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, should time should be fuzzy as well?

Journal of Physics: Conference Series

PAPER • OPEN ACCESS

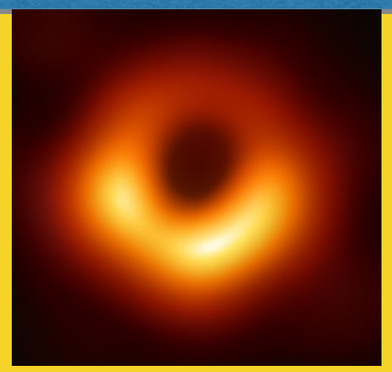
Time dispersion in quantum mechanics

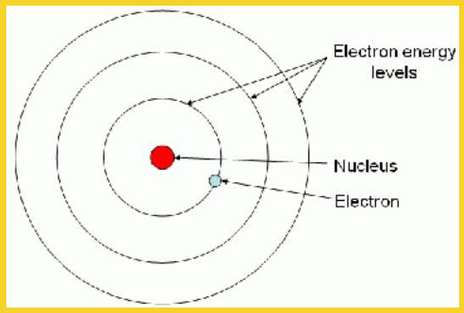
John Ashmead

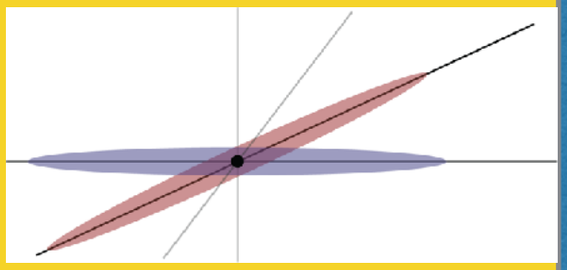
Published under licence by IOP Publishing Ltd
Journal of Physics: Conference Series, Volume 1239, conference 1

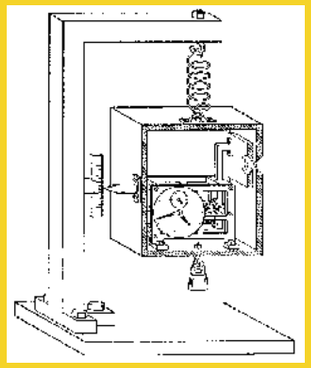
John Ashmead

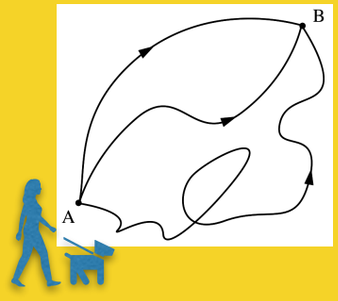
Is Time Fuzzy?

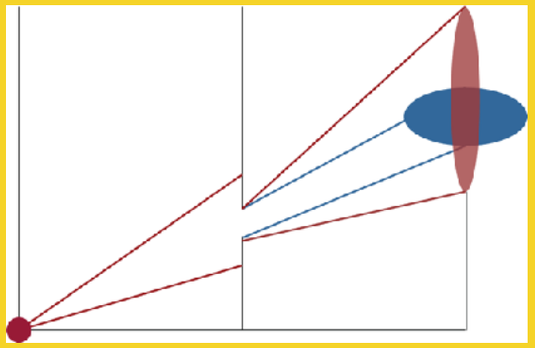


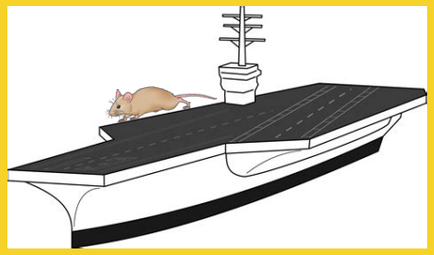


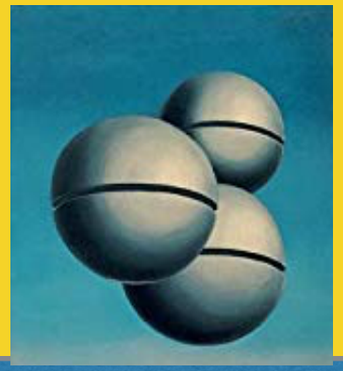






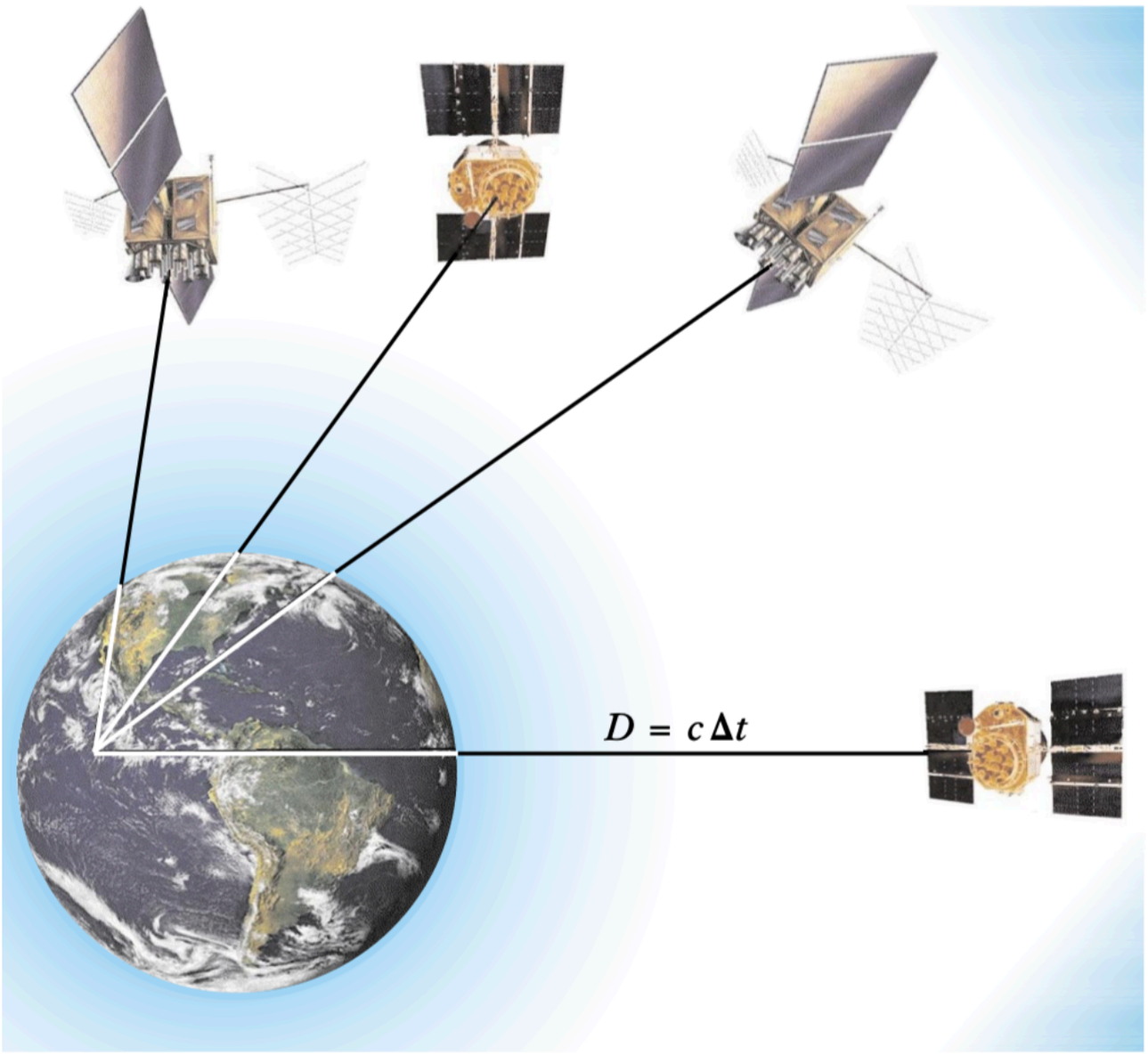






Arrival in 33 slides

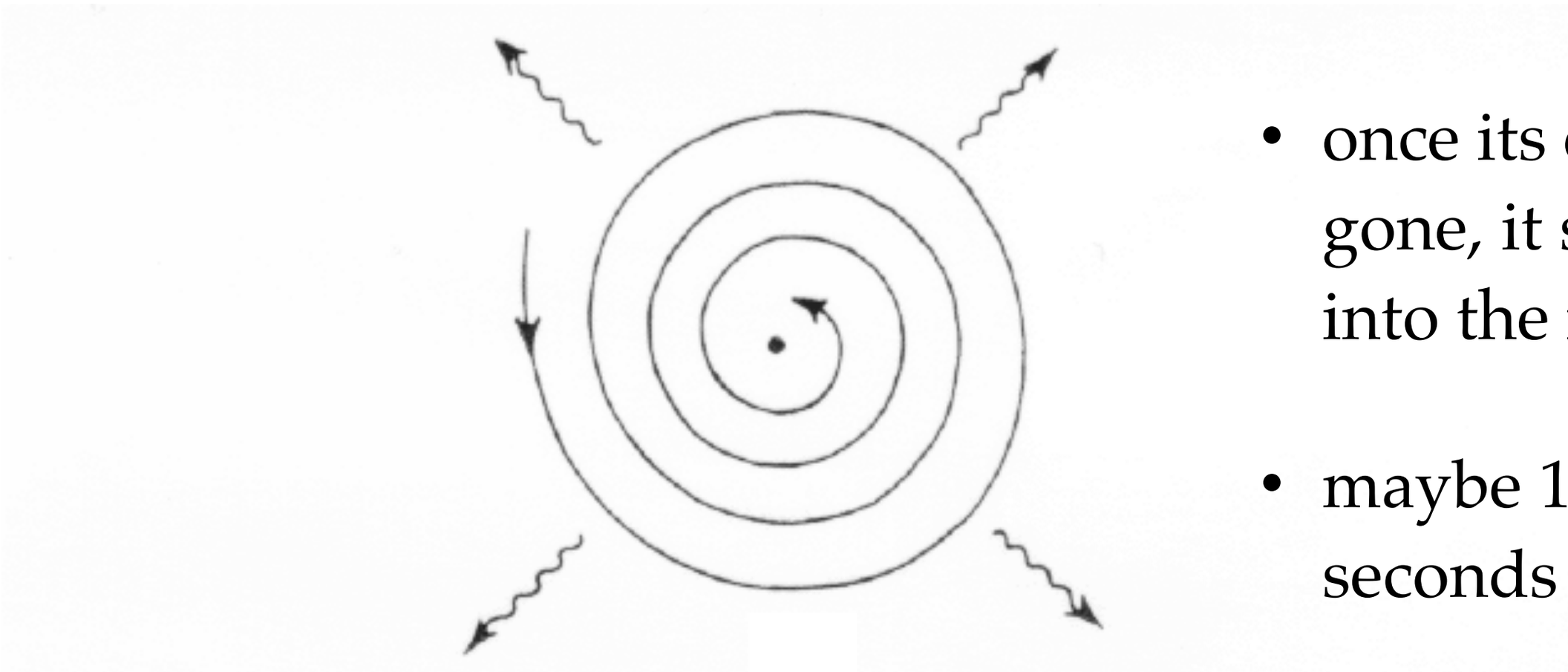
Relativity & the GPS



- Without including relativistic effects, errors of 11km/day!
- Slowing due to relativistic speed: -1×10^{-10}
- Speed up due to blueshift: $+5 \times 10^{-10}$
- Sagnac effect: due to rotating Earth

Neil Ashby. Physics Today 2002 May 41-47

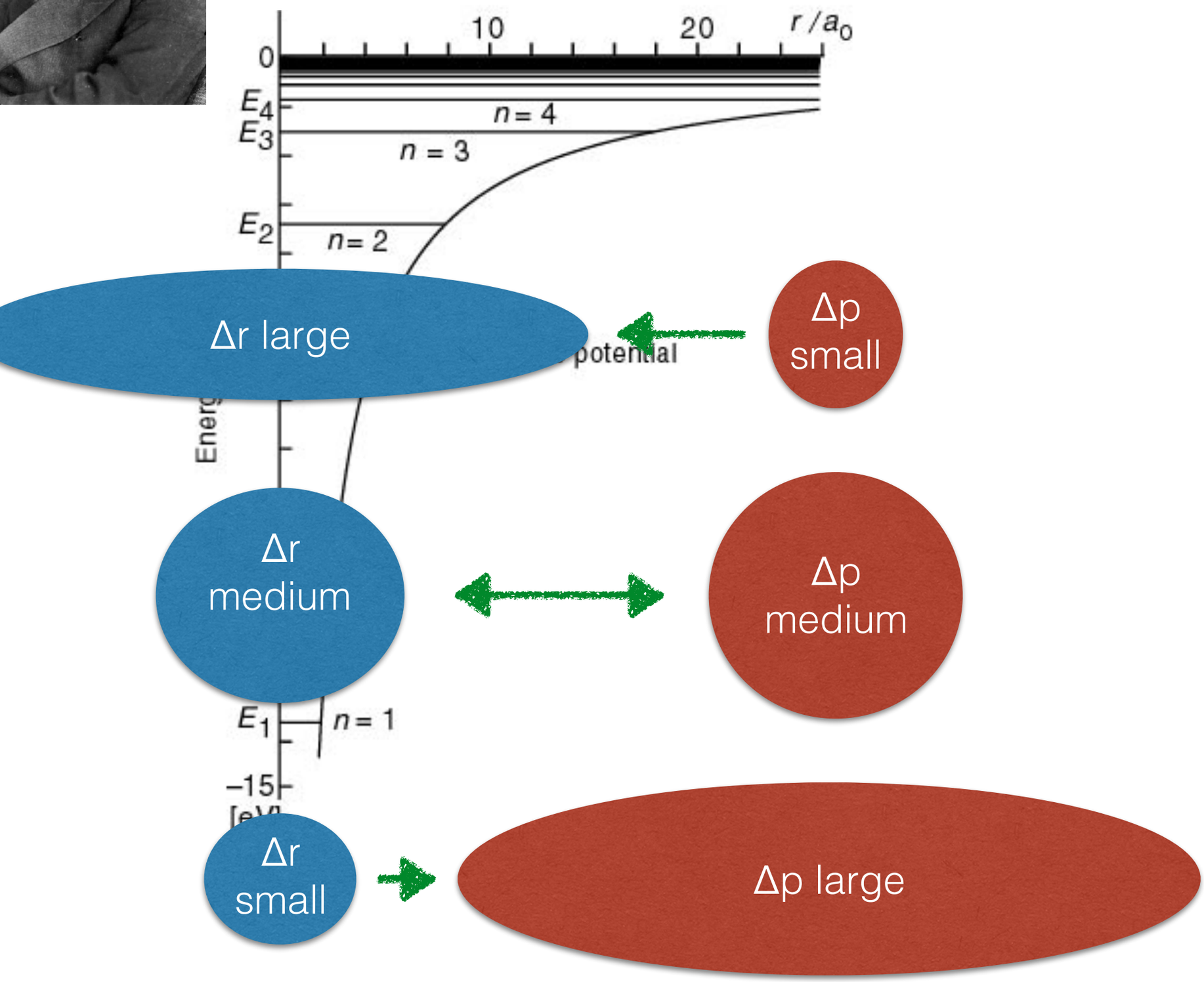
Life span of an atom



- accelerated electron radiates
- once its energy is gone, it spirals into the nucleus
- maybe 10^{-14} seconds

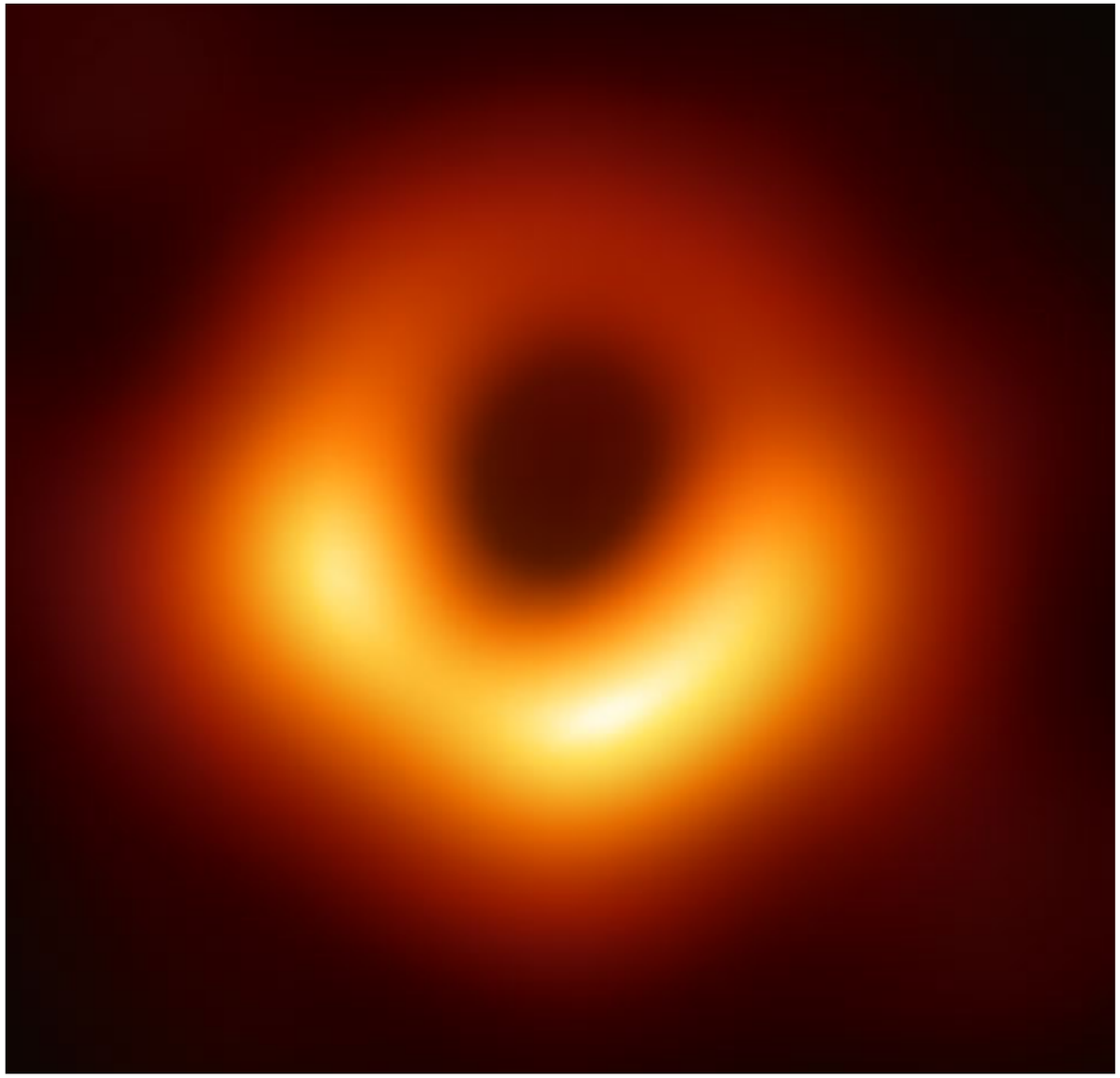
According to classical physics, an electron in orbit around an atomic nucleus should emit electronmagnetic radiation (photons) continuously, because it is continually accelerating in a curved path. The resulting loss of energy implies that the electron should spiral into the nucleus in a very short time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

Uncertainty & atoms



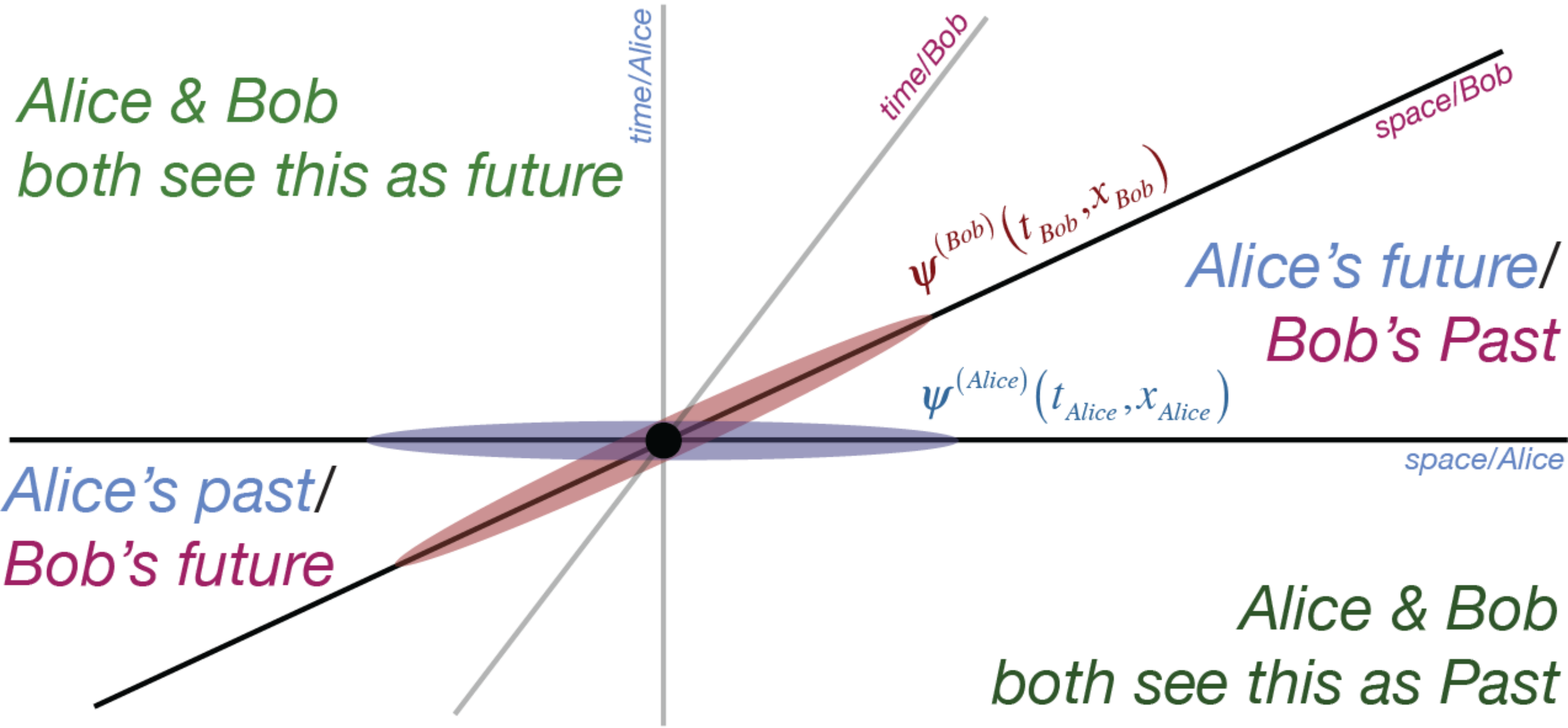
Hi Ya Goldilocks!

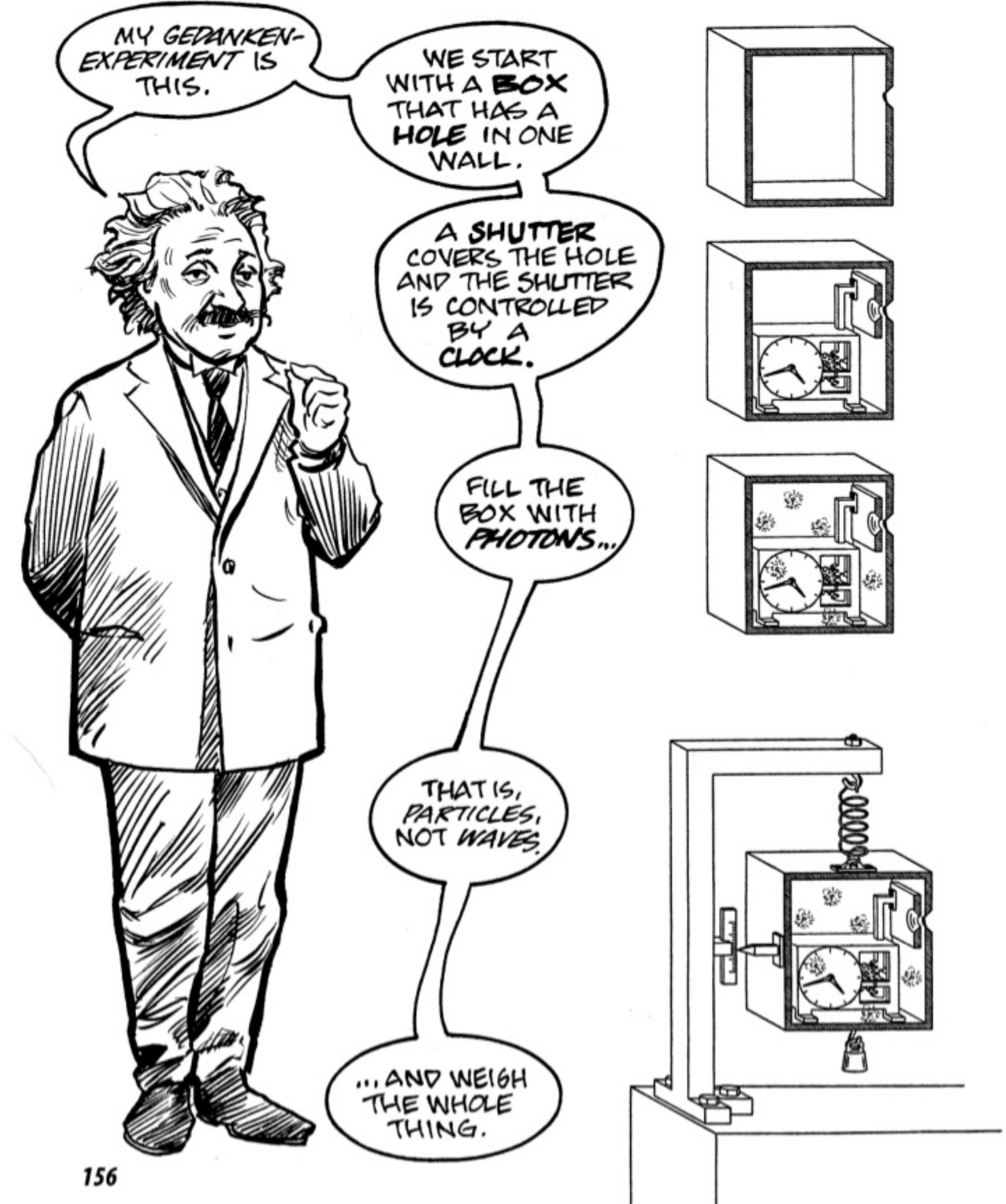
Black Hole poses for photo – and about time!



- Near a black hole, time is stretched
- At Schwarzschild radius, time and space (*seem to*) exchange roles
- Perhaps time stretches out to infinite future?

Minkowski diagram



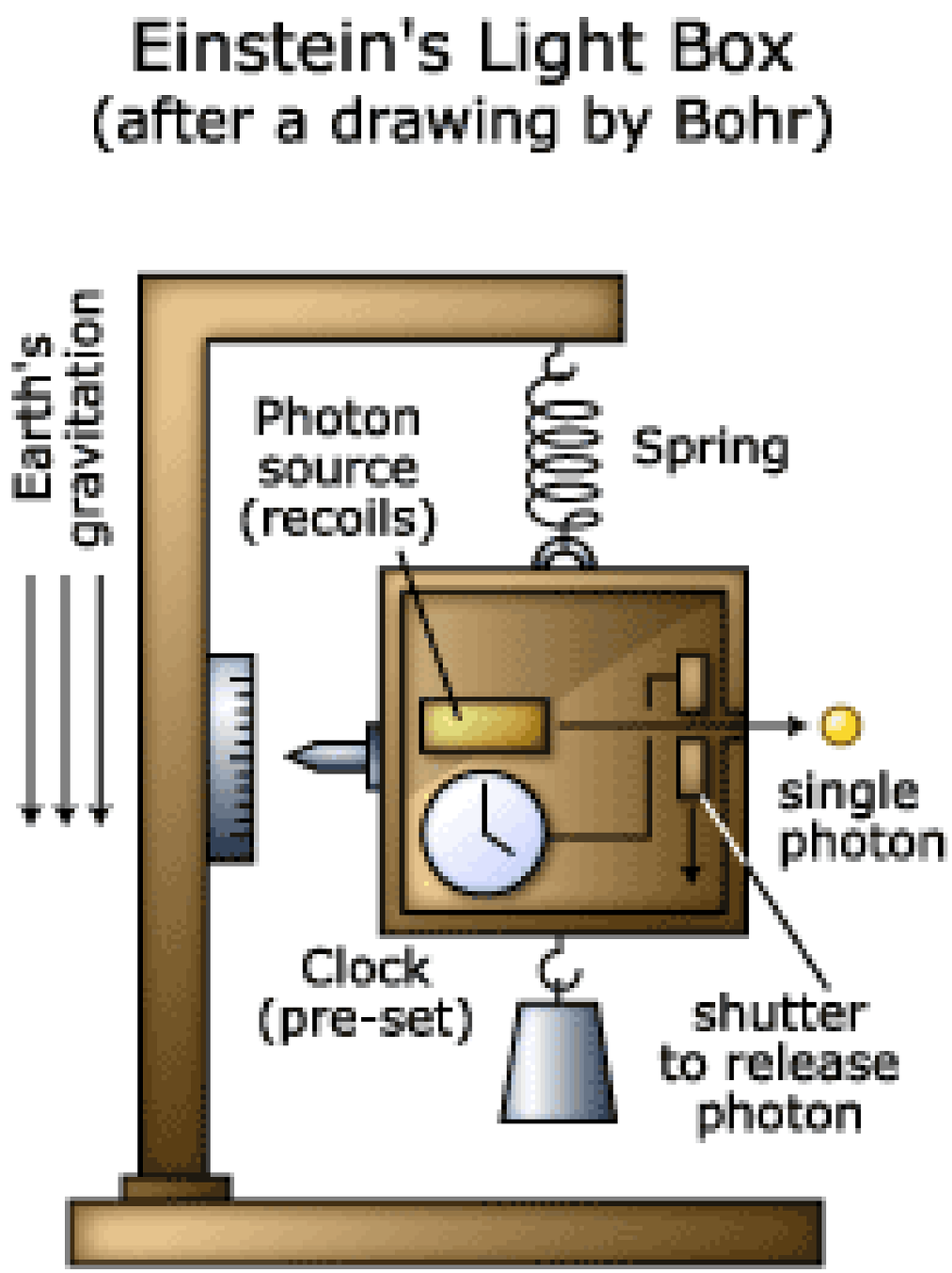


Einstein's clock in a box

- now have the uncertainty in time
- now weight the box — exactly
- **Einstein: Violates $\Delta E \Delta t \geq 1$**

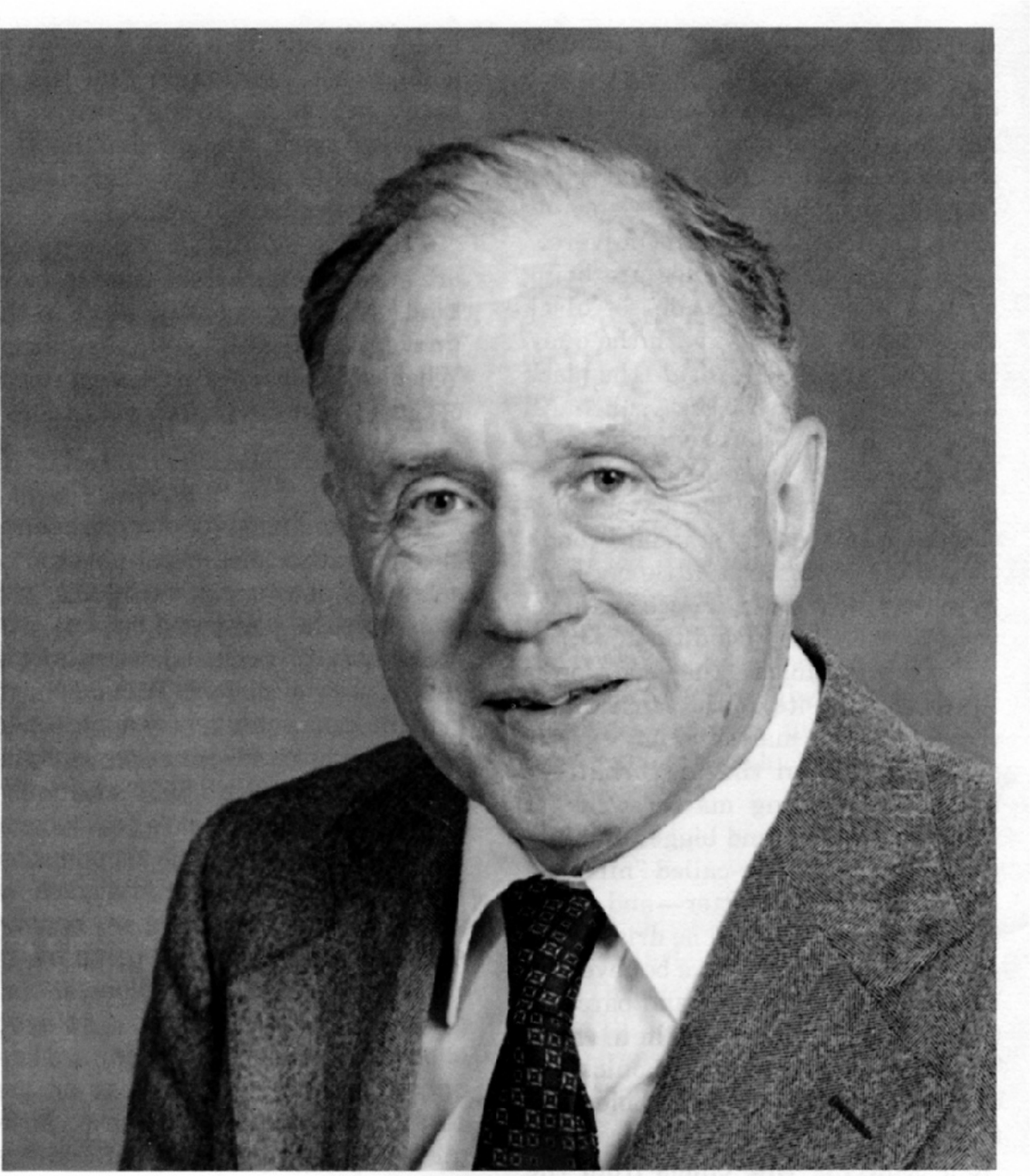
http://timeandquantummechanics.com

Bohr's response



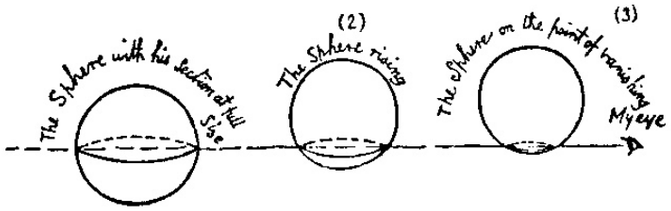
- To measure energy ΔE we add a test weight Δm over a time T
- Implies uncertainty $\Delta p_z \leq g\Delta mT$
- Implies $\Delta z \geq 1/g\Delta mT$
- Implies red shift $(\Delta t/T)=g\,\Delta z$.
- Implies $\Delta t=gT\,\Delta z \geq 1/\Delta m$
- **Bohr: Implies $\Delta E\Delta t \geq 1$**

Radical Conservatism

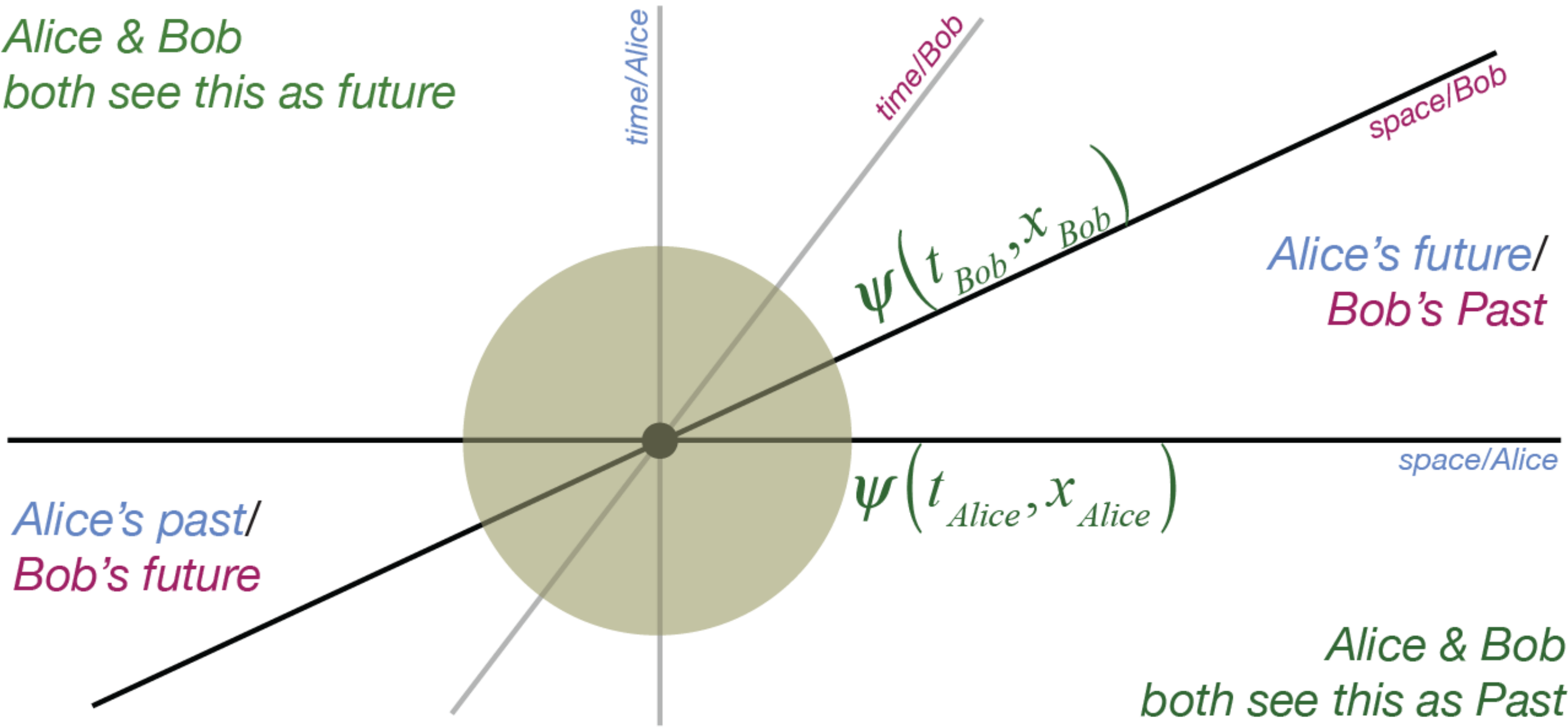


Wheeler

"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 well-established physical principles, but probe them by exposing their most *radical* conclusions." – Kip Thorne



Here come the Fuzz



First, prove Yourself Wrong!

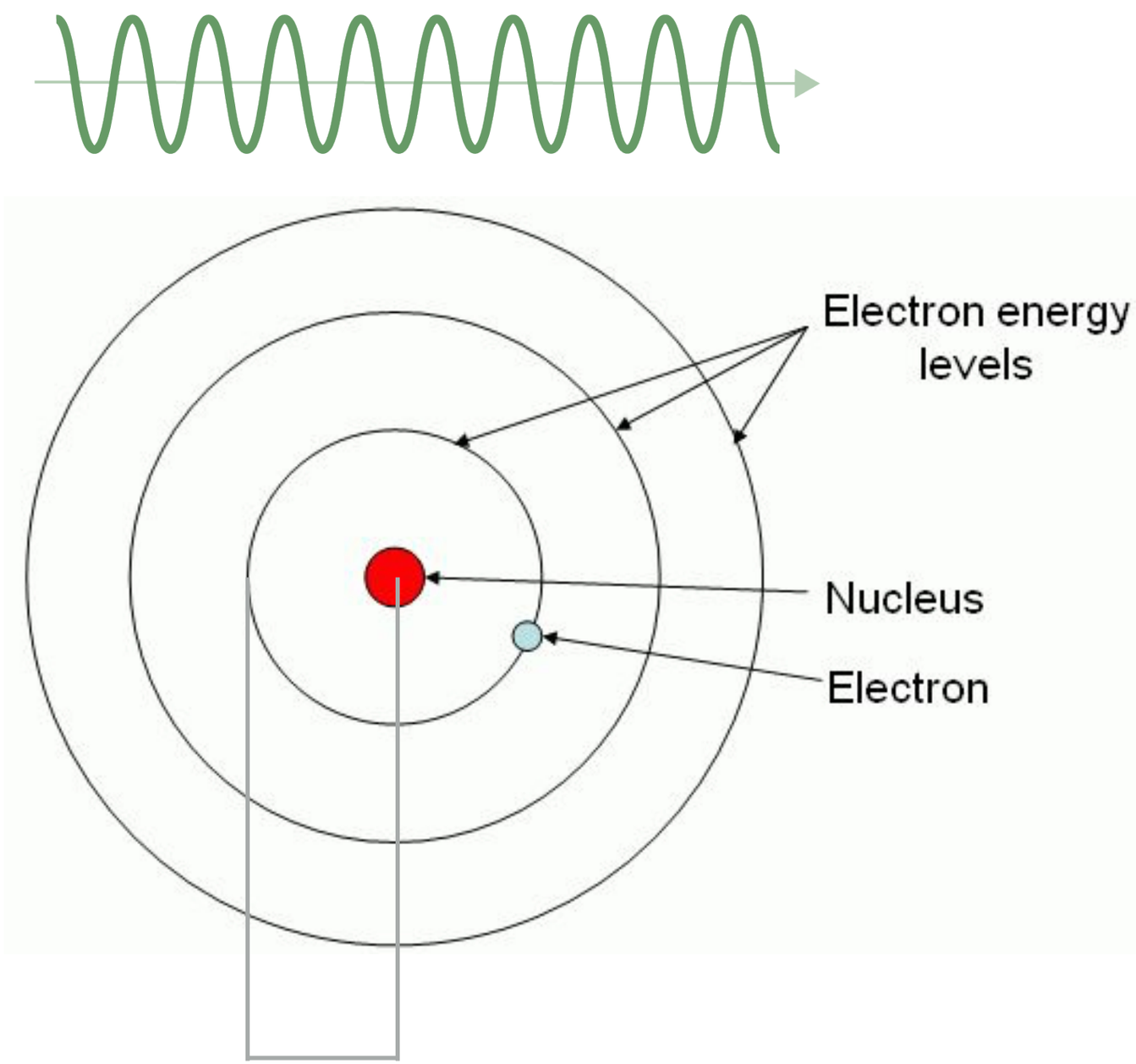
What is the estimated size of the effects?

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

Hi Ya Goldilocks!

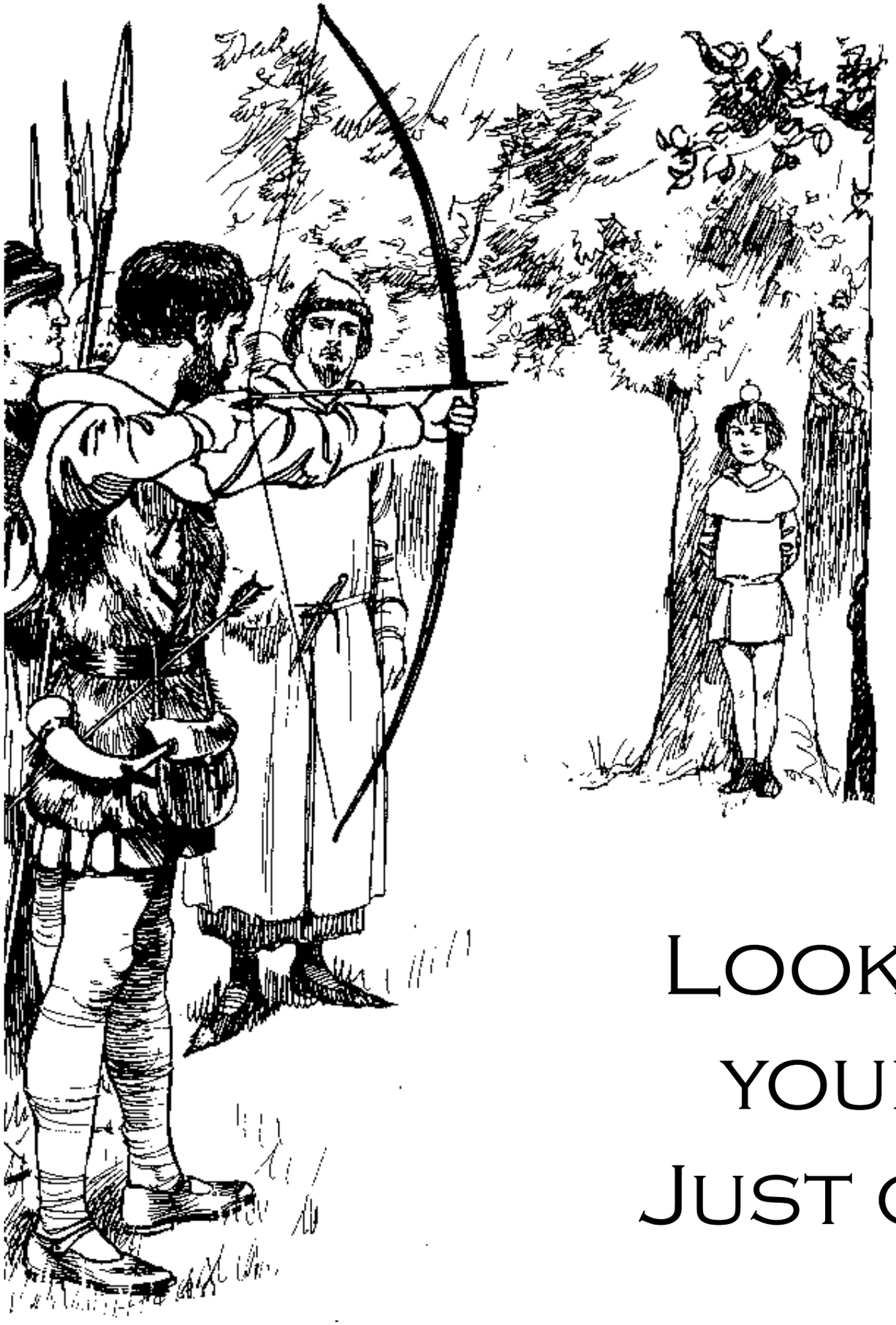
Size so large we should have seen already!

Bohr Radius in Time



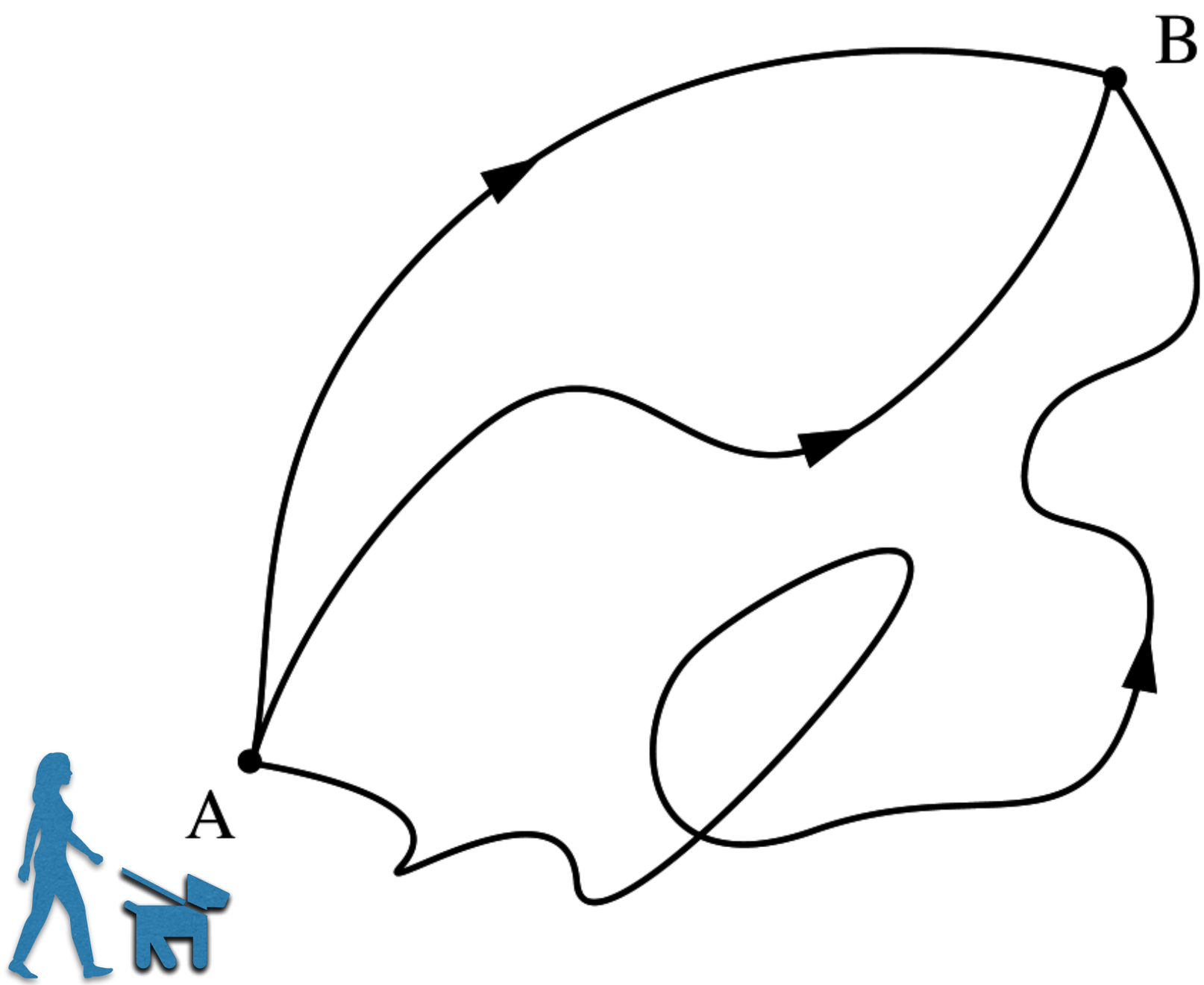
$a_0=5x10^{-11}m$

- In comes a photon, traveling at $c = 3x10^8 m/sec$
- Bohr radius of atom is $a_0=5x10^{-11}m$
- That works out to .2 attoseconds
- 1 attosecond = 10^{-18} seconds
- **But** Ossiander et al (2016) did experiment at .025 attoseconds!

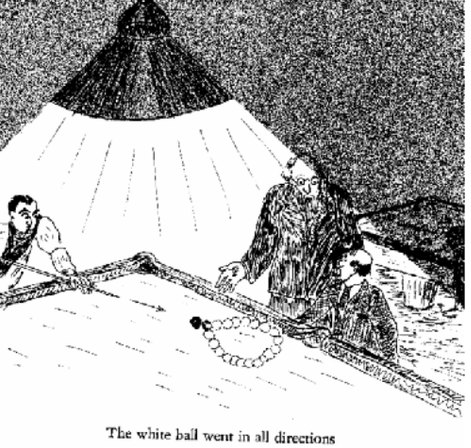


Look, I don't care what your theory of time is. Just give me something I can prove wrong

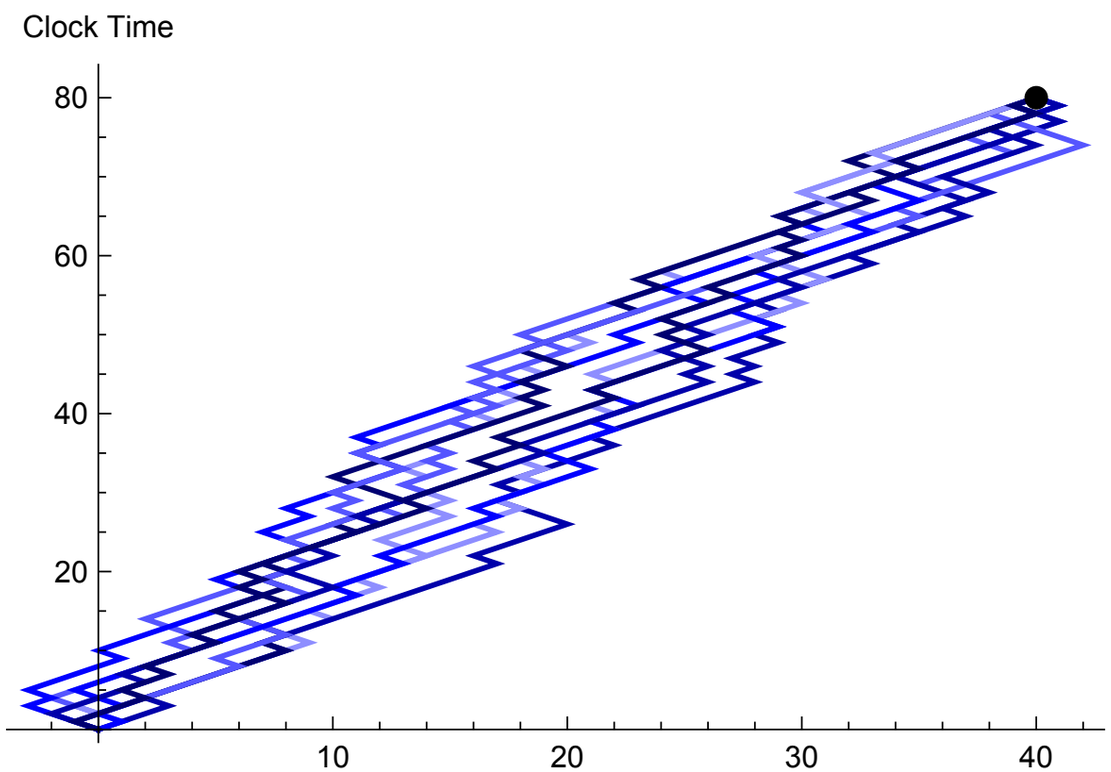
What are path integrals?



- 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?

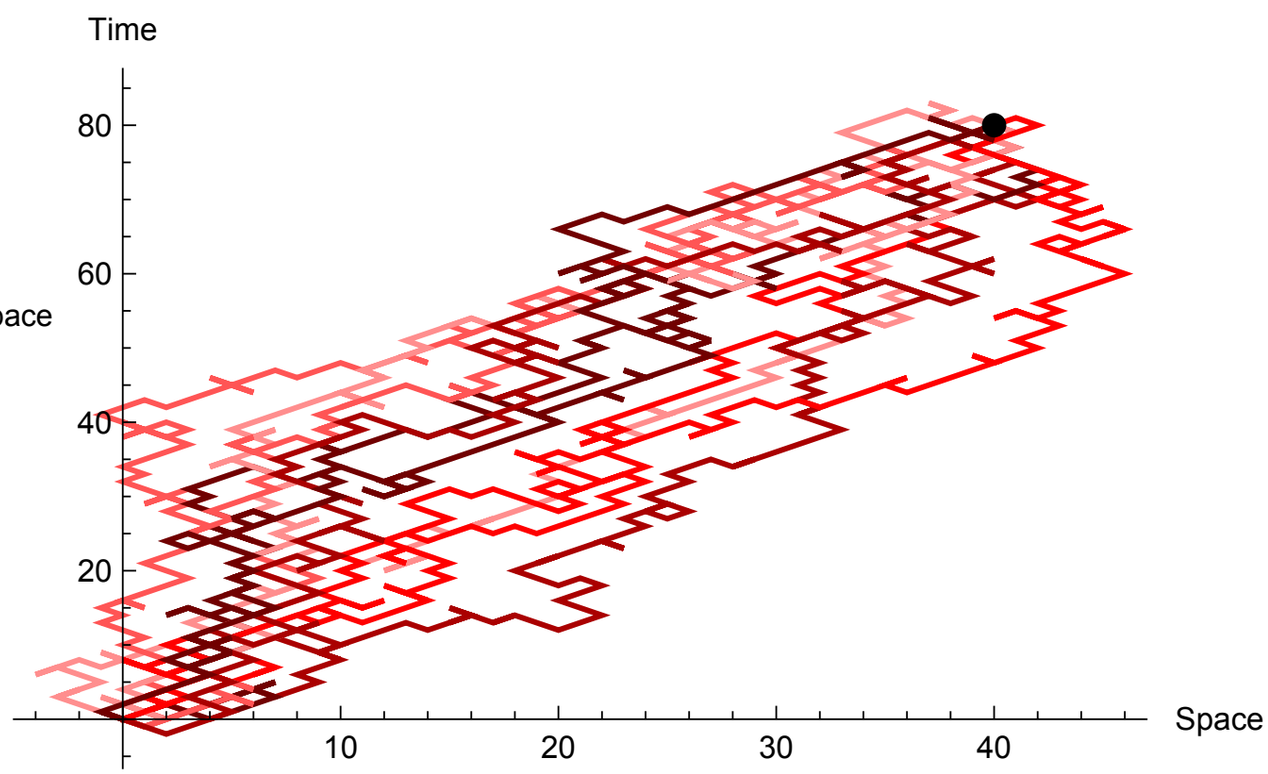


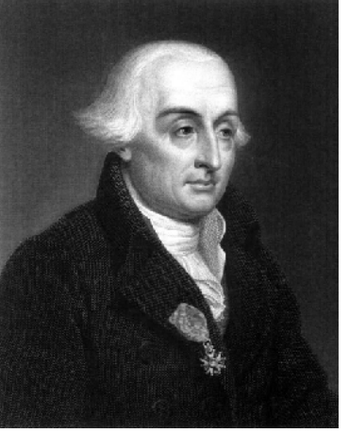
Paths



Paths in space only

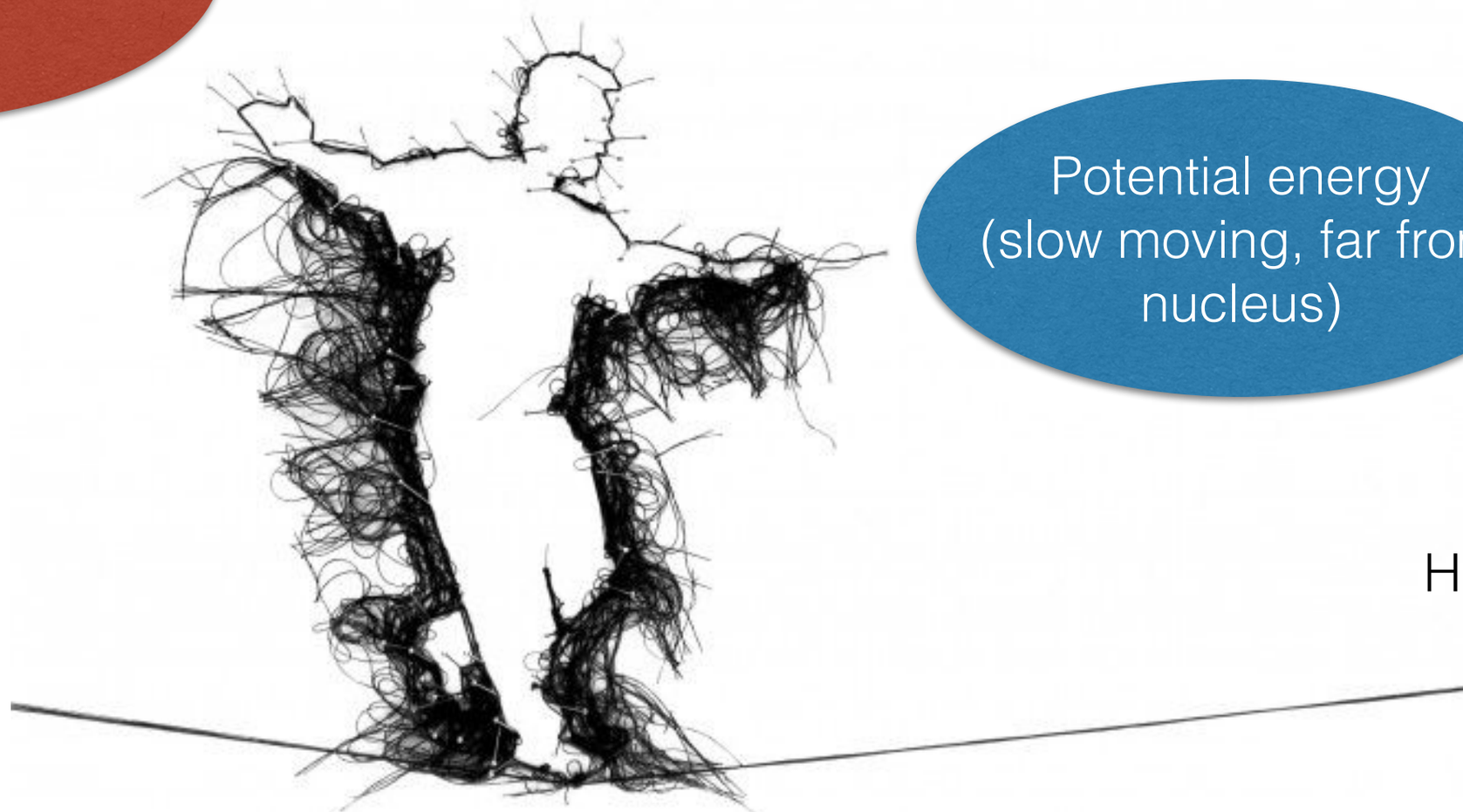
Paths in time as well as space





Balancing Act

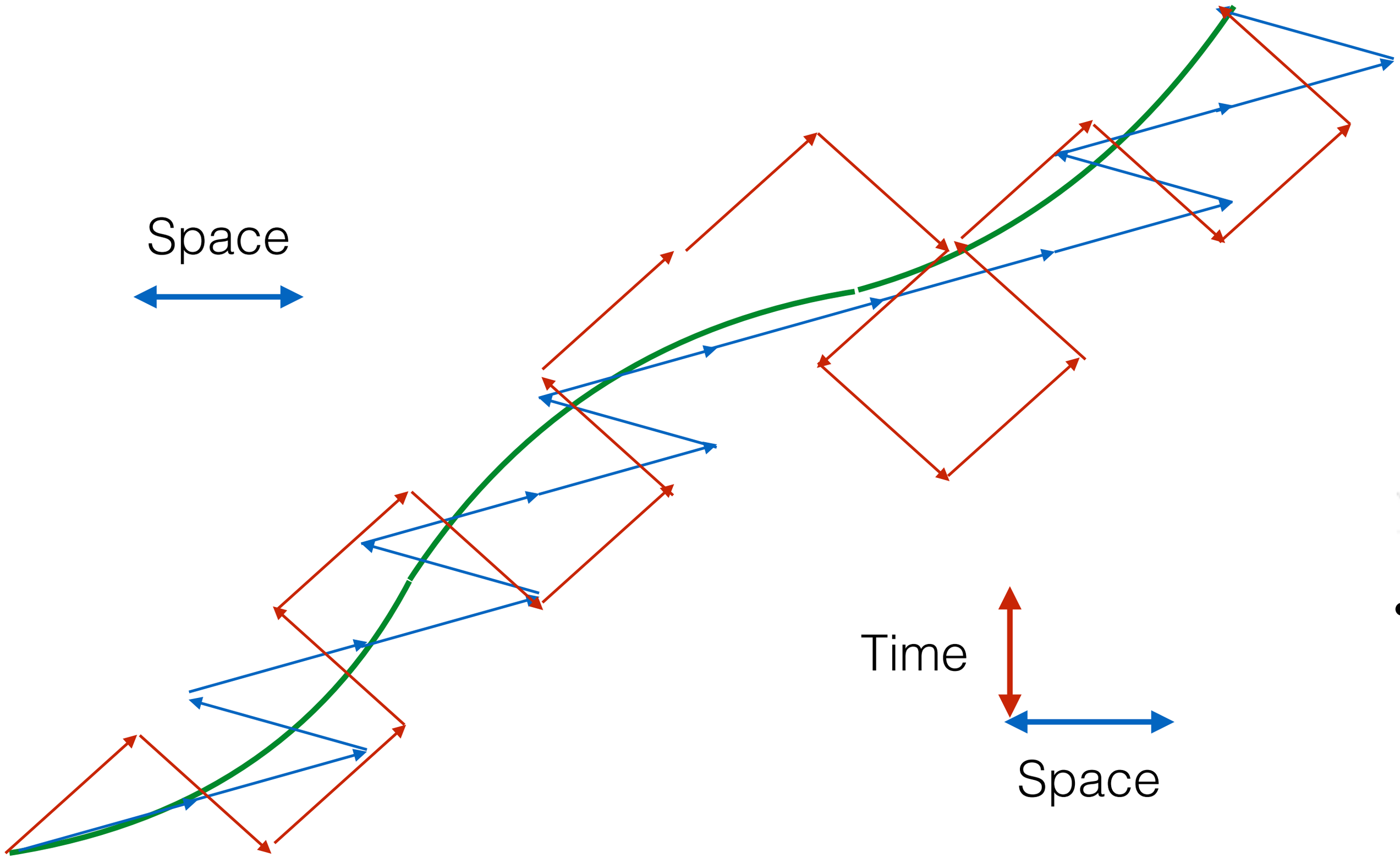
Kinetic energy
(fast moving, close to nucleus)



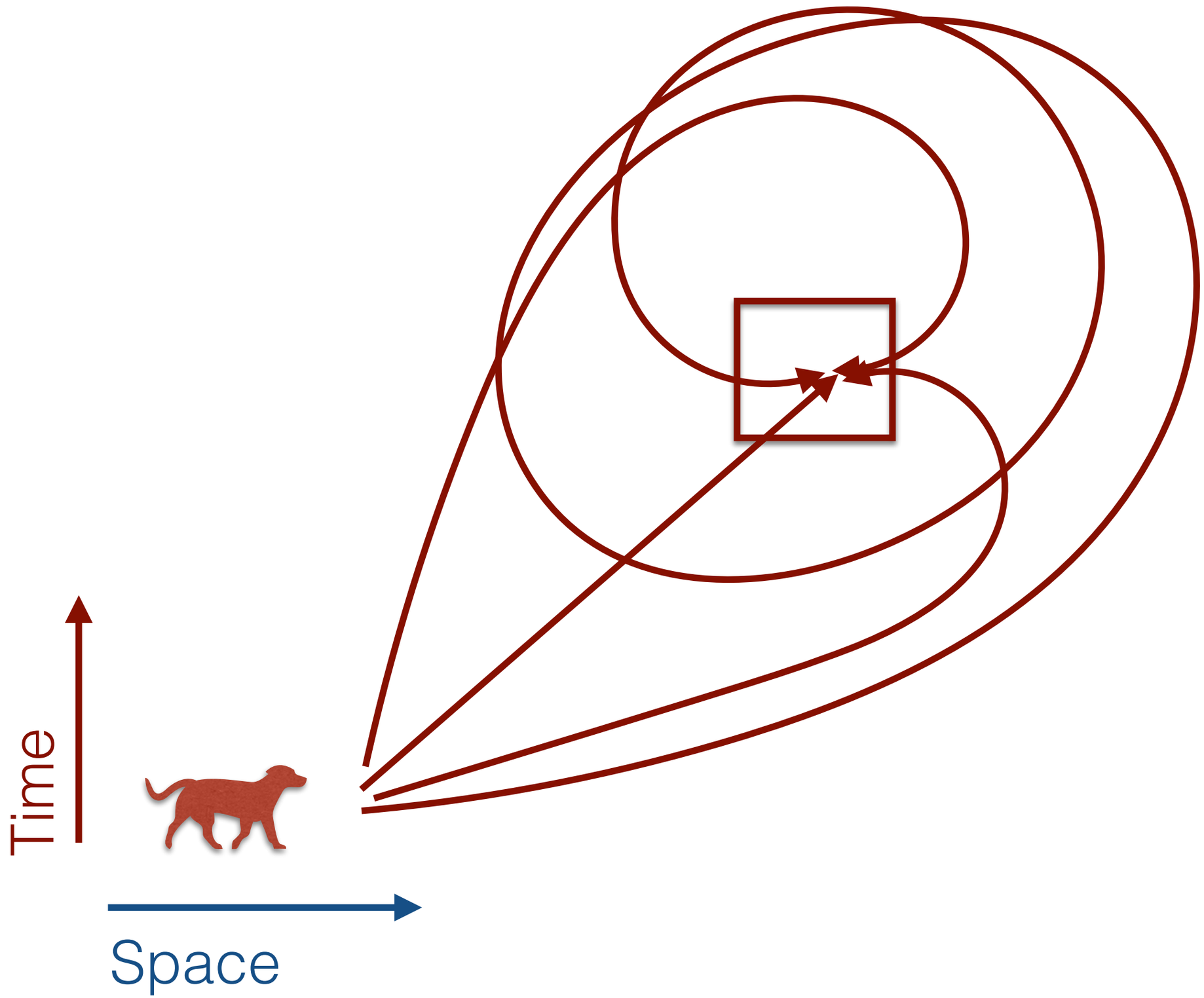
Potential energy
(slow moving, far from nucleus)

Hi Ya Goldilocks!

The river valley

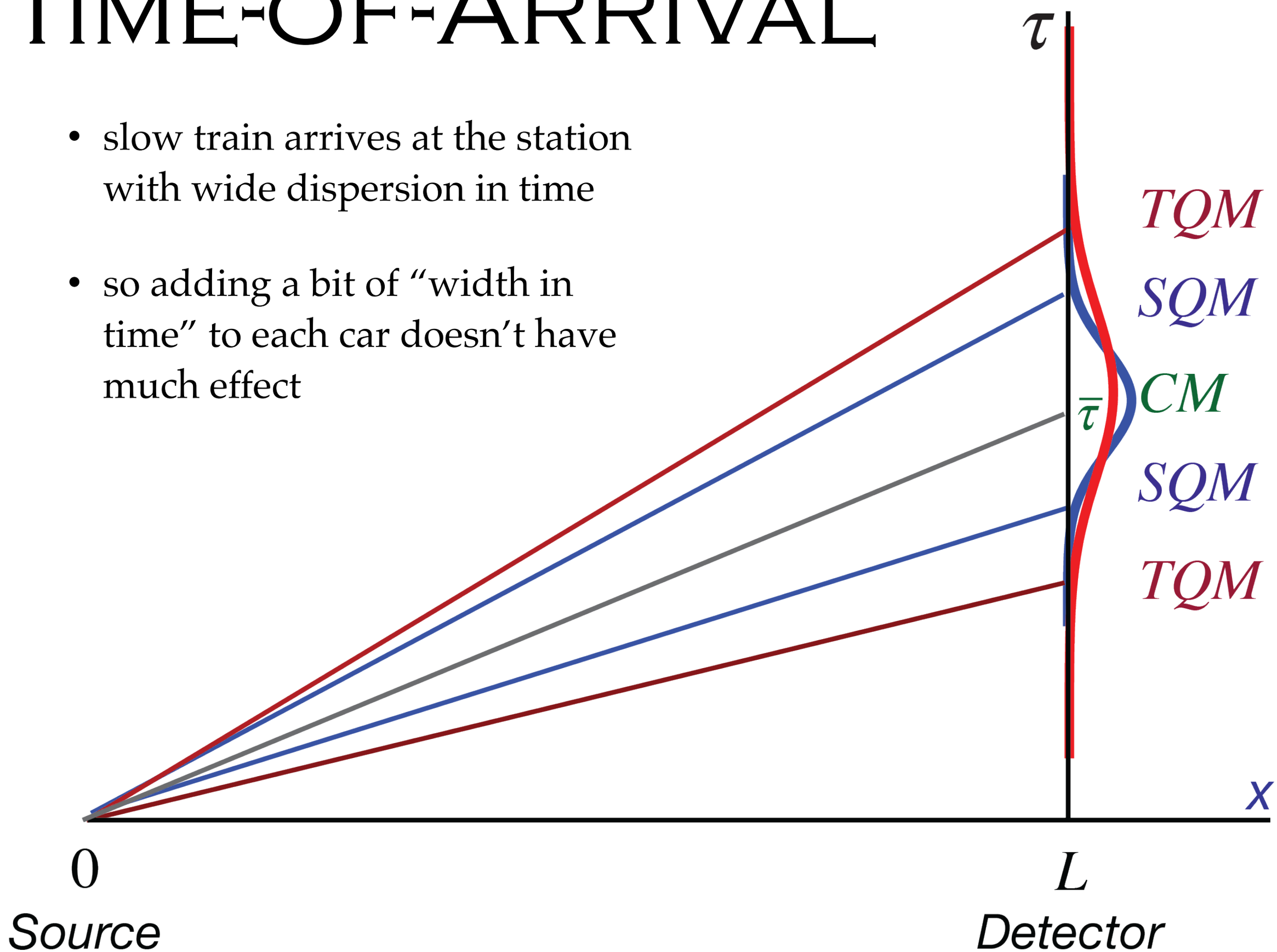


Simple and complex Paths

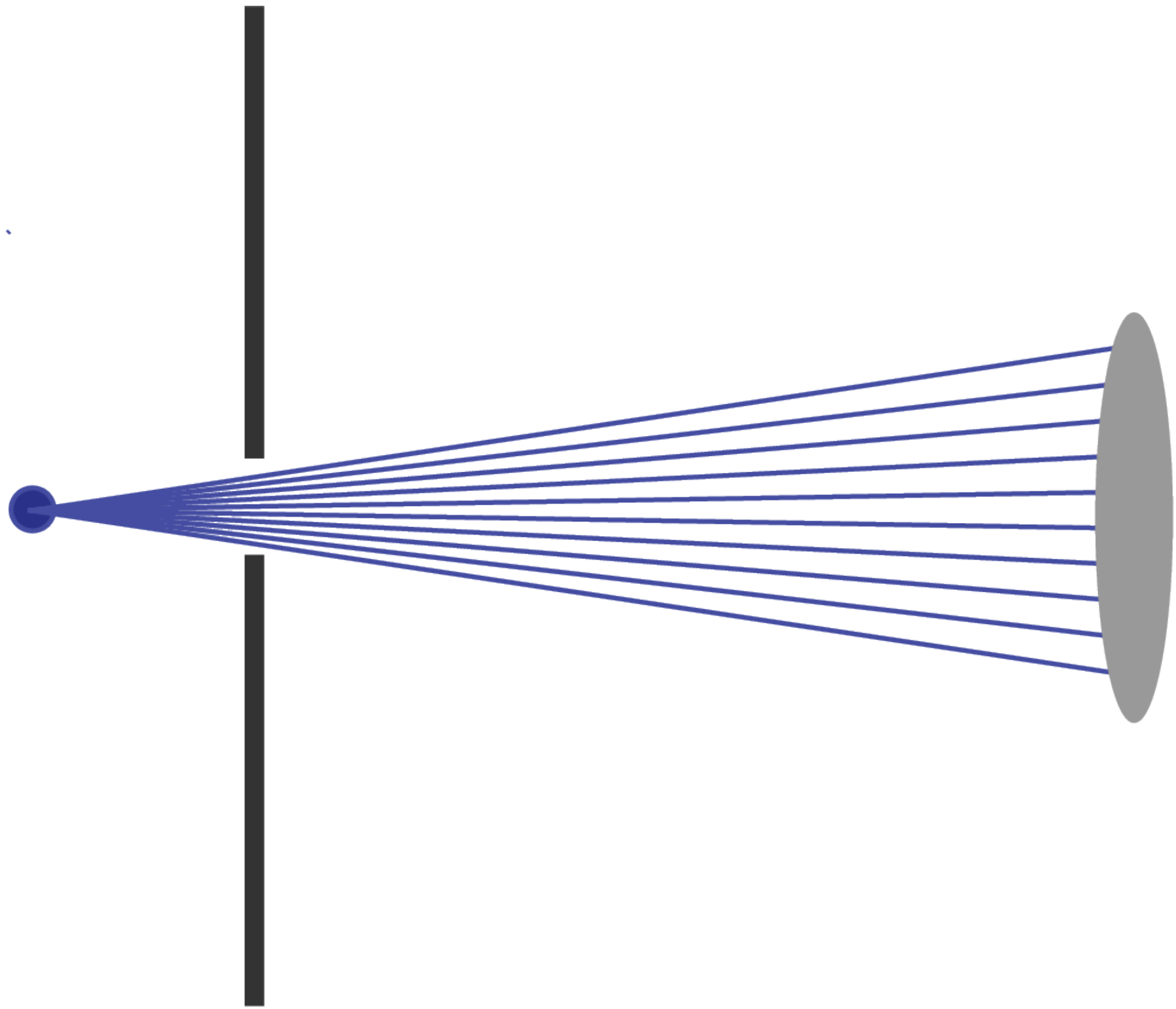


Time-of-Arrival

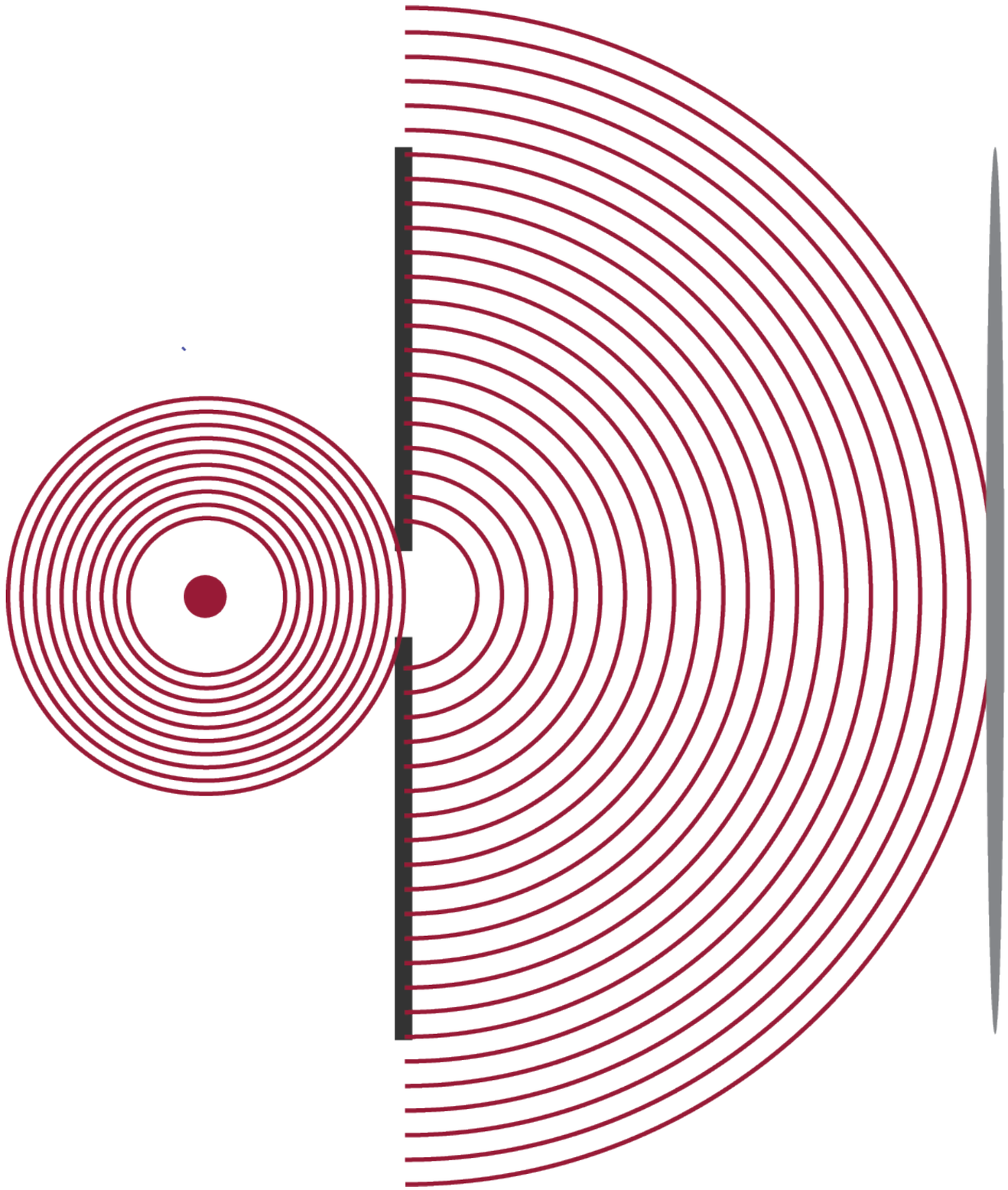
- slow train arrives at the station with wide dispersion in time
- so adding a bit of "width in time" to each car doesn't have much effect



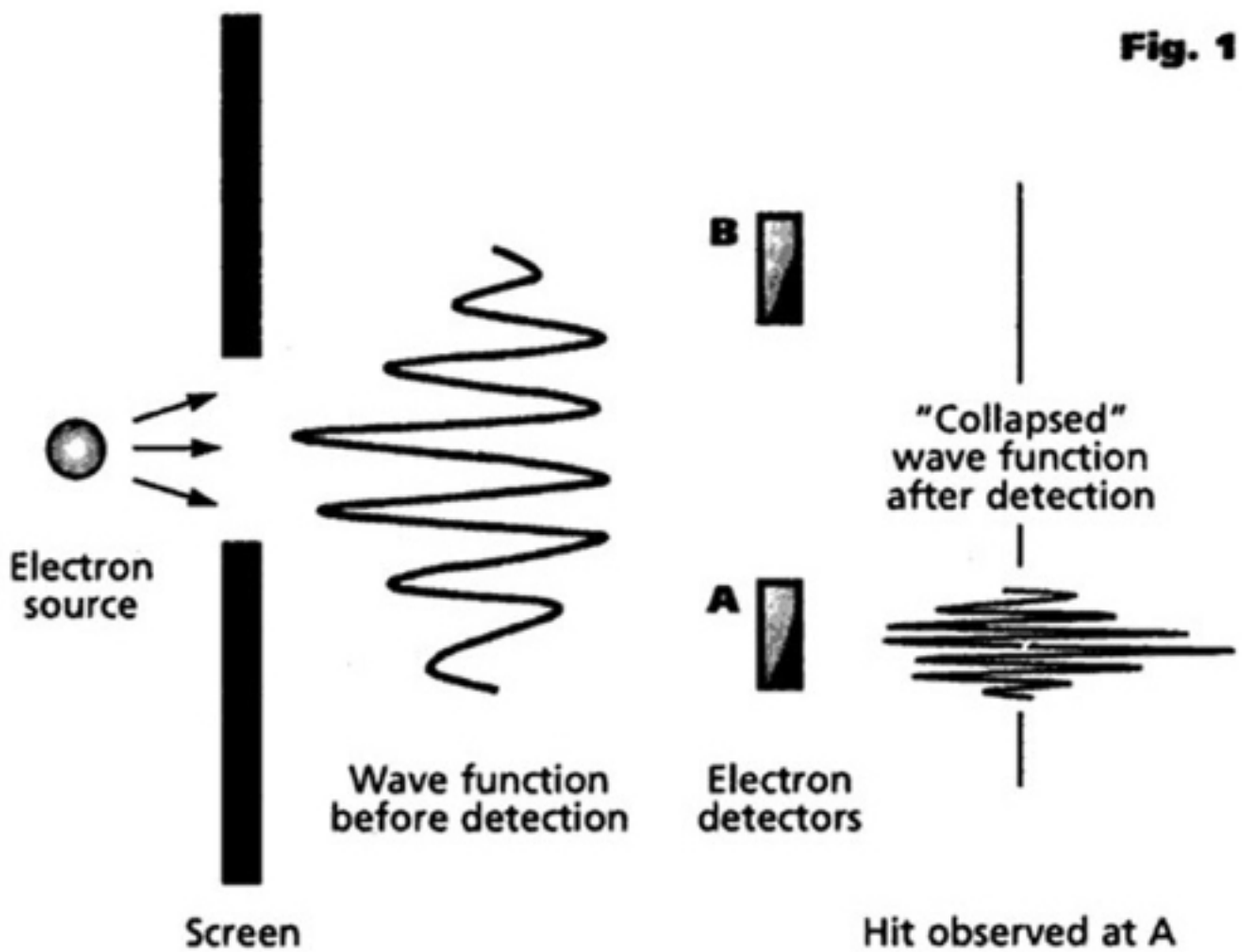
Single Slit/Bullets



Single Slit/Waves

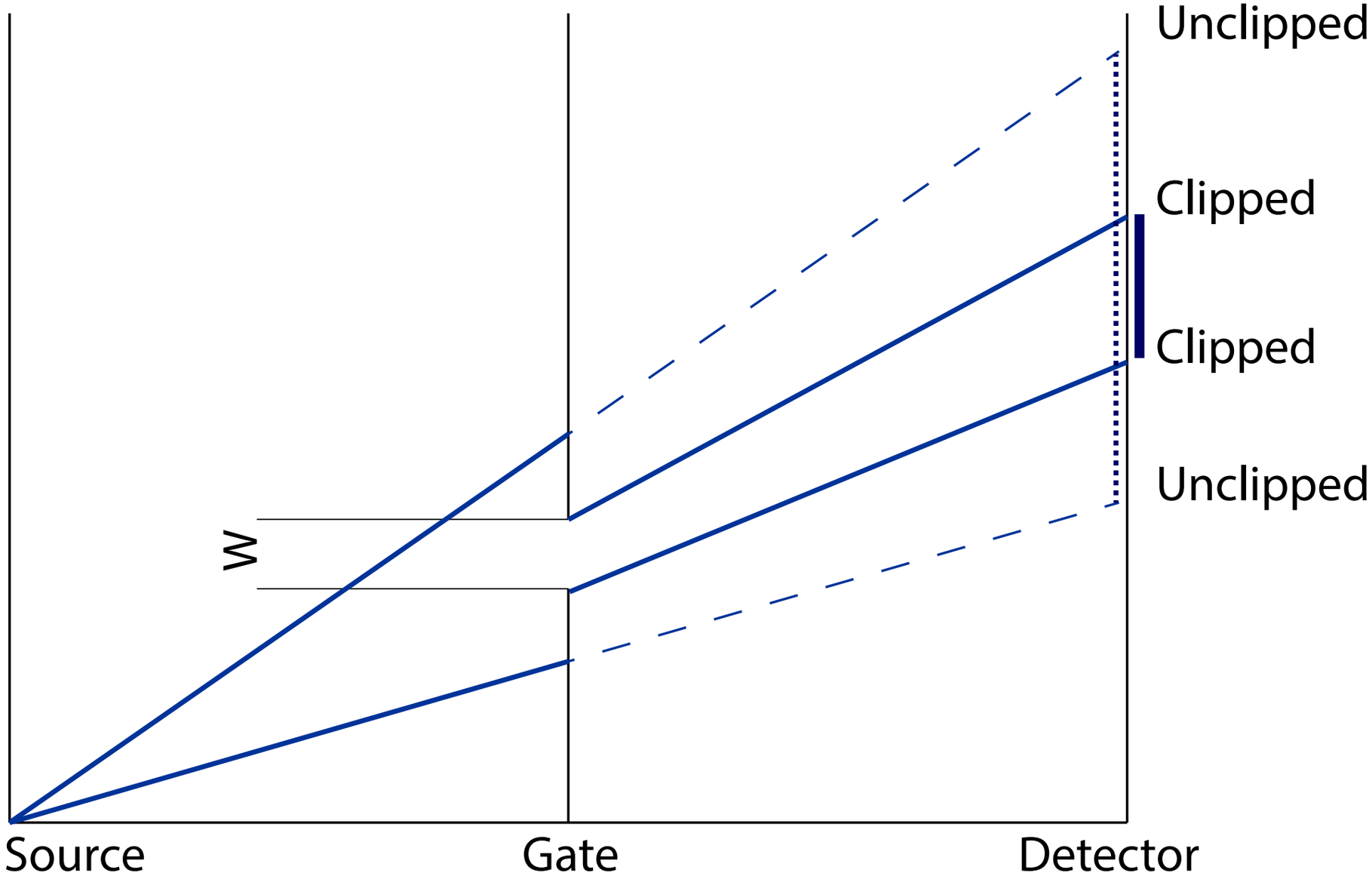


Single Slit/Quantum Mechanics



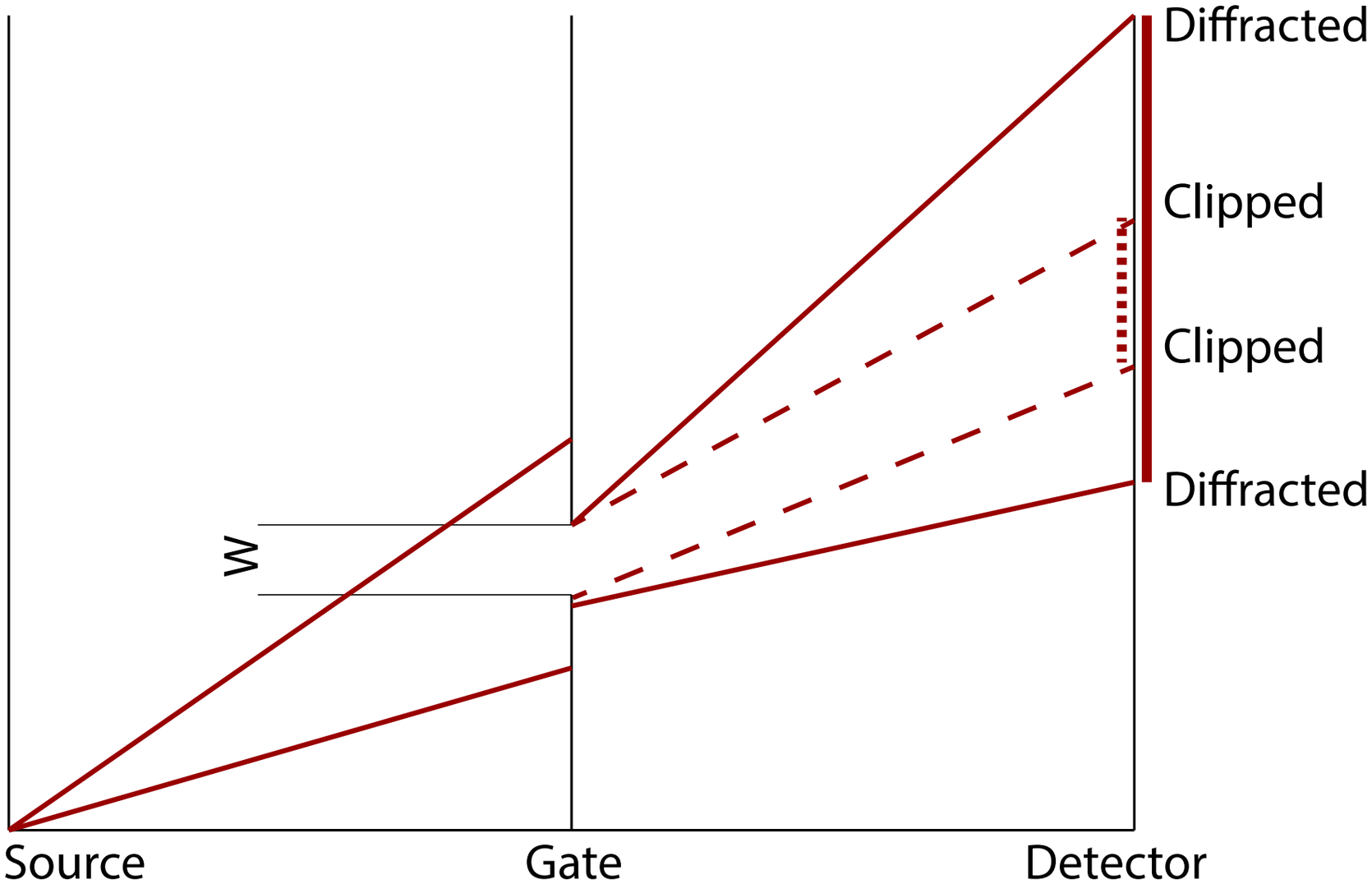
- QM waves are complex
- And we are using a finite slit
- So actual pattern is much "wavier"

Single slit in Standard QM (SQM)



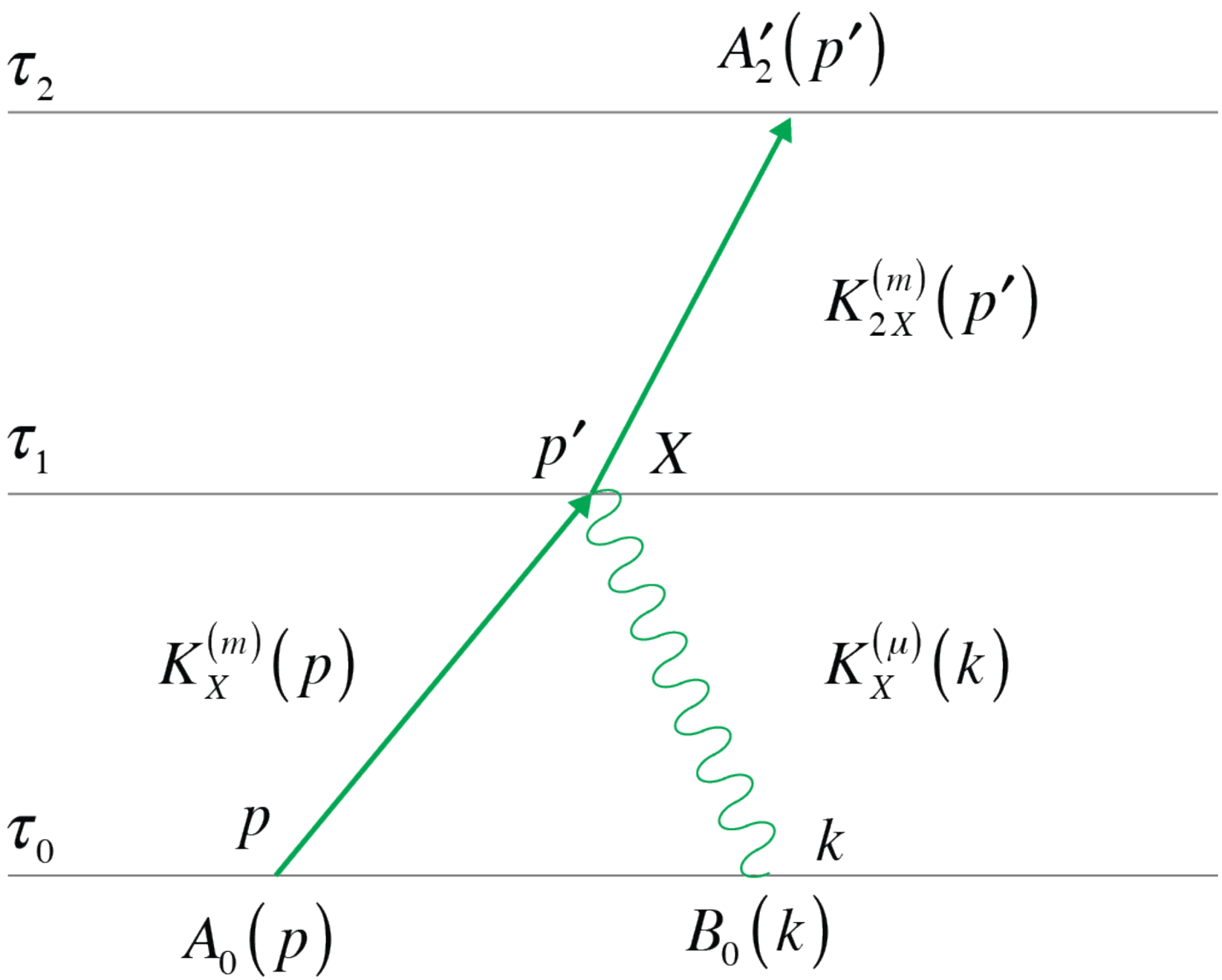
- No uncertainty principle in time/energy
- Fast shutter constricts gate
- Arbitrarily small dispersion

Single slit in QM with Time (TQM)



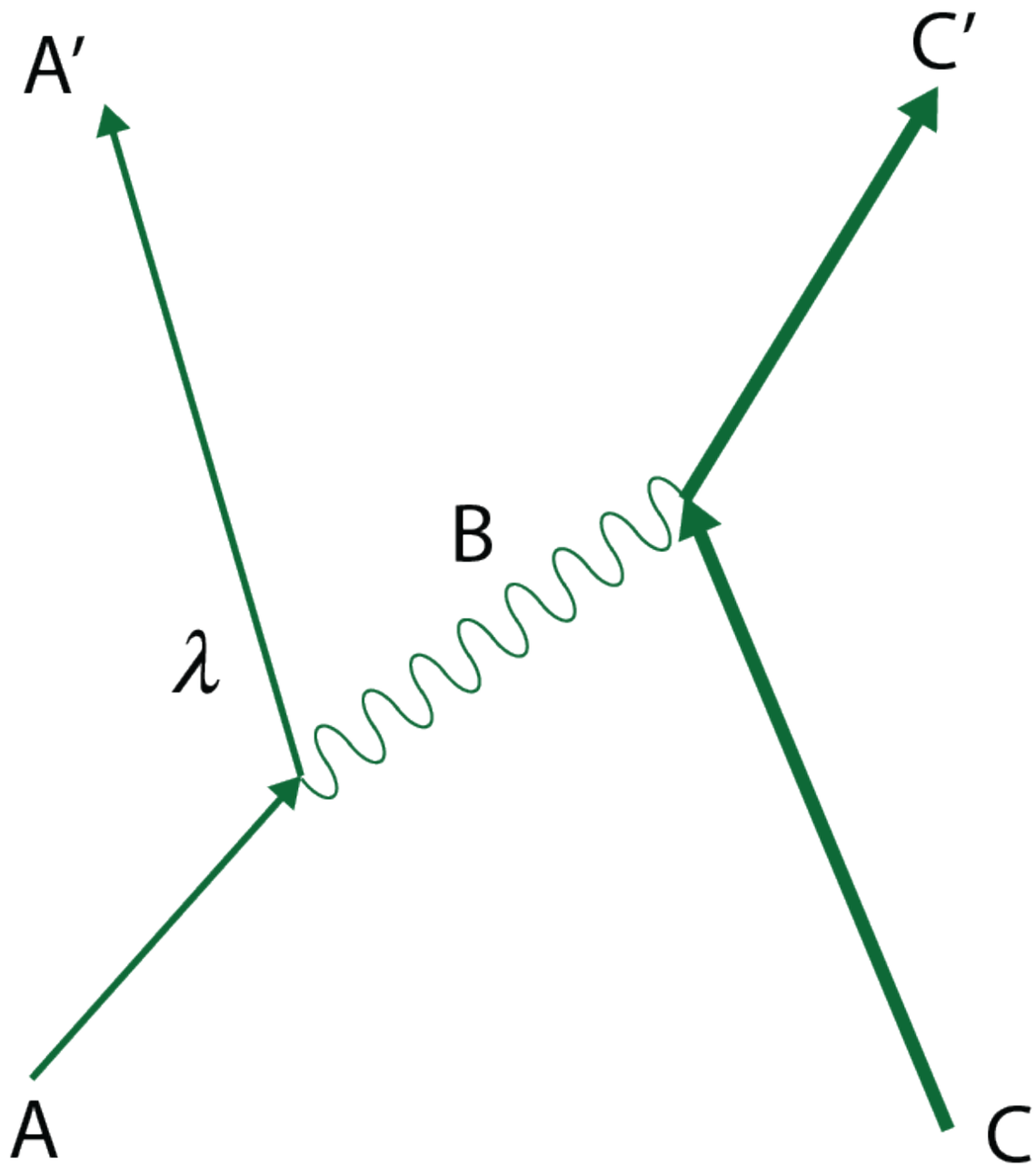
- Uncertainty principle in time/energy
- Diffraction
- Arbitrarily large dispersion
- **Falsifiable**

Two (or more) Particles



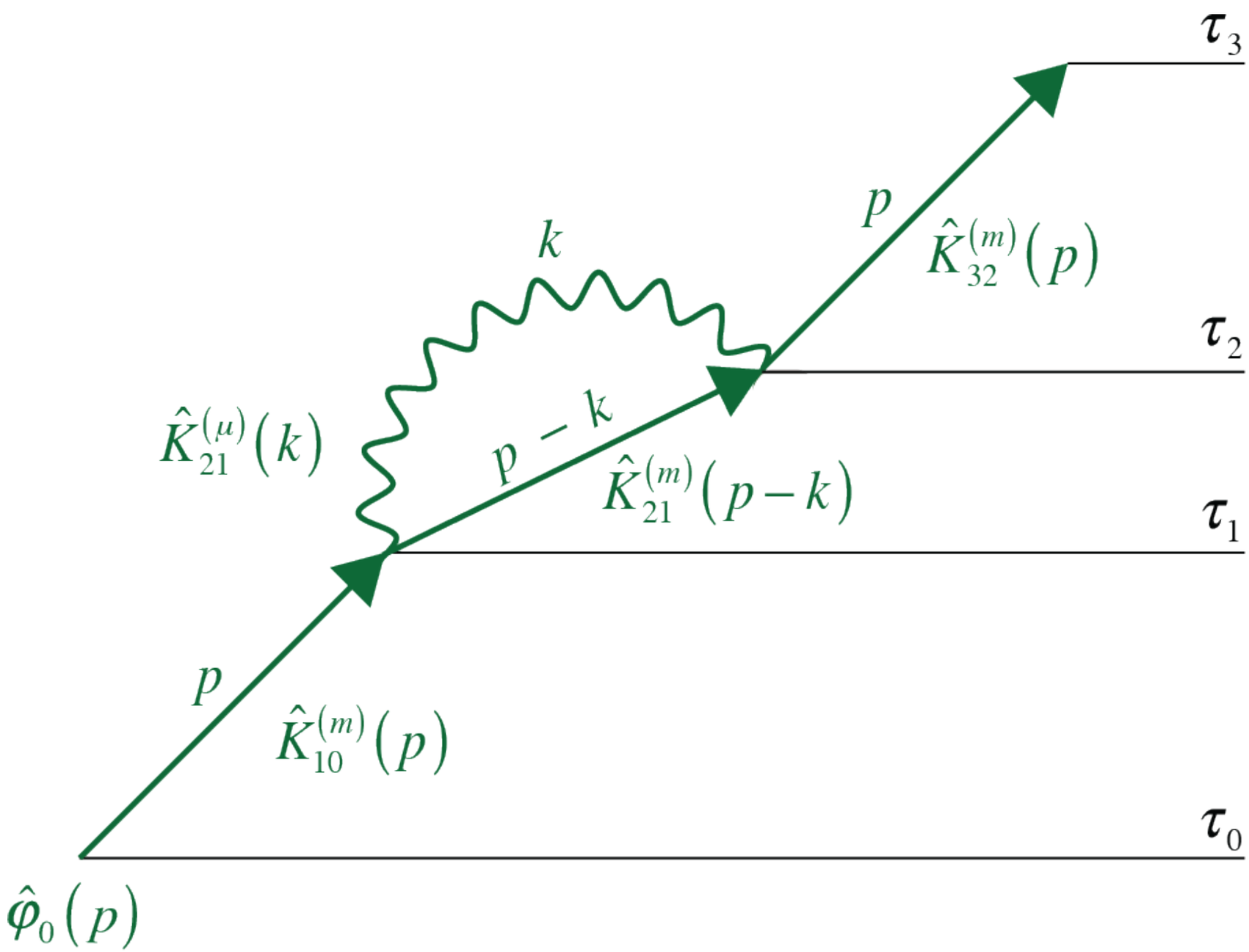
- Same basic approach (more math)
- Lets us look at high energies
- And more complicated (& interesting) experiments
- And, make sure this makes sense

Feynman diagrams



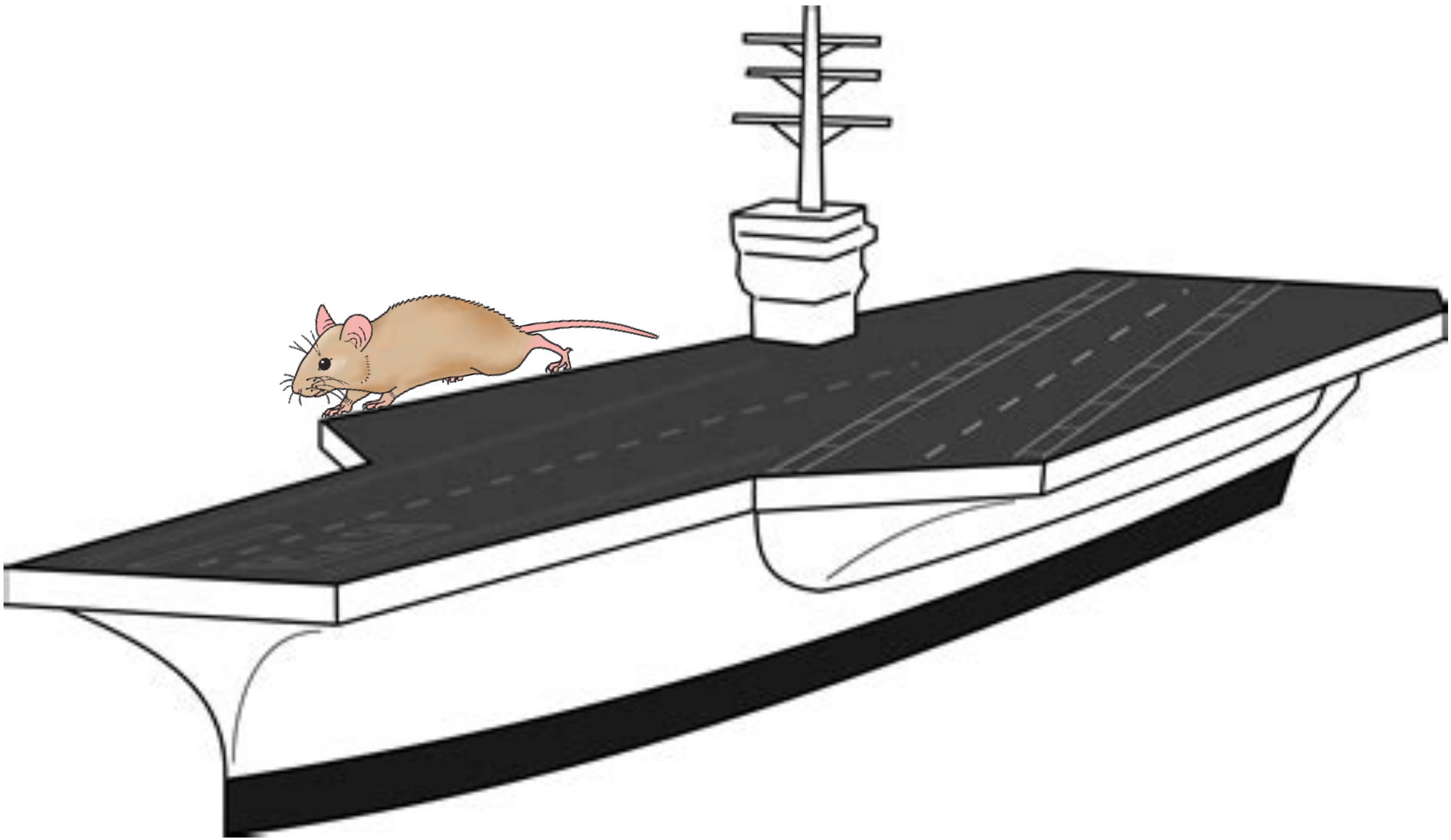
- Tinkertoy
- Arbitrarily complex
- Anchor for calculations

Advanced Loopiness

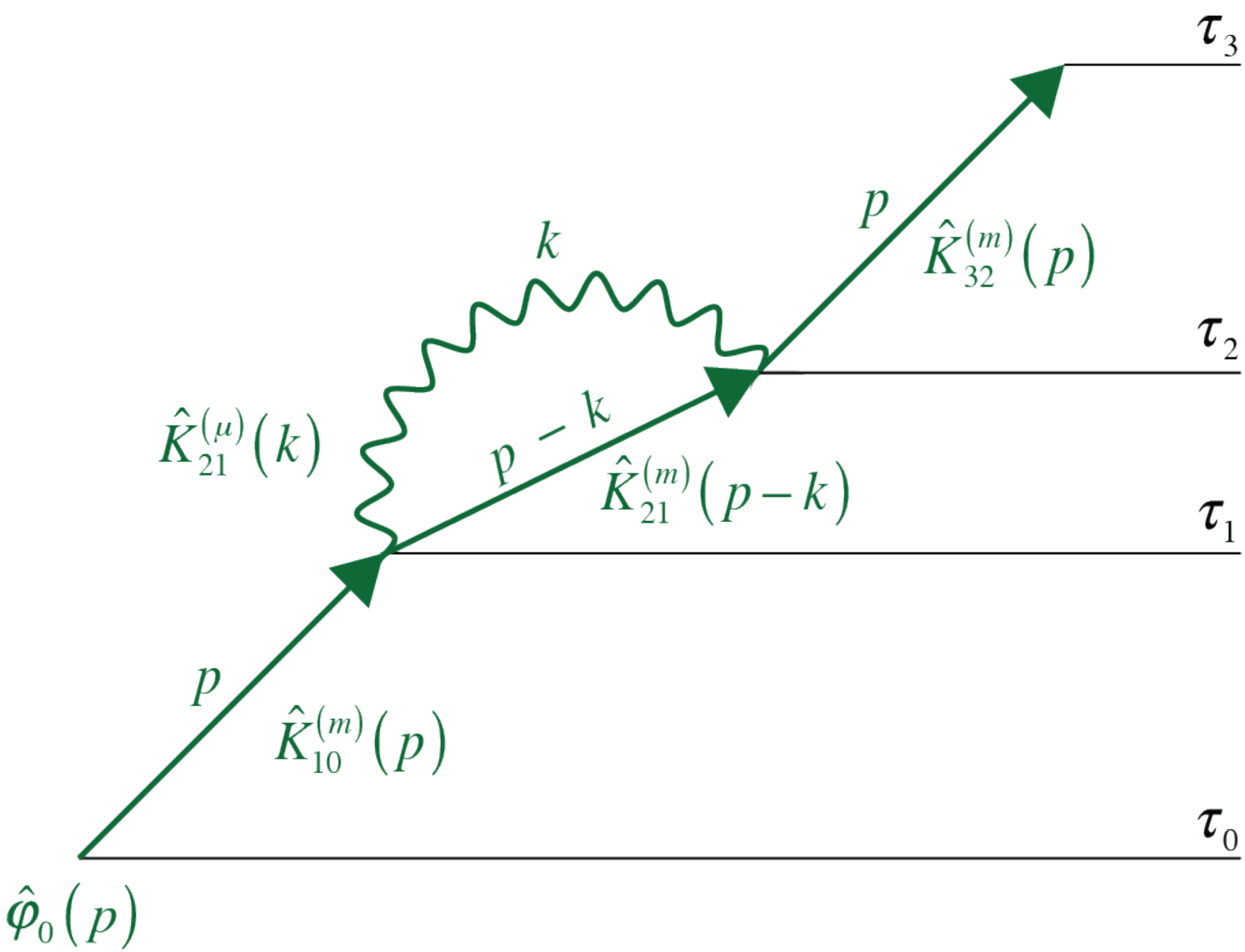


- small effect but lots of possibilities
- like being eaten by mice

How to weigh a mouse

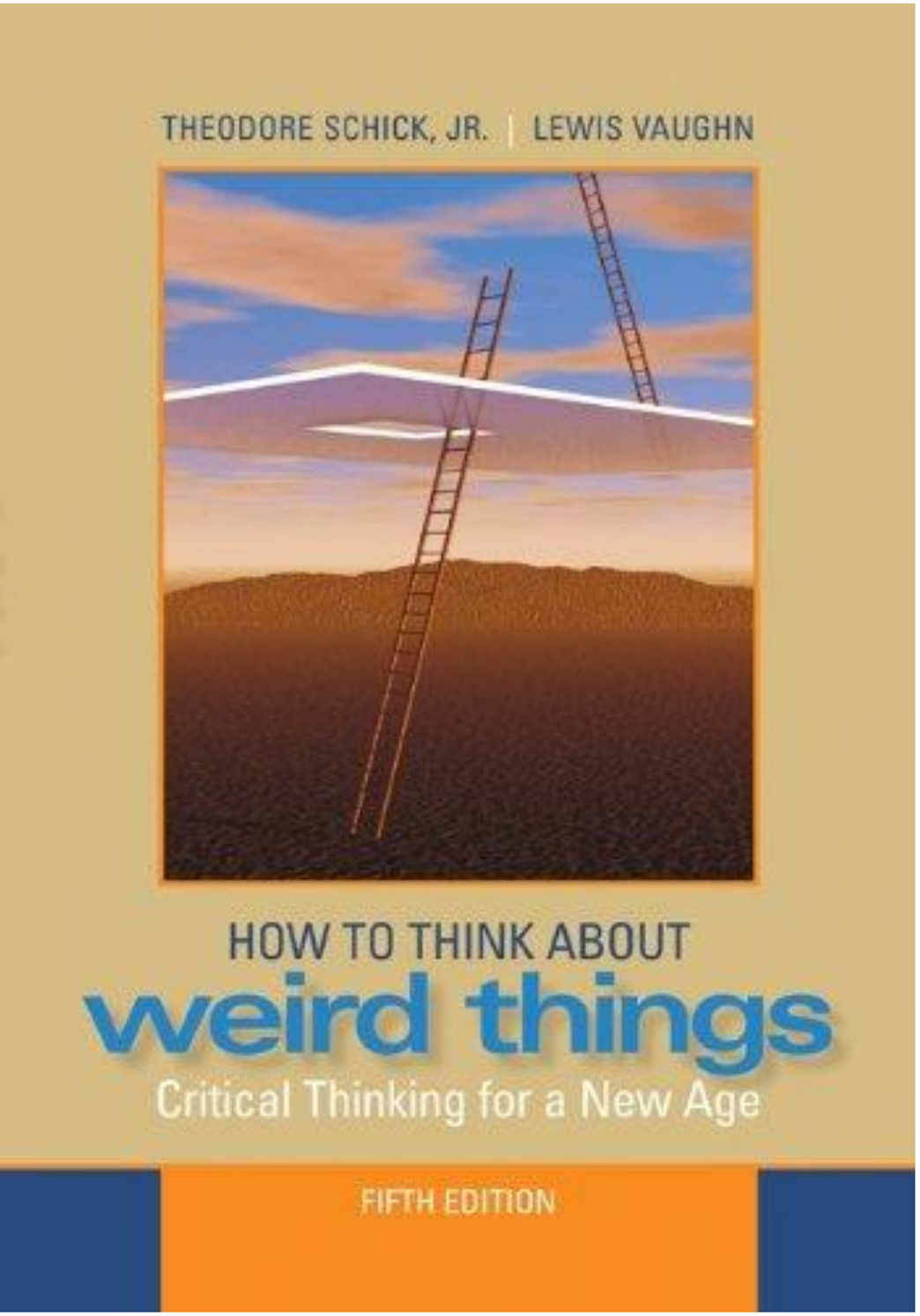


Advanced Loopiness II



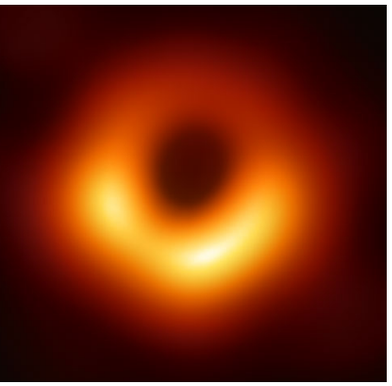
- opening wave function is limited in time
- entangled with next
- and with next
- chain keeps loop integral finite
- bridge of mice

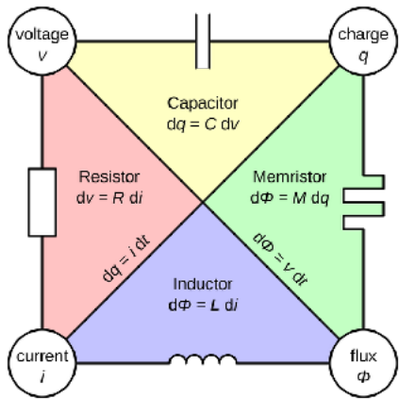
How to think about Weird things

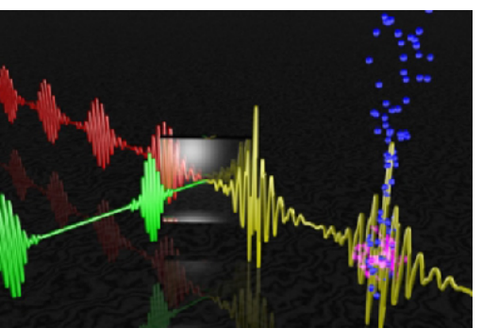


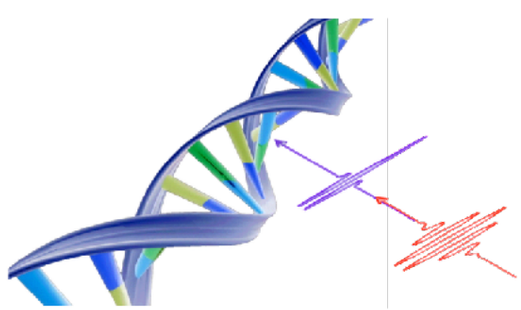
- **Consistent**: effects usually at scale of attoseconds
- **Falsifiable**: no free parameters, large enough to measure.
- **Simple**: complete symmetry between time and space, measure mice without use of aircraft carriers
- **Scope**: any quantum experiment varying at time scale of attoseconds
- **Fruitful**: lots of experiments, lots of interesting tech, no null experiments.

Uses



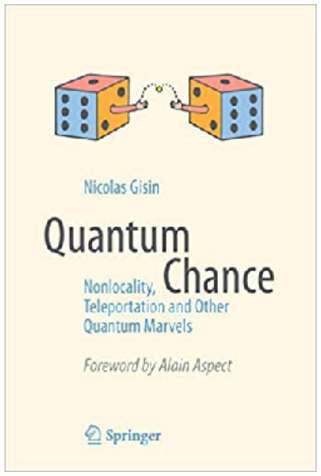


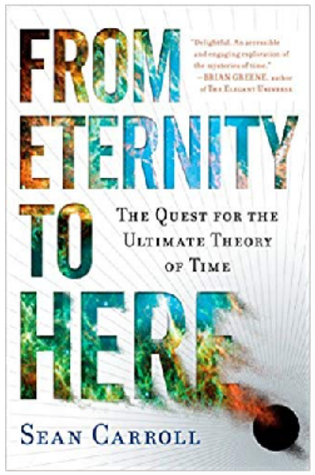


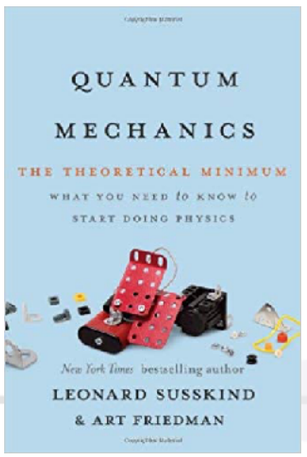


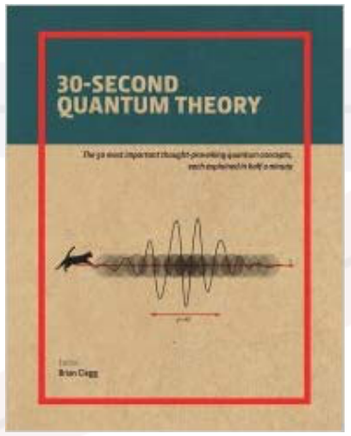
- Quantum gravity without costs & risks of black holes
- New communication channels, new circuit elements, as memristors
- Attosecond chemistry; attoseconds are the time scale for electron/molecule interactions
- Attosecond biology; better understanding of DNA, protein formation, …
- Let's take a flyer on the future; you never know where the lightning will strike!

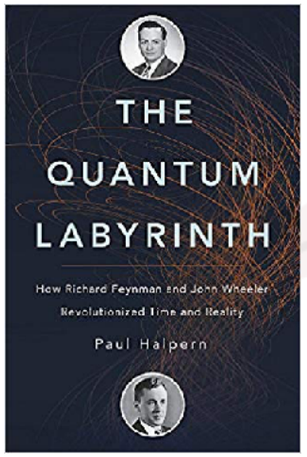
References











- Gisin - Quantum Chance
- Carroll - From Here to Eternity
- Susskind & Friedman - Quantum Mechanics
- Clegg et al - 30-second Quantum Theory
- Halpern - Quantum Labyrinth
- Ashmead - Time dispersion in quantum mechanics - (2019 J. Phys.: Conf. Ser. 1239 012015)

Thanks!

- Ferne Welch
- Jonathan Smith
- Nicolas Gisin — for the goal!
- IARD: especially Martin Land & Larry Horwitz
- Balticon 2019 & Miriam Kelly
- And you!

Destination in Zero Slides