11 Problems in Physics

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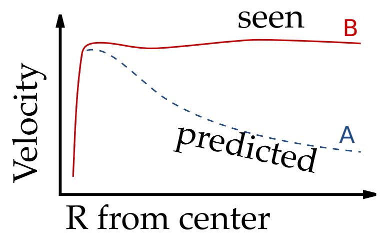
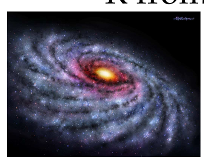
Weak Gravity

When gravity is 10^{-10}g, Newton's law doesn't work





History

1932 Jan Oort, Milky Way motions too fast
1933 Fritz Zwicky, motions of galaxies too fast
1962 Alar Toomre, thin disc galaxies too fast, unstable
1970s Vera Rubin rotation profile data

Current Efforts

Dark matter - plug in what is needed
MOND - change Newton's law from $1/R^2$ to $1/R$

My Efforts

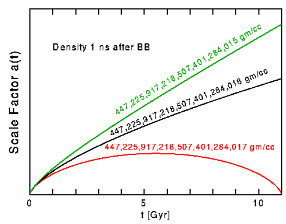
Need a stable, constant velocity solution for gravity
The product rule may come into play
Use BOTH 1st order terms (only 1st is, 2nd ignored)

$$dq^2 = \left(\left(1 - 2\frac{GM}{c^2 R}\right)dt^2 - \left(1 + 2\frac{GM}{c^2 R} + O(2)\right)dR^2 / c^2,\ 2\ \ dt\ \ dR / c\right)$$

Old Gravity

The start of the Universe is not stable, it should ball up.
There is no reason matter should move at the same speed.

Flatness problem:
initial conditions
are unstable

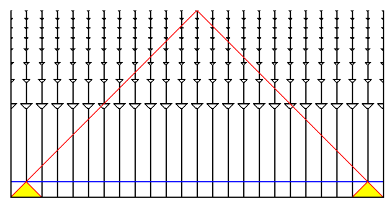


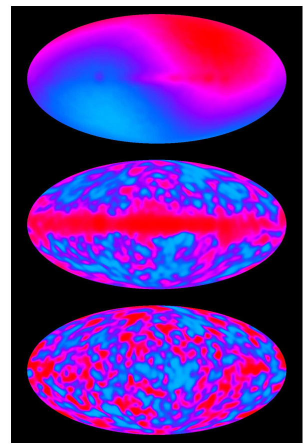
$$\left(\frac{\rho_c}{\rho} - 1\right)\rho a^2 = -\frac{3}{8\pi G}kc^2$$

$$\frac{\rho}{\rho_{c\ \mathrm{now}}} \approx 1.01$$

$$\frac{\rho}{\rho_{c\ \mathrm{Big\ Bang}}} \approx 1.00..(\mathrm{lots\ of\ 0's})..001$$

Horizon problem:
velocities have no
way to agree to
1 part in 100,000





History

1969 Dicke, the Universe is flat now, but had to be far more flat at the start

Current Efforts

Inflation - magic! Universe briefly grows like crazy

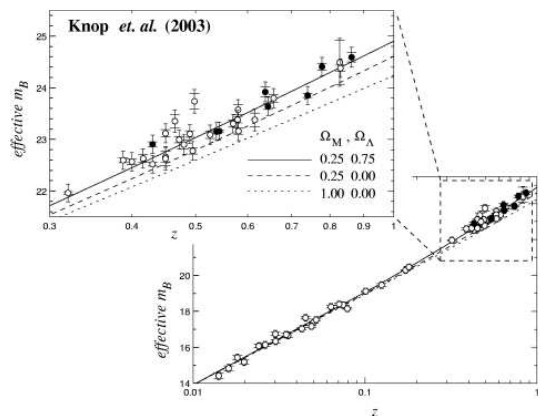
My Efforts

Don't use Newton out-of-the-box, things are moving
Need a stable, constant velocity solution for gravity.
Product rule may come into play
Use BOTH terms, not just the first one

$$dq^2 = \left(\left(1 - 2\frac{GM}{c^2R}\right)dt^2 - \left(1 + 2\frac{GM}{c^2R} + O(2)\right)dR^2/c^2,\ 2\ \ dt\ \ dR/c\right)$$

Big Gravity

The Universe is now going faster, not slowing down



History

1998 Perlmutter, Schmidt, Riess

Type 1a supernovae moving slow in the past
meaning we are accelerating now

Current Efforts

Dark energy The cosmological constant fix

My Efforts

The data looks like a real, but small, math error
Nothing can do nothing (observering nothing is subtle)
The Universe is not a static, non-rotating, spherical mass
The product rule could come into play
Account for light
Use BOTH terms

$$dq^2 = \left(\left(1 - 2\frac{GM}{c^2R}\right)dt^2 - \left(1 + 2\frac{GM}{c^2R} + O(2)\right)dR^2 / c^2,\ 2\ \ dt\ \ dR / c\right)$$

Small Gravity

Get gravity to work nicely with quantum mechanics.

$$\left(\frac{d^2}{dt^2} - c^2\nabla^2\right) A^\mu = J^\mu \xrightarrow[\text{picking a gauge}]{\text{invert by}} A^\mu = e^{ikx} \underset{\text{gauge dep. stuff}}{\ldots}$$

Field eqs — propagator

$$\mathcal{L} = \text{simple}$$
$$+ A^\mu \ldots \text{perturbation}$$

The issue: does the perturbation converge in a scattering calculation? "Yes" for 4 linear EM eqs, "no" for 10 nonlinear GR eqs.

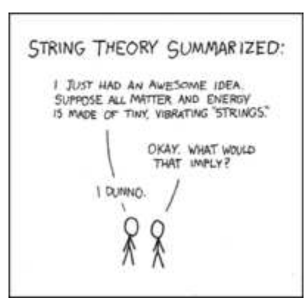
History

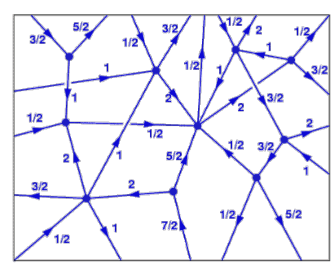
1916+ Force laws the same, so quantization the same, no?

Current Efforts

Work with strings

Loop quantum gravity





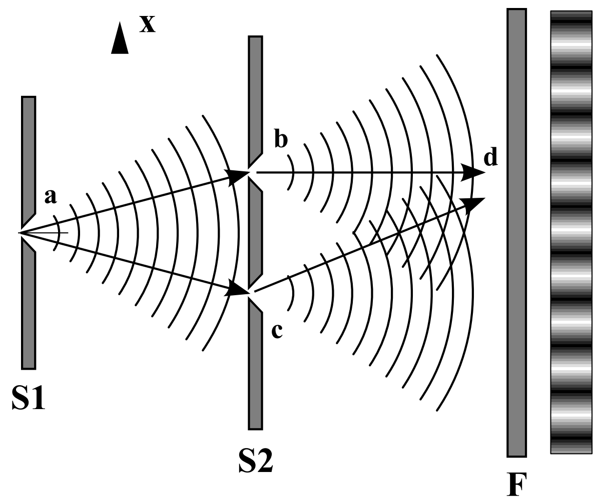
Nodes + Lines+ Arrows +Labels = Spin network

My Efforts

Space-times-time equivalence class as gravity means there are NO gravitons and nothing to quantize.

Small Physics

Why is quantum mechanics wierd?



History

1920s Einstein vs Bohr

Your choice: Copenhagen, many worlds, ... no winner

Double slit experiment - wave and a particle - how so?

Current Efforts

Philosophical physicist continue the stalemate

http://bit.ly/qm_visual

My Efforts

Visualize complex numbers correctly

Not a totally ordered set

Coherent source is well-organized in space-time

Fast Physics

How does Nature impose the speed of light limit?

History

1887 Nichelson-Morley, speed of light unchanged
by the speed of the Earth

1905 Einstein's special relavity

Current Efforts

Its the Lorentz group, stupid (no need to explain)

My Efforts

Wavelength and frequency do change, their ratio doesn't

Changes in time = changes in space, the definition of unity in space-time

Photons have no story to tell

Small and Fast Physics

Calculations in relativistic quantum field theory require management of infinities (regularization and renormalization)

$$\left(\frac{d^2}{dt^2} - c^2\nabla^2\right) A^\mu = J^\mu \xrightarrow[\text{choosing a gauge}]{\text{Invert by}} A^\mu = e^{ikx}\ldots$$

Field eqs. Propagator

$\mathcal{L} = \text{simple}$

$+ A^\mu \ldots \text{perturbation}$

History

1940s Developed by Feynman, Tomonaga, Schwinger

Old masters uncomfortable (Feynman, Dirac)

Current Efforts

Shut up and calculate the most precise calcs in physics

My Efforts

Nature uses all well-formed terms.

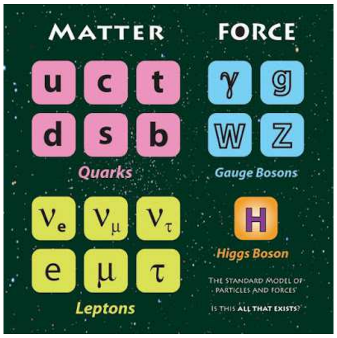
Use a Lagrangian's neighbors. $(\mathcal{L}, \vec{P}) = \frac{1}{2}(B^2 - E^2, 4\,\vec{E} \times \vec{B})$

Using the complete set, field equations can be inverted
without choosing a gauge

B^2-E^2 unchanged by time reversal, *E*x*B* does change

Fundamental Forces

Why are these 4 forces in particular the ones Nature uses?



Force	**Symmetry**
Gravity	Diff(M)
EM	U(1)
Weak	SU(2)
Strong	SU(3) w/confinement

History

1666 Newton wrote equations for gravity
1767 Priestley shows similar equation for EM
1865 Maxwell unified E w/M, has U(1) sym.
1930s Initial work on weak and strong forces
1960s Electroweak unification w/SU(2)xU(1)
1970s Strong force w/confinement SU(3)

Current Efforts

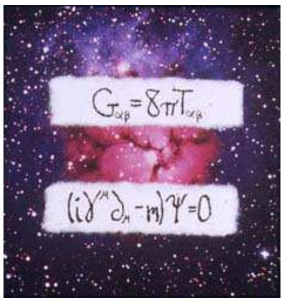
Groups SU(5) and SU(10) tried, so far failed
Work on strings has no testable predictions so far

My Efforts

Only symmetries, not forces, work for 13 billion years
Symmetries should be baked into the math
Gravity is space-times-time equivalence class. Numbers have different representations, but same squares
Space-time number with norm of 1 has: U(1), SU(2) and Q_8 symmetries.

Unified Physics

How does Nature make it all work, from tiny to HUGE?



Fieled equations of general relativity

Dirac equations of quantum field theory

History

Common goal at the end of a career in physics

Current Efforts

Work on strings makes the most claims

My Efforts

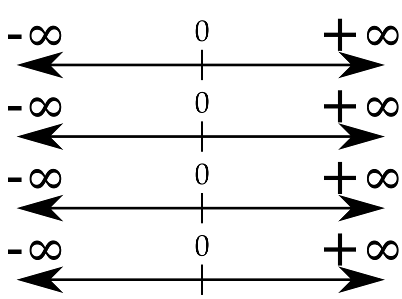
Build causality into number theory:

[0, 1) timelike, [1] lightlike, (1, ∞) spacelike

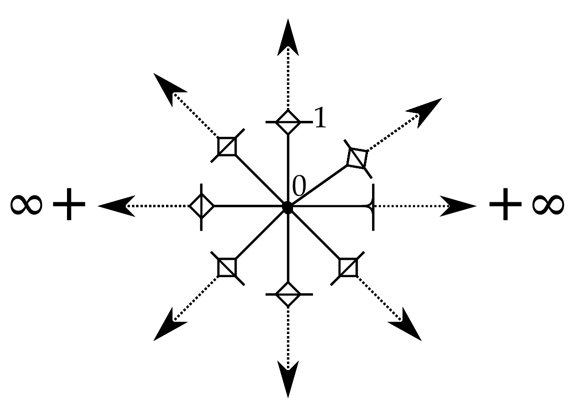
Quaternion analysis needs factors of 1/3, good for quarks

Working on the quaternion manifold may need maps that return in 2pi and 4pi, good for bosons and fermions

Give zero - the observer, the right topology to 1 in space-time



4 zeros is BAD



One zero for the observer, good, 8 1's, odd

The Arrow of Time

The laws of physics are symmetrical for time reversal, but the Universe apparently is not

$$F = m\frac{d^2R}{dt^2} = m\frac{d^2R}{d(-t)^2} \qquad \Lambda_{\text{time reversal}} = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

CPT symmetry

History

1800s Boltzmann saw asymmetry put into 2nd law of thermodynamics "by hand"

Current Efforts

Information theory

Holographic principle

My Efforts

$$F = \left(\frac{d}{dt}, c\vec{\nabla}\right)\left(E^2/c^4 - P^2/c^2, 2E\vec{P}/c^3\right)\left(\frac{d}{dt}, c\vec{\nabla}\right)(ct, \vec{R}) = m\frac{d^2R}{dt^2} + \delta$$

Classically, delta is super tiny, but adds up with 10^{23} particles, so laws are not space-time symmetric.

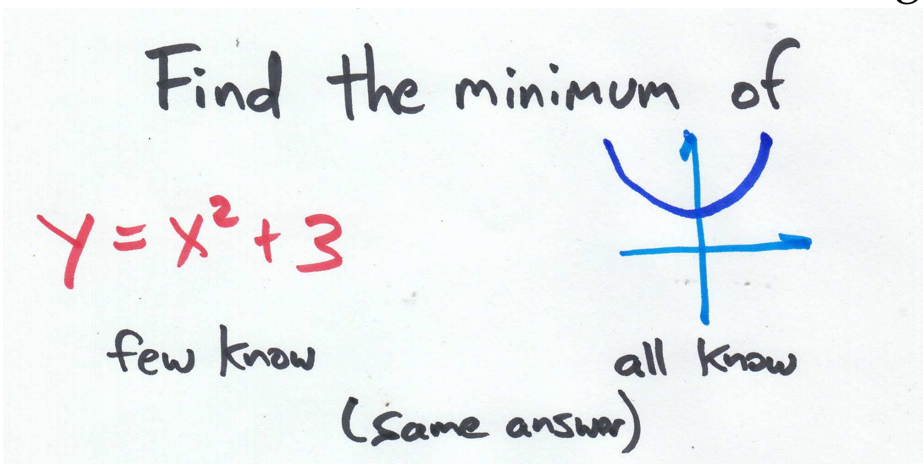
Maxwell equations are invariant under time reversal:

starts from B^2-E^2

Poynting vector ExB flips sign under time reversal

Visualizing Physics

People cannot understand calculations, but can get pictures



History

1637 Descartes created analytic geometry

1660+ Newton graphed infinitesimal change

Current Efforts

Many sites devoted to visualizing classical physics

Bernd Thaller worked on quantum mechanics

My Efforts

Created animated gifs

Neet to treat as a "game" that can be changed on the fly