electron radiates
- once its energy is gone, it spirals into the nucleus
- in about one hundred trillionth of a second!

According to classical physics, an electron in orbit around an atomic nucleus should emit electronmagnetic radiation (photons) continuously, because it is continually accelerating in a curved path. The resulting loss of energy implies that the electron should spiral into the nucleus in a very short time (i.e. atoms can not exist).

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Planck's Quanta (Blob of Mercury)

Мēmængym



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MINKOWSKI'S DIAGRAM



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EINSTEIN'S CLOCK IN A BOX

- now have the uncertainty in time
- now weigh the box

 exactly
 (remember E=mc
 squared?)
- Einstein: Violates
 Heisenburg
 Uncertainty
 principle in time/
 energy



BOHR'S RESPONSE

Einstein's Light Box (after a drawing by Bohr)



- To measure energy we add a test weight over a period of time
- But this means the box is going to jiggle up & down
- But if it jiggles up & down in a gravity field, its time rate is uncertain
- So measuring the energy creates an uncertainty in time
- Just enough to bring back the uncertainty principle in energy/time

ALMOST 90 YEARS PASS



- Bohr, Einstein, Heisenberg all agree time is fuzzy!
- But times are too small to measure.
- And that which we can not measure does not exist!
- Until we can measure it!

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WHEELER'S RADICAL CONSERVATISM



Wheeler

"Wheeler's often unconventional vision of nature was grounded in reality through the principle of radical conservatism, which he acquired from Niels Bohr: Be conservative by sticking to wellestablished physical principles, but probe them by exposing their most *radical* conclusions." – Kip Thorne

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HERE COME THE FUZZ



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Feynman:First, prove Yourself Wrong!

What is the estimated size of the effects?

Size so tiny we can't see in foreseeable future!

Size so large we should have seen already!

Just right! We can see *if* we look in the right way.

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WIDTH OF AN ATOM IN TIME



- In comes a photon, traveling at the speed of light
- The atom is not big; in fact it is about one billionth of a centimeter wide
- That means that light crosses the atom in about one attosecond (one billion billionth of a second)
- **But** Ossiander and a few close friends measured to fractions of an attosecond in 2016!

one billionth of a centimeter

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GISIN: LOOK, I DON'T CARE WHAT YOUR THEORY OF TIME IS. JUST GIVE ME SOMETHING I CAN PROVE WRONG

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WHAT ARE PATH INTEGRALS?



- Alice walks her dog from A to B
- She takes one path
- Her dog can take many paths
- And being a quantum dog, takes all at once
- In space: left & right, forwards & backwards.
- And in time?

PATHS UP CLOSE

Time



Paths in time as well as space



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LAGRANGE'S BALANCING ACT



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Dog Walking in Time







Source

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http://timeandquantummechanics.com

Detector

SINGLE SLIT/BULLETS

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SINGLE SLIT/WAVES



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SINGLE SLIT IN QM WITH TIME (TQM)



- Uncertainty principle in time/energy
- Diffraction
- Arbitrarily large dispersion
- Falsifiable

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HOW TO THINK ABOUT WEIRD THINGS

THEODORE SCHICK, JR. LEWIS VAUGHN



HOW TO THINK ABOUT weind things Critical Thinking for a New Age

FIFTH EDITION

- **Consistent**: effects usually at scale of attoseconds
- **Falsifiable:** no free parameters, large enough to measure.
- **Simple**: complete symmetry between time and space
- **Scope**: any quantum experiment varying at time scale of attoseconds
- **Fruitful**: lots of experiments, lots of interesting tech, no null experiments.

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USES OF DISPERSION IN TIME





- Quantum gravity without costs & risks of black holes
- New communication channels, new circuit elements, as memristors
- Attosecond chemistry; attoseconds are the time scale for electron/molecule interactions



• Let's take a flyer on the future; you never know where the lightning will strike!







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REFERENCES













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PAPER • OPEN ACCESS Time dispersion in quantum mechanics

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- Carroll From Eternity to Here
- Susskind & Friedman Quantum Mechanics
- Clegg et al 30-second Quantum Theory
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IS TIME FUZZY? WE STILL DON'T KNOW, BUT PERHAPS WE CAN FIND OUT



- Ferne Welch
- Jonathan Smith
- Nicolas Gisin
- Martin Land & Larry Horwitz
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