Time-Space Invariance and Quantum Gravity: or how c, G, and $\hbar$ created the fabric of Reality!

By Dr. Harold Williams of Montgomery College Planetarium
The Persistence of Memory (1931) (La persistencia de la memoria in Spanish or La persistència de la memòria in Catalan) is the most famous painting by artist Salvador Dalí. The painting has been in the collection of the Museum of Modern Art (MoMA) in New York City since 1934. It is very
La Desintegración de la Persistencia de la Memoria or The Disintegration of the Persistence of Memory (oil on canvas, 1954), is a painting by the Spanish surrealist Salvador Dalí. It is an oil on canvas re-creation of the artist's famous 1931 work The Persistence of Memory, and measures a diminutive 25.4 × 33 cm. It was originally known as The Chromosome of a Highly-coloured Fish's Eye Starting the Harmonious Disintegration of the Persistence of Memory, and first exhibited at the Carstairs Gallery in New York in 1954.\[1\]
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.
World Lines

- $t$ for **time**
- $x$ for **distance**
- $dx/dt$ for **speed**
Light Cone
Another Light Cone

Minkowski visualised space and time as a light cone defining a boundary between past and future accessible locations
Still 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 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 curvature in both time and space
Green future light cone
Red past light cones
Bending of the light Cone near an events horizon
Since time-space curvature is to be used differential geometry and curvature tensor and possibly torsion tensor.

- Solutions will depend upon energy which may be a function of particles (things) mass and momentum and angular momentum and the speed of light, $c$, and the Newtonian gravitational constant, $G$, will appear in the classical general relativistic solutions.

- Mathematics will be monstrous!

- Clifford Algebra will make things a little easier, but understanding will still be hard.
There are exact solutions of the field equations, but not all of the solutions make any physical sense. Some do though.

- Exact Solutions to Einstein’s Field Equations (second edition) 2003 by Hans Stephani, Dietrich Kramer, Malcolm Maccallum, Cornelius Hoenselerers, and Eduard Herlt

- All authors are Europeans, evidently Americans just don’t have the guts, Germans and one Scot.
• 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
Five Roads to Quantum Gravity, QG

• 1. Effective Field Theory

• 2. String Theory or M theory or ?

• 3. Loop Quantum Gravity

• 4. Thermogravity maybe holographic principle

• 5. Emergent gravity

• with apologies to Three Roads to QG by Lee Smolin
Standard Model of particle physics

What are some of the things in the universe

Three generations of matter (fermions)

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Quarks

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Leptons

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Gauge bosons

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Higgs boson

?=125.3
supersymmetry

**SUPERSYMMETRY**

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<th>Leptons</th>
<th>Force particles</th>
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<td>u, c, t</td>
<td>ν_e, ν_μ, ν_τ</td>
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<td>~Higgsino</td>
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Standard particles

SUSY particles
Death of super symmetry?

- http://www.scientificamerican.com/article.cfm?id=is-supersymmetry-dead
History of the Planck length, time, and mass


\[ l_P \equiv \sqrt{\frac{G\hbar}{c^3}} \approx 1.616199(97) \times 10^{-35} \text{ m} \]

\[ t_P \equiv \sqrt{\frac{G\hbar}{c^5}} \approx 5.39106(32) \times 10^{-44} \text{ s} \]

\[ m_P \equiv \sqrt{\frac{c\hbar}{G}} \approx 2.17651(13) \times 10^{-8} \text{ kg} \approx 21\mu\text{grams} \]
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**
  \[ f = 1 / t \]
Fine-structure constant

\[ \alpha \equiv \frac{e^2}{(4\pi\varepsilon_0)\hbar c} = \frac{k_e e^2}{\hbar c} = \frac{c\mu_0 e^2}{2\hbar} \]

\[ \alpha \doteq 7.2973525698(24) \times 10^{-3} = \frac{1}{137.035999074(44)} \]

For Jack Gaffey and Walter Faust
Newtonian Gravity

\[ F_{12} = G \frac{m_1 m_2}{r_{21}} \hat{r}_{21} \]

\[ r_{21} \equiv | \mathbf{r}_2 - \mathbf{r}_1 | \]

\[ \hat{r}_{21} \equiv \frac{\mathbf{r}_2 - \mathbf{r}_1}{r_{21}} \]

- *Hypotheses non fingo*, I feign no hypotheses
Velocity-addition formula

\[ \mathbf{v}_1 \oplus \mathbf{v}_2 \equiv \frac{\mathbf{v}_1 + \mathbf{v}_2}{1 + \frac{\mathbf{v}_1 \cdot \mathbf{v}_2}{c^2}} + \frac{1}{c^2} \frac{1}{1 + \sqrt{1 - \frac{\mathbf{v}_1^2}{c^2}}} \frac{\mathbf{v}_1 \times (\mathbf{v}_1 \times \mathbf{v}_2)}{1 + \frac{\mathbf{v}_1 \cdot \mathbf{v}_2}{c^2}} \]

- 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.
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 must be 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 also called QCD, Quantum Chromodynamics, it is a Yang-Mills field theory with SU(3) symmetry and three generations or copies of SU(3).

- This theory is asymptotically 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 run, around a fermi.
QCD

• Also time reversal invariant.
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.
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!!!
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 Uncle Albert Einstein taught us in the Special Theory of Relativity, SR. Everything is about relationships. Your relatives are important.
Space Again!

• You can’t measure distance smaller than the smallest structure that exist in space.
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 Uncle Jano, Eugene Wigner. So time and mass are linked in any measurement even though they are very different things. Some clocks are much heavier and this depends upon precession and running time. See Wigner’s papers on this.
Wigner Papers on Time and Mass

Earlier Wigner and Salecker paper

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 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

\[ ds^2 = c^2 dt^2 + \tau^2 d\nu^2 - dx^2 - dy^2 - dz^2 \]

- s, proper time, wrist watch time
- c, maximum speed in the universe, the speed of light
- t, time, what good clocks keep, when it is.
- \( \tau \), age of the universe \( 1/Hubbles \) constant
- \( \nu \), recessional velocity of galaxies
- x, y, z are the usual length, width, and breadth in space, where it is.
Isaac Newton on philosophy in Physics

• *Hypotheses non fingo*. I feign no hypotheses
Kerr-Newman metric

\[ r_h \equiv \frac{GM}{c^2} + \sqrt{\left(\frac{GM}{c^2}\right)^2 - \left(\frac{G^{1/2} Q}{c^2}\right)^2 - \left(\frac{JM}{c}\right)^2} \]

\[ A = \int_0^\pi d\theta \int_0^{2\pi} d\vartheta \sqrt{g_{\theta\theta}g_{\vartheta\vartheta}} = 4\pi \left( r_h^2 + \left(\frac{JM}{c}\right)^2 \right) \]
New Gauge Symmetry in Gravity and
the Evanescent Role of Torsion
by H. Kleinert
Kerr Geometry as Space-Time Structure of the Dirac Electron
A. Burinskii