The Nature of Time from the Planck time moment to Now and Maybe Beyond

The Nature of Time

By Dr. Harold Williams
of Montgomery College Planetarium
And NCA member

Human understanding of Time starts in the Sky

- Day and Night, moving Sun in the Day, moon half of the time in the night
- Moon moves and has phases which change
- Stars at night which move and change with the seasons
- Seasonal changes on the Earth and in the Sky

Persistence of Memory

memory (irreversibility) is important to time

Disintegration of the Persistence of Memory

Speed is important,

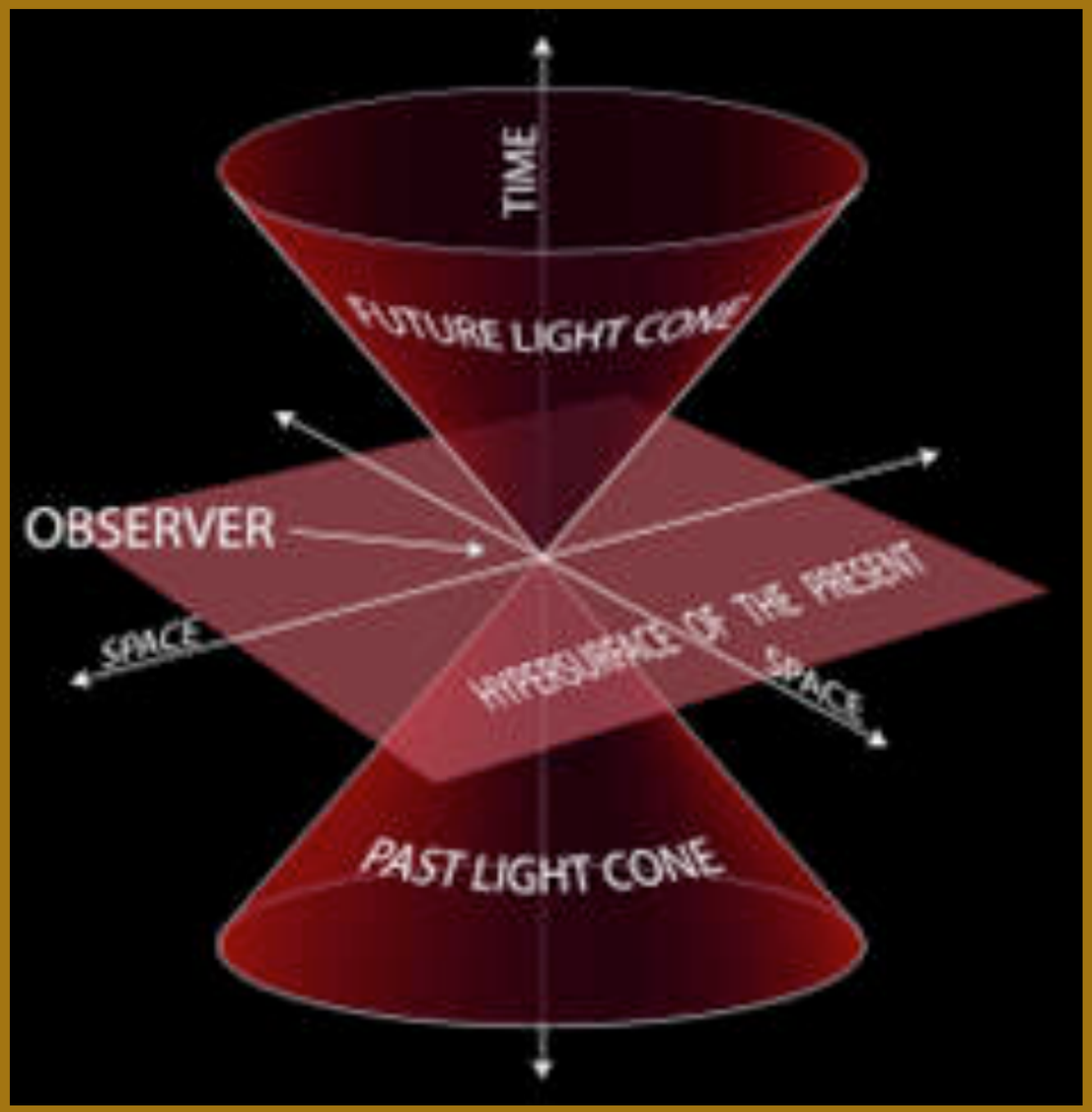
things do move in our universe.

- For our universe to be causal there must be a maximum speed of information.
- Since we receive most of our information about the universe from seeing, there is a maximum speed at which we see, LIGHT.
- We shall denote the maximum speed with the letter, c, and call it the speed of light in a vacuum.

Infinity has no bound,
so c can not be infinite,
this does have consequences.

- The speed of light, c, is very fast compared to average speeds that you and I normally go at relative to other things around us.
- Galileo Galilei and Isaac Newton tried to measure the speed of light, but failed since the technology at the time was not capable of it.
- Ole Roemer, a Danish astronomer did so quantitatively in 1676. Newton was still living.

Another Light Cone

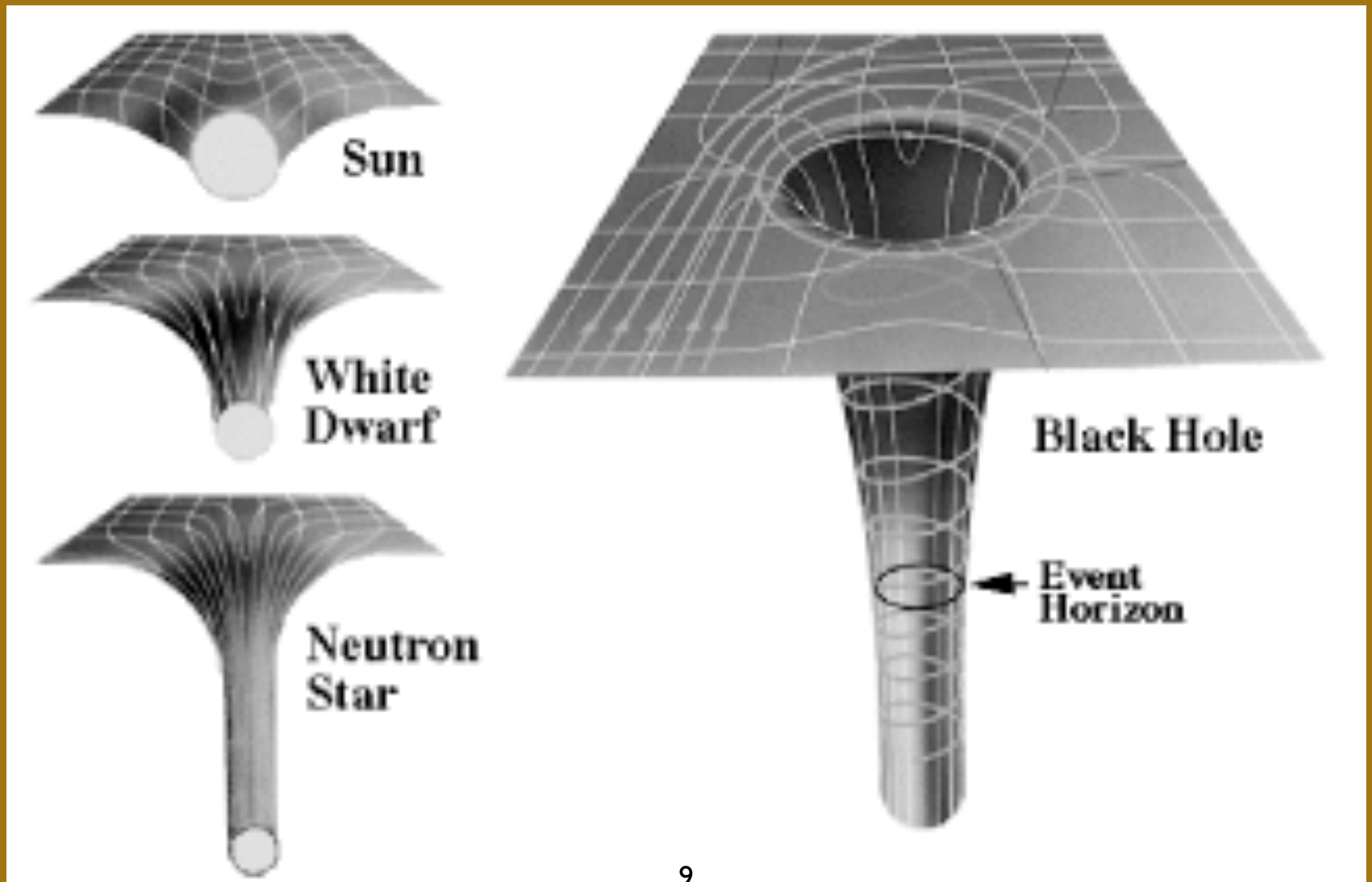


Key idea of General Relativity

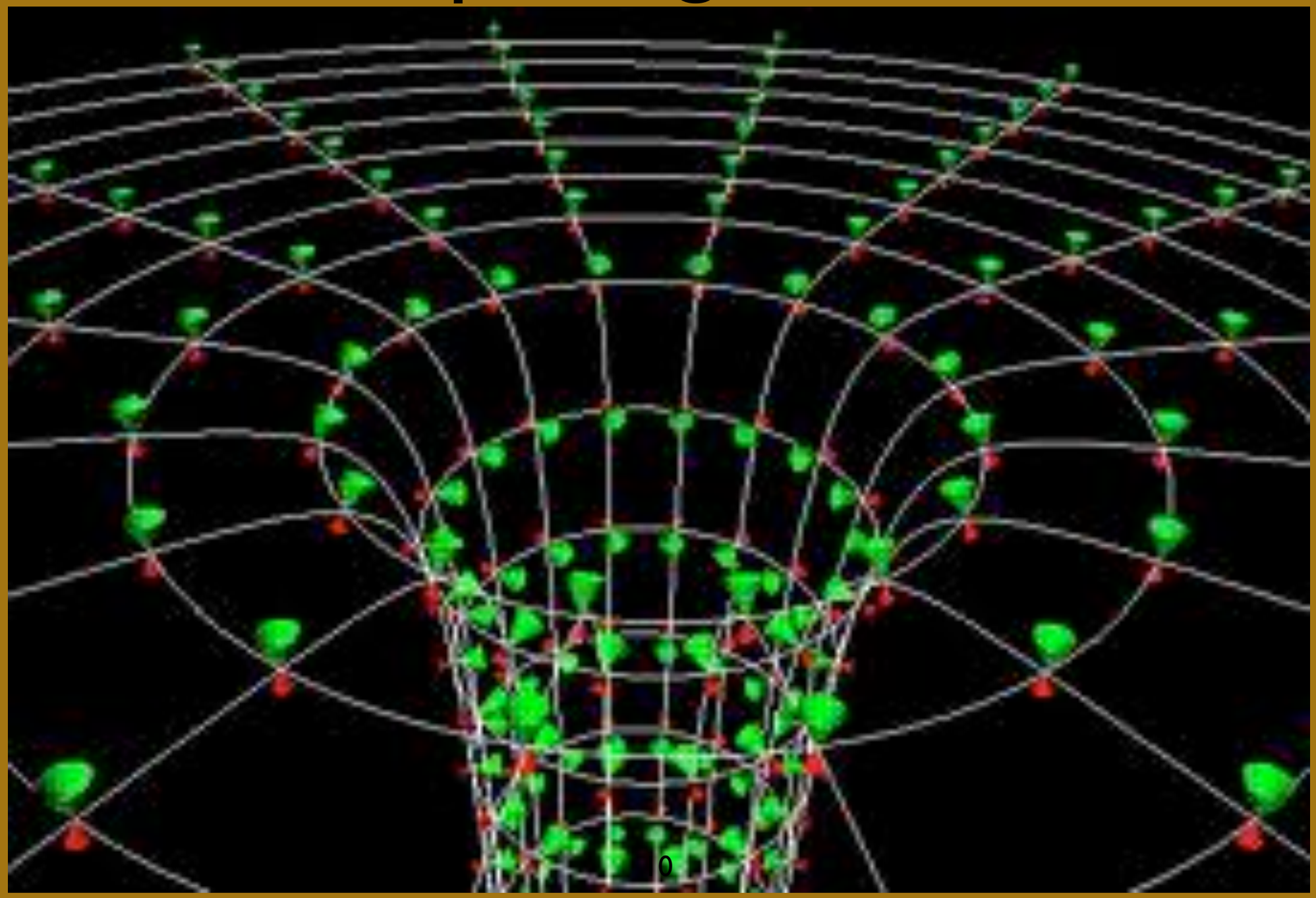
a model of Gravity

- Time-Space tells things with energy how to move; things with energy tells time-space how to curve.
- A current fact, locally most energy is locked up in mass, so to first order I can replace energy with mass in the above statement and only make a small error most of the time, unless the thing with energy is moving at or somewhat near c, the maximum speed.

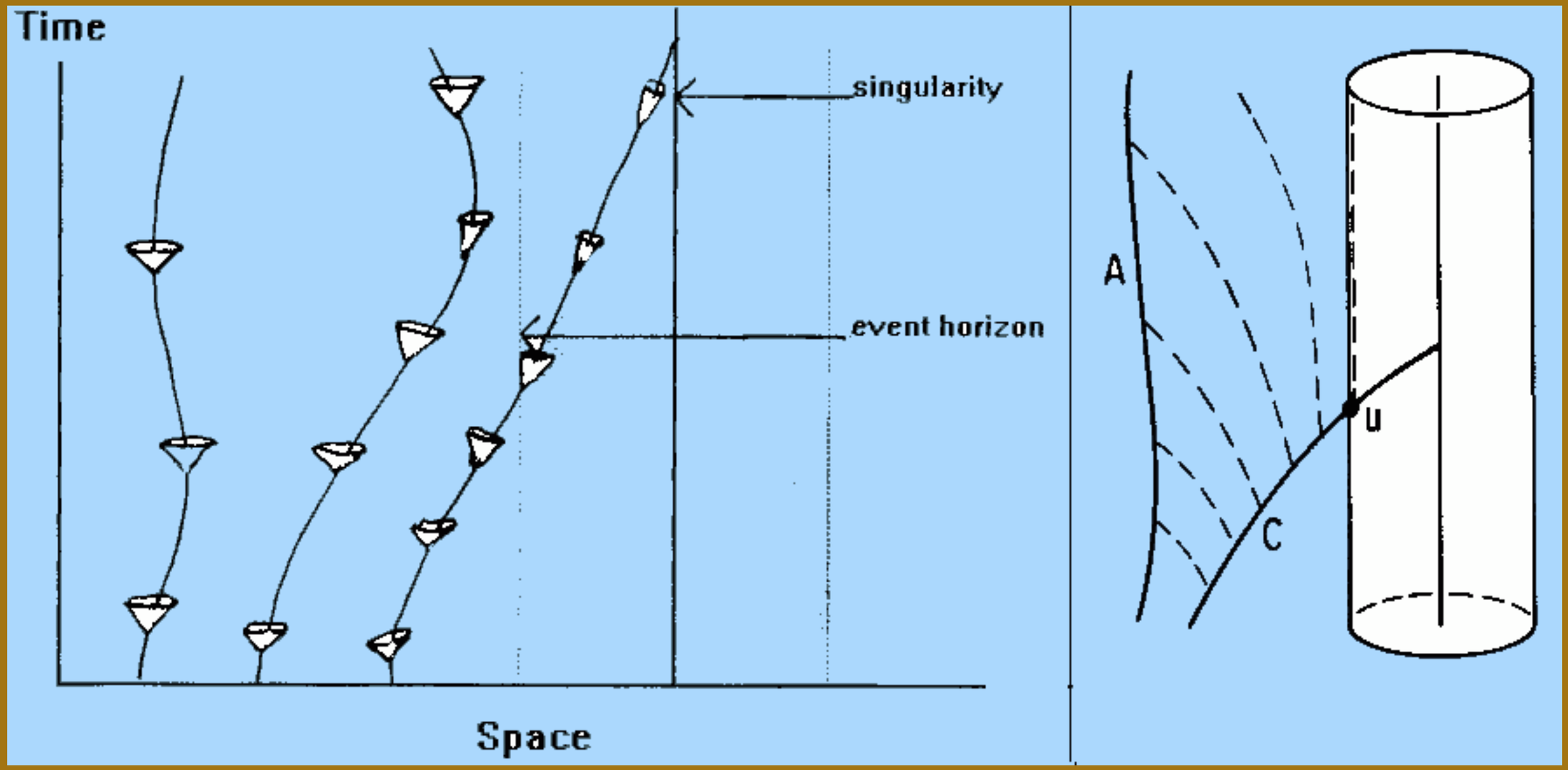
Gravity's curvature is in both time and space



Near an Events Horizon,
Green future light cone
Red past light cones



Bending of the light Cone near an events horizon, future cone shown



Since time-space curvature is to be used differential geometry and curvature tensor and possibly torsion tensor.

- Solutions will depend upon energy, E, which may be a function of particles (things) mass, M, and momentum, P, and angular momentum, L, and the speed of light, c, and the Newtonian gravitational constant, G, will appear in the classical general relativistic solutions.
- Mathematics will be challengingly, monstrous!
- Clifford Algebra will make things a little easier, but understanding will still be hard.

Chapter 3 Plunging

Exploring Black Holes Introduction to Relativity by Taylor and Wheeler

- If you will not take the answer too seriously, and consider it only as a kind of joke, then I can explain [general relativity] as follows. It was formerly believed that if all material things disappeared out of the universe, time and space would be left. According to the relativity theory, however, time and space disappear together with the things. -Albert Einstein

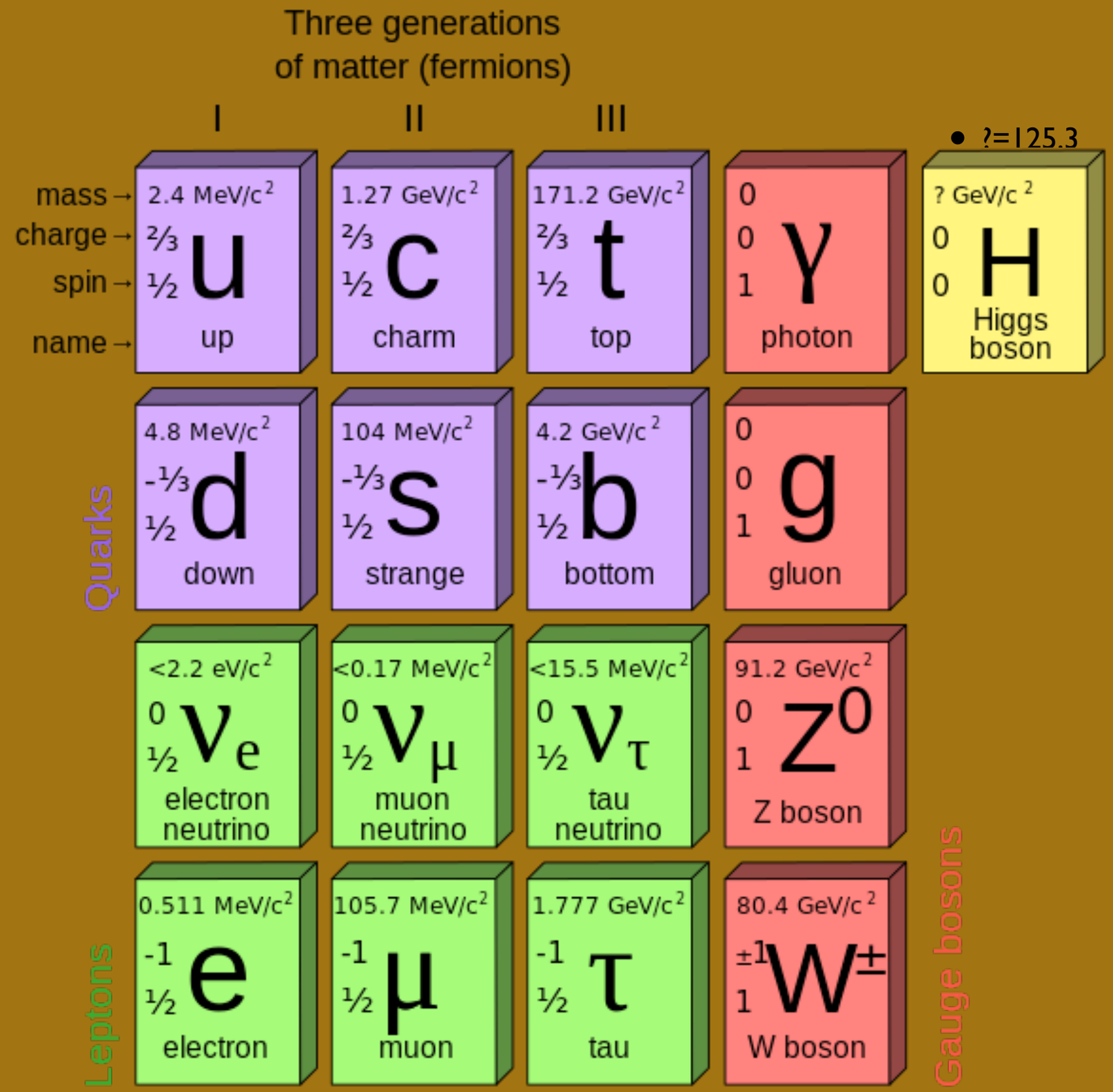
Now Quantum Mechanics,

what are things fundamentally made of

- Standard Model of Wavicle (Particle) Physics
- You knew Planck's constant was coming, right?
- You do now!

Standard Model of particle physics

what are some of the things in the universe



- ?=125.3

History of the Planck length, time, and mass

- In 1899 a year before he formulated blackbody radiation in December of 1900 in Prussian Academy of Sciences, Max Planck: 'Über irreversible Strahlungsvorgänge', Sitzungsberichte der Preußischen Akademie der Wissenschaften, vol. 5, p. 440-479-480 (1899). He just used dimensional analysis.

$$l_P \equiv \sqrt{\frac{G\hbar}{c^3}} \doteq 1.616199(97) \times 10^{-35} \ m$$

$$t_P \equiv \sqrt{\frac{G\hbar}{c^5}} \doteq 5.39106(32) \times 10^{-44} \ s$$

$$m_P \equiv \sqrt{\frac{c\hbar}{G}} \doteq 2.176\,51(13) \times 10^{-8} \ kg \approx 21 \mu grams$$

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aussermenschliche Culturen nothwendig behalten und welche daher als »natürliche Maasseinheiten« bezeichnet werden können.

Die Mittel zur Festsetzung der vier Einheiten für Länge, Masse, Zeit und Temperatur werden gegeben durch die beiden erwähnten Constanten a und b, ferner durch die Grösse der Lichtfortpflanzungsgeschwindigkeit c im Vacuum und durch die der Gravitationsconstante f. Bezogen auf Centimeter, Gramm, Secunde und Celsiusgrad sind die Zahlenwerthe dieser vier Constanten die folgenden:

$$a = 0.4818 \cdot 10^{-10} [\text{sec} \times \text{Celsiusgrad}]$$

$$b = 6.885 \cdot 10^{-27} \left[\frac{\text{cm}^2\text{gr}}{\text{sec}}\right]$$

$$c = 3.00 \cdot 10^{10} \left[\frac{\text{cm}}{\text{sec}}\right]$$

$$f = 6.685 \cdot 10^{-8} \left[\frac{\text{cm}^3}{\text{gr. sec}^2}\right]^1.$$

Wählt man nun die »natürlichen Einheiten« so, dass in dem neuen Maasssystem jede der vorstehenden vier Constanten den Werth 1 annimmt, so erhält man als Einheit der Länge die Grösse:

$$\sqrt{\frac{bf}{c^3}} = 4.13 \cdot 10^{-33}\,\text{cm},$$

als Einheit der Masse:

$$\sqrt{\frac{bc}{f}} = 5.56 \cdot 10^{-5}\,\text{gr},$$

als Einheit der Zeit:

- Max Planck: 'Über irreversible Strahlungsvorgänge'. Sitzungsberichte der Preußischen Akademie der Wissenschaften, vol. 5, p. 480 (1899)

- ferner durch die Grosse der Lichtfortpflanzungsgeshwindigkeit
- further Great Light reproduction tempo
- E=hf, already formulated in words!

The only equations you need are:

Event Horizon $R_s = \frac{2GM}{c^2}$ 1917 GR

1905 SR $E = Mc^2$

Tautology $c = \lambda f$

Max Planck Rule $E = hf$ 1900

definition $f = 1/t$

Velocity-addition formula

$$\boldsymbol{v}_1 \oplus \boldsymbol{v}_2 \equiv \frac{\boldsymbol{v}_1 + \boldsymbol{v}_2}{1 + \frac{\boldsymbol{v}_1 \cdot \boldsymbol{v}_2}{c^2}} + \frac{1}{c^2} \frac{1}{1 + \sqrt{1 - \frac{\boldsymbol{v}_1^{\,2}}{c^2}}} \frac{\boldsymbol{v}_1 \times (\boldsymbol{v}_1 \times \boldsymbol{v}_2)}{1 + \frac{\boldsymbol{v}_1 \cdot \boldsymbol{v}_2}{c^2}}$$

- velocity addition paradox, not contradiction!
- non-commutative unless velocities are in line
- also non associative.
- always less than or equal to the maximum speed, speed of light in a vacuum, c.

So what is Time?

- Time is what clocks measure, all clocks have a mass at rest, a rest mass.

What is mass?

- Mass measures the resistance to acceleration. You know mass is equal to force, pushing or pulling, divided by acceleration. Rest mass is what keeps things from going at the maximum speed.

Photons and Gluons have no rest mass!

- If something has no rest mass it can not be accelerated and it is already traveling at the maximum speed, the speed of light in a vacuum.

Photons Again!

- Photons are the exchange boson of electromagnetism.
- Photons have no mass, electromagnetism is time reversal invariant.
- Electromagnetism is the simplest of all quantum field theories and its symmetry is U(1).

Gluons Again!

- Gluons are the exchange boson of the strong nuclear force. They carry color charge so this force is called QCD, Quantum Chromodynamics, it is a Yang-Mills field theory with SU(3) symmetry and three generations or flavors of SU(3).
- This theory is asymptoticly free, and when the quarks get further apart more gluons are generated pulling the quarks together keeping them from escaping so this force is limited to the nuclear distances, and is short range, around a fermi~10^-15 meters.

Weak, Nuclear Force

- Definitely not time reversal invariant, as its exchange particles, the W and Z are massive, limiting the range of exchange to much less than a fermi~10^-17 meters.
- Responsible for nuclear decay, decay is always irreversible!!!! Sorry about that, but that is the way the universe works!

What are clocks?

- Clocks measure the lapse of time by counting repetitions of event like the swinging of a pendulum mass or oscillations of a quartz crystal, movement of the earth around its axis (a day), movement of the earth around the sun (a year), or almost any other countable but irreversible movement. Events in the time-space manifold have a nonzero lapsed proper time unless they travel at the maximum speed, the speed of a photon of light in a vacuum. Time answers the question, when is it?

Event Separation!

$$ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2$$

- Light cones again and again!
- Things like photons and gluons travel at the maximum speed in the universe and have no proper time, no wrist watch time, they also have no rest mass!!! ds=0.

What is space?

- Space is about where it is!
- Clocks measure when
- Rulers measure where it is!
- Where and When are not independent questions as Albert Einstein taught us in the Special Theory of Relativity, SR, in 1905.
- Everything is about relationships. Your relatives are important.

Space Again!

- You can't measure distance smaller than the smallest structure that exist. Which is probably around Planck length ~1.6x10^-35 meters.

Real Numbers, R, have a property space does NOT have!

- Given any two numbers no matter how close, there are always an infinite number of real numbers between those two numbers.
- So do not use real numbers to describe space when the distances are very small.
- Or you will not only have paradoxes, but contradictions with the REAL universe we live in.

Time and Time again!

- Time can not be measured except by using an apparatus called a clock that has a nonzero rest mass of at least the size of a flea egg according to Jano, Eugene Wigner. So time and mass are linked in any measurement even though they are different IDEAS. Some clocks are much heavier and this depends upon precision and running time. See Wigner's papers on this.

Wigner Papers on Time and Mass

- Chapter 5 Relativistic Invariance and Quantum Phenomena, but starting on page 62 subsection Quantum Limitations of the Concepts of General Relativity through page 81 in the book *Symmetries and Reflections SCIENTIFIC ESSAYS* by Eugene P. Wigner, copyright 1967.

Earlier Wigner and Salecker paper

- Quantum Limitations of Measurement of of Space-Time Distances, by H. Saleker and E.P. Wigner, in Physical Review, volume 109, number 2, January 15, 1958.

Fundamentals of Time

- Time is more fundamental than space, and while you have some freedom in space to go forward or backwards, you cannot go backward in time, metaphorically, unless you are made of antimatter.

While SR (1905) pops out of electromagnetism as a gift just by understanding light and optics; GR, General Relativity, Uncle Albert's 1915 theory, a theory of gravity, is more complicated and ultimately leads to masses that have rest masses so you can build clocks.

QGR, Quantum General Relativity or QG, Quantum Gravity

- Quantum GR is still on the bleeding edge of physics and makes physicist loopy or stringy or just plain tied up in knots. At least that's what it did to me.

Cosmological Relativity the Special and General Theories for the Structure of the Universe by Moshe Carmeli

$$ds^2 = c^2 dt^2 + \tau^2 d\upsilon^2 - dx^2 - dy^2 - dz^2$$

- s, proper time, elapsed time between events
- c, maximum speed in the universe, the speed of light in a vacuum, speed of causality!
- t, time, what good clocks keep, when it is.
- x,y, z are the usual length, width, and breadth in space where it is.
- τ , big bang time
- υ ,recessional velocity of galaxies