Physics 100 - March 26, 2007

- **Presentation schedule**

  April ~~11~~

  16   17, Solar System formation

  18   2, nucl. bombs — 6, GPS — 18, Football

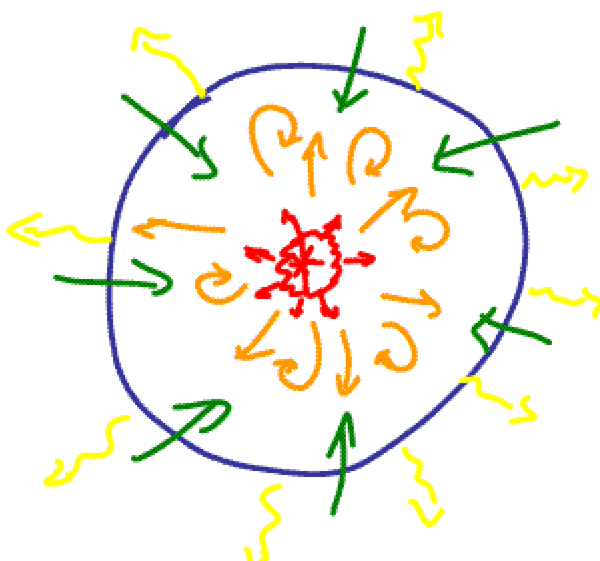
  23   24A, Feynman — 23, comets mass ext.

  25   24, Galileo — 26, Music

- Exam 2 in 2 weeks → ~~April 9~~ — Will Try to Move to April 11 Due To Proximity to Easter ... STAY Tuned.

  During regular class time in Hoyt
  Probably similar to Exam 1 in form
  Index card w/ Formulas / notes ok
  Calculator
  Formula sheet
  Next week's Recitations → mostly review

Last time: intimate relation between the large + small drive the stars and synthesize the elements



- gravity pulls in
- heat (radiation pressure) pushes out
- "Thermonuclear" fusion reactions in core
- Starts w/ H → He but can work way up to ^{56}Fe
- Heavier elements formed in supernovae
- white dwarfs, neutron stars, Black Holes

Rotation comes from Conservation of "Angular Momentum"

Pages 8-26 in Hobson — nice brief review of highlights of human view of universe and Earth's place in it

Sir Isaac Newton
1643-1727
(England)

universal law of gravitation

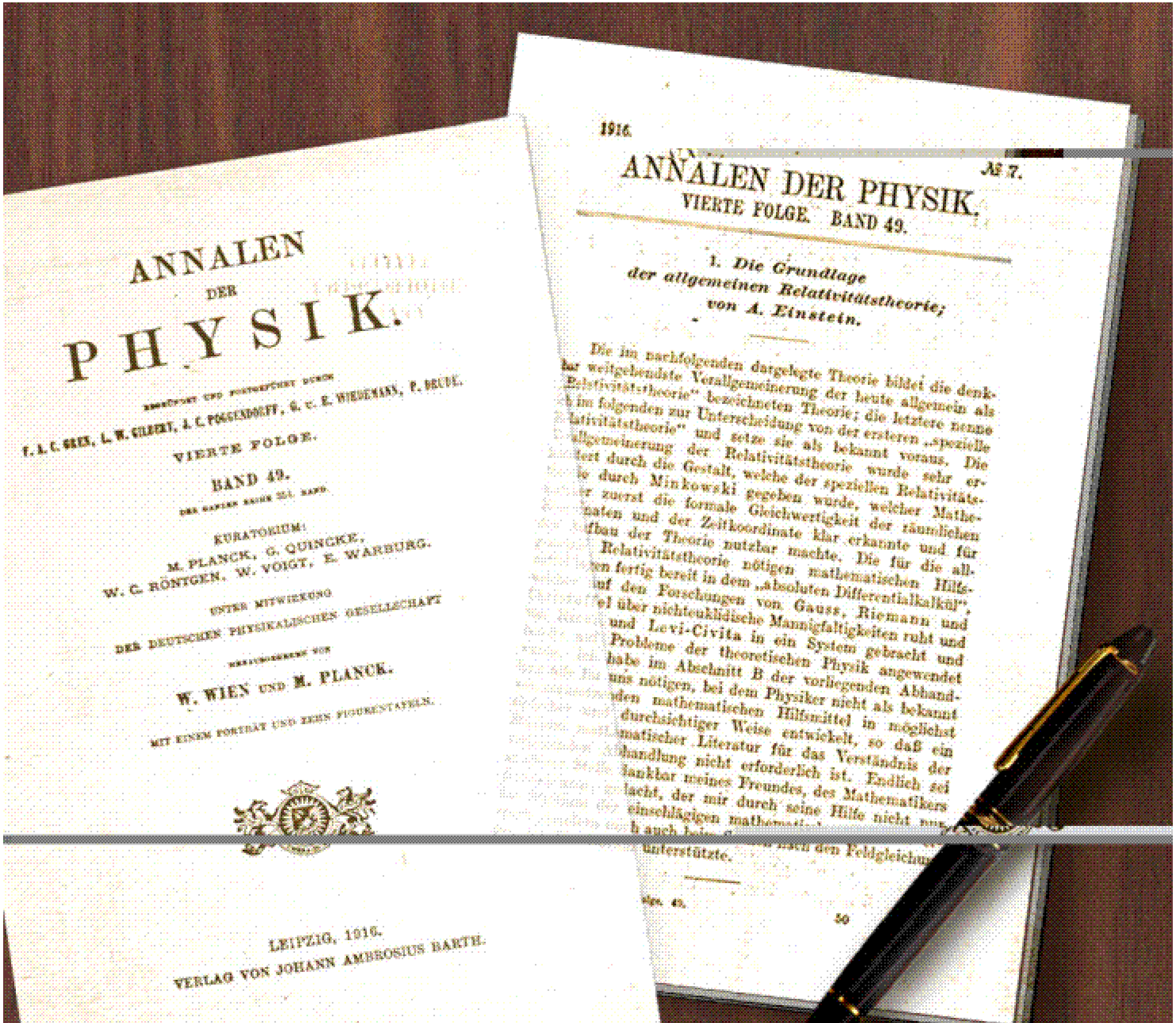
$$F = \frac{G M_1 M_2}{r^2}$$

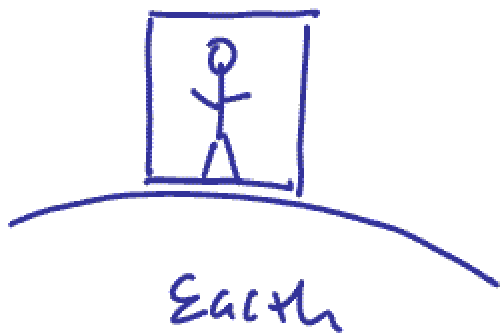
+

Laws of Motion

$\Rightarrow$ derived Kepler's 3 laws of planetary motion

The Theory of General Relativity – Einstein 1916





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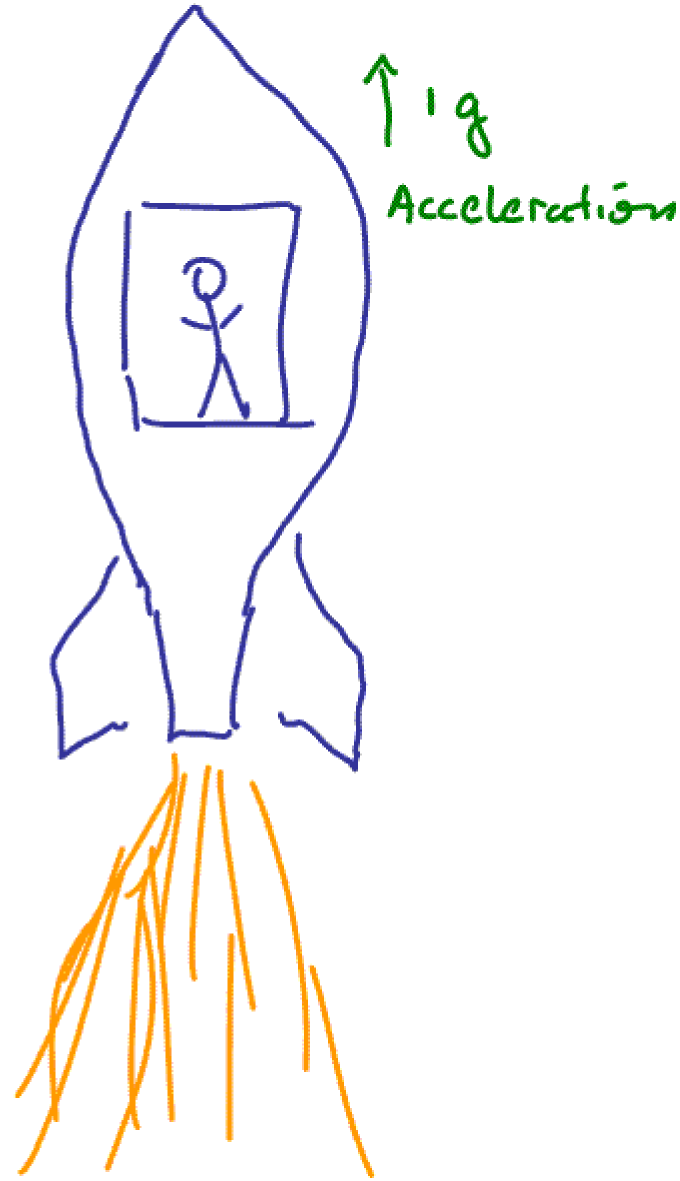


accelerated reference frames

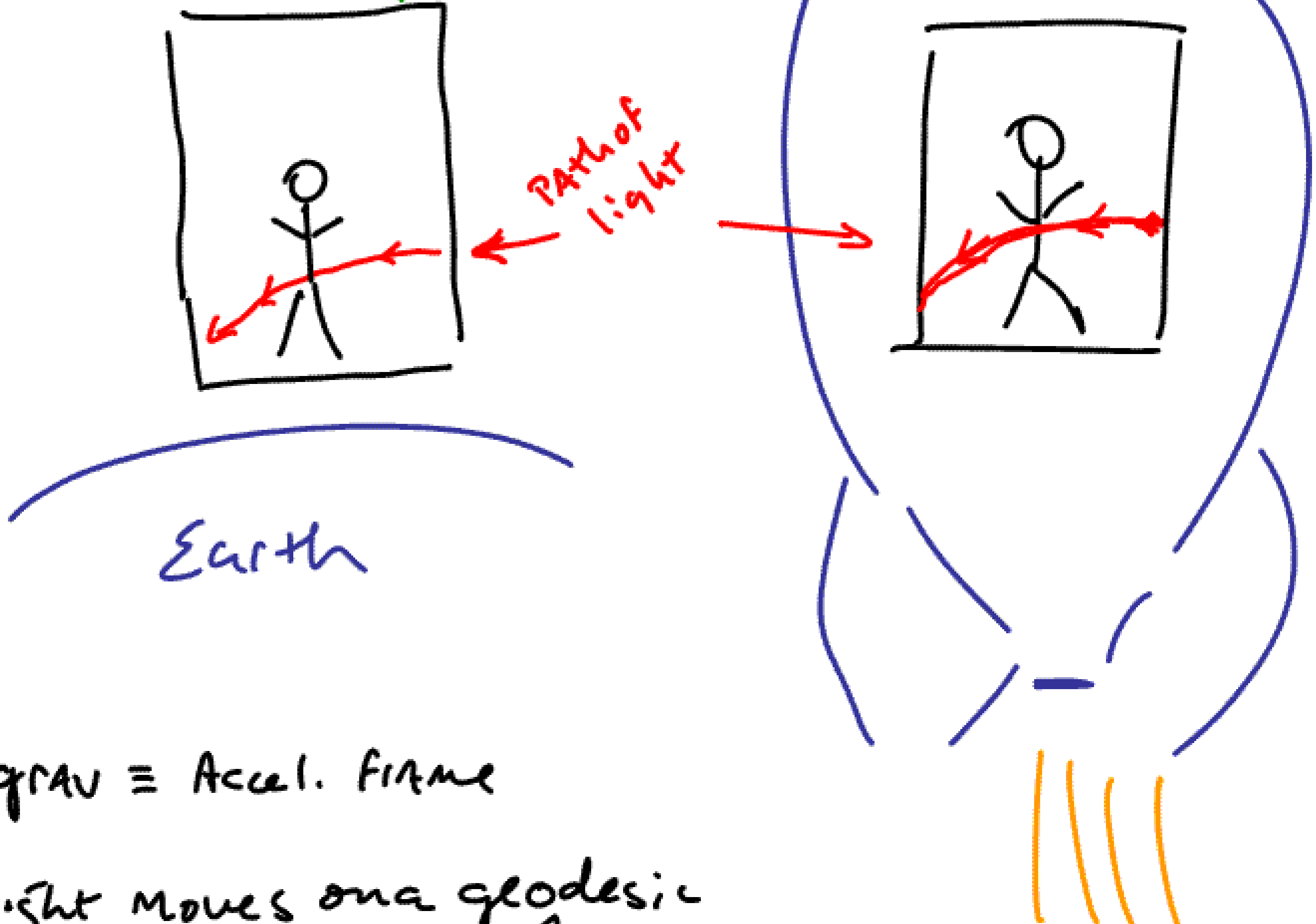
≡

gravitational field

If you are in a closed box —
you can't tell if you are at rest on earth's surface or accelerating in a rocket at 1g.

Equivalence w/ gravity ⟸ In accelerated rocket ship case, light would seem to travel on curved path

Means grav. field must curve spacetime



Accel.

↑ 1g

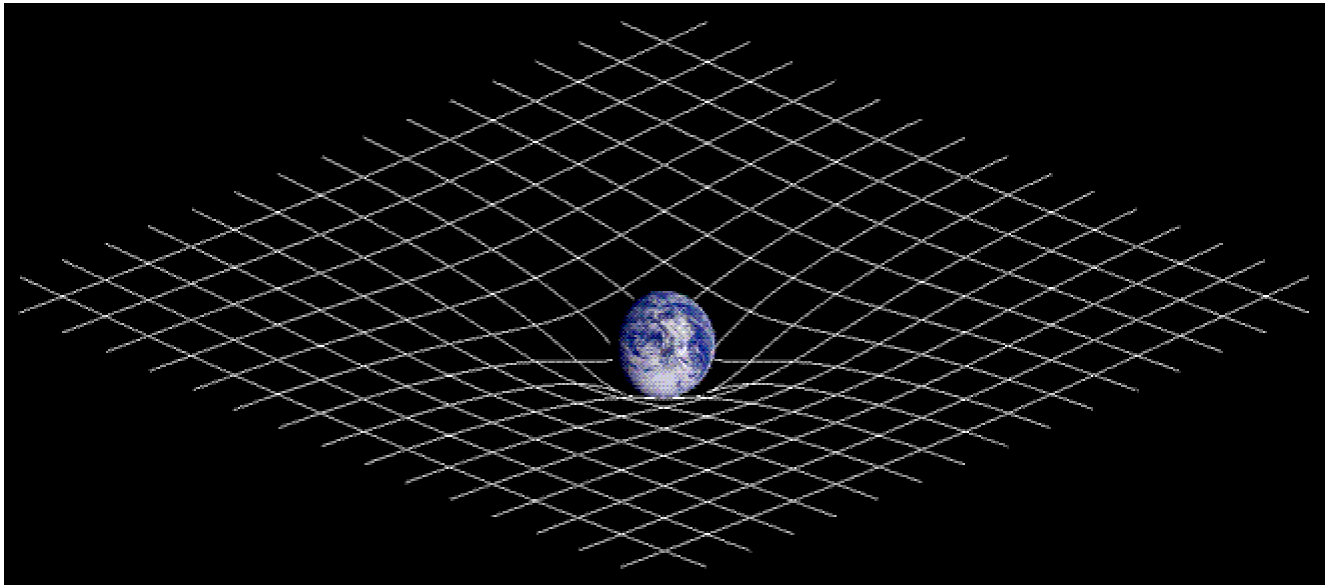
grav ≡ Accel. frame

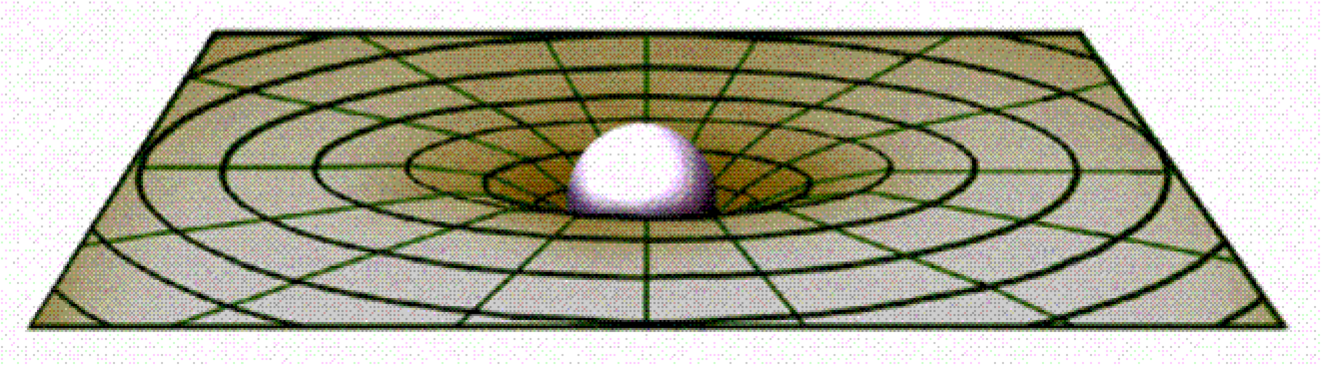
light moves on a geodesic

↑

Shortest dist. between two points

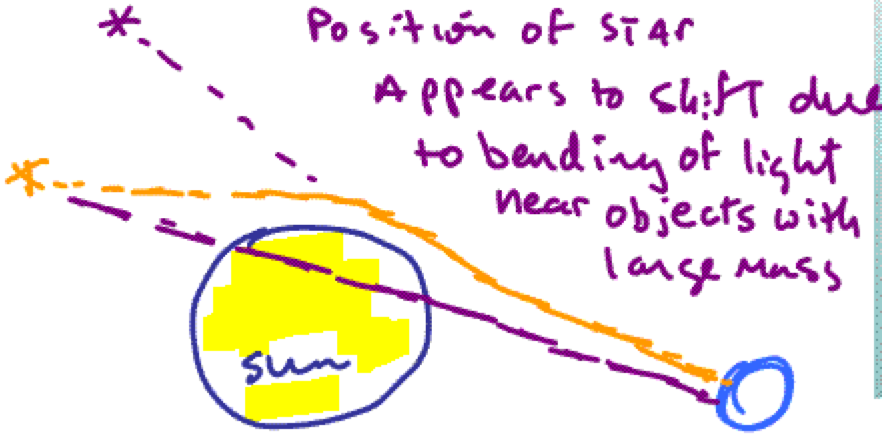
So, Einstein interprets gravitation as a curvature of spacetime

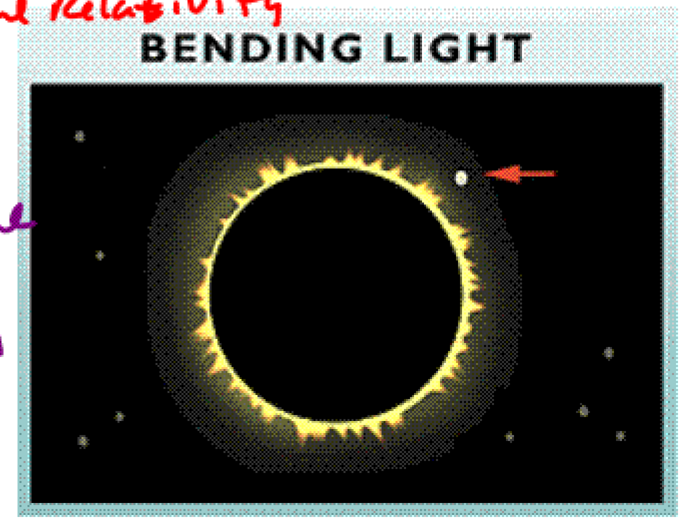




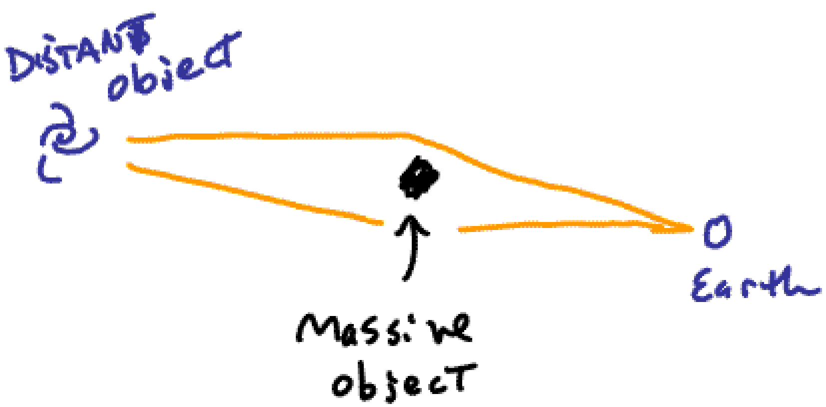
Imagine that mass causes curvature / depression in
the fabric of spacetime ... is it true??

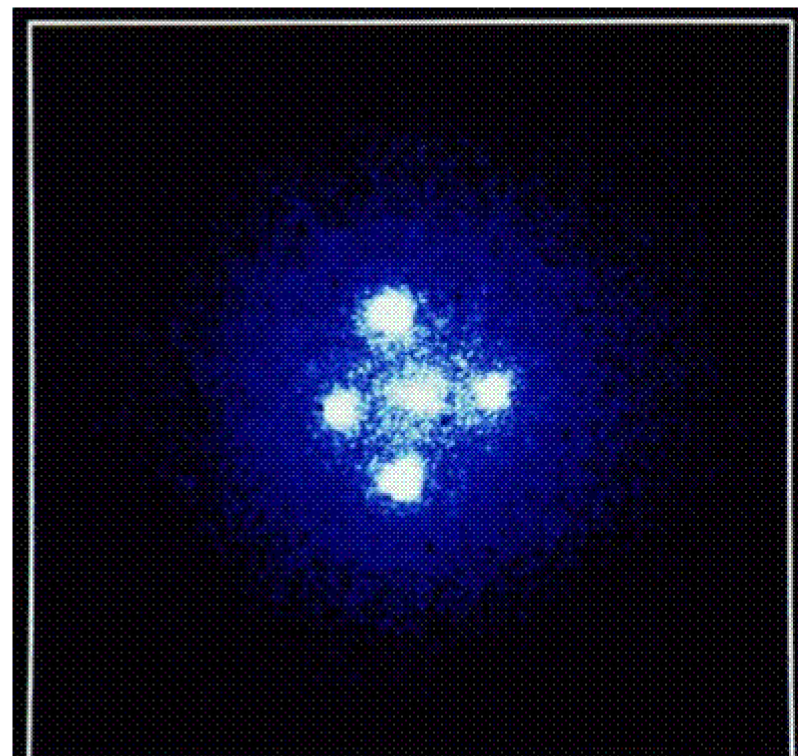
Experimental evidence supporting General Relativity

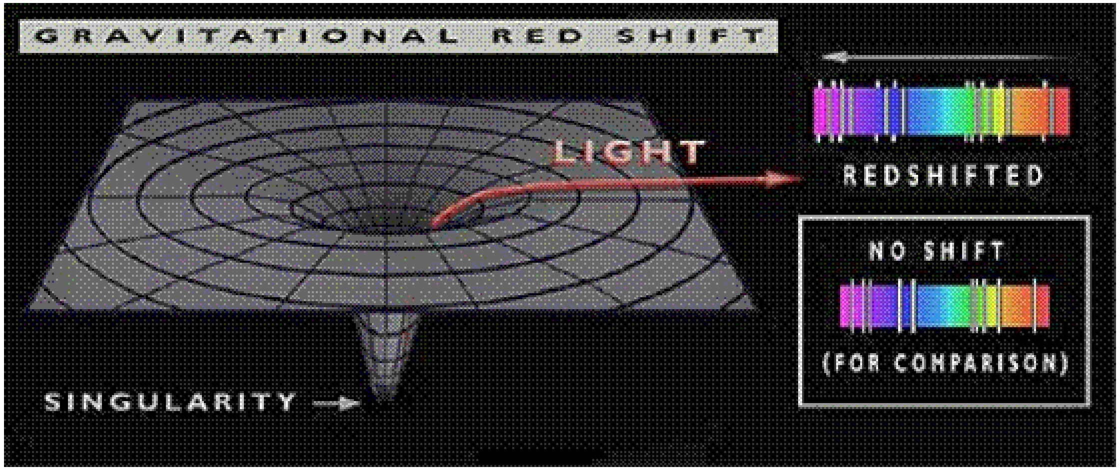




Gravitational Lensing




Gravitational Lens G2237+0305



Spectral lines shifted to lower frequency as light leaves massive object

→ observed for STARS and Earth.

Light loses energy fighting its way out of gravitational "well"

frequency shifts lower

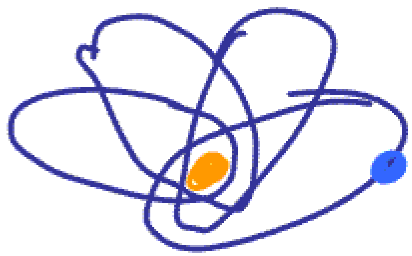
wavelength becomes longer

Stronger gravity ⟶ more of a redshift

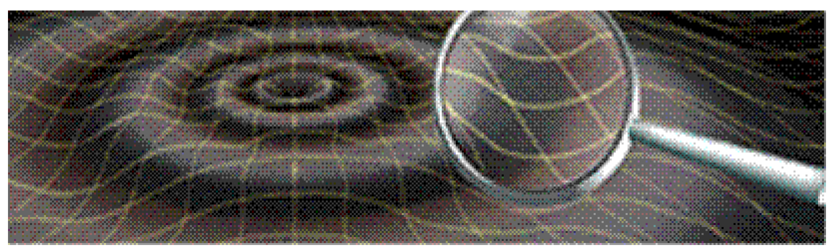
G.R. needed to understand fine details of planetary orbits

Perhelion Advance of Mercury

(show animation)



G.R. predicts existence of waves traveling in the fabric of spacetime → gravitational waves



grav. waves would be very small distortions in spacetime traveling at speed of light from large gravitational disturbances

gravitational waves

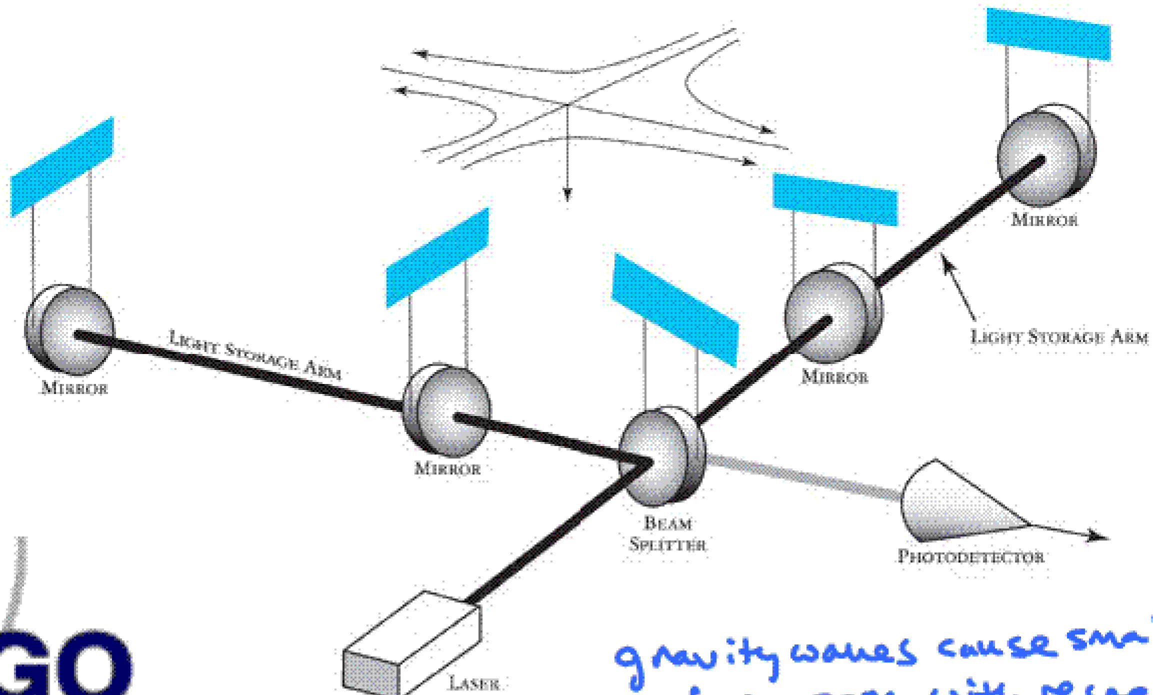
major experiment aiming to detect grav. waves → LIGO

LIGO - Laser Interferometer Gravitational Wave Observatory

http://www.ligo.caltech.edu/

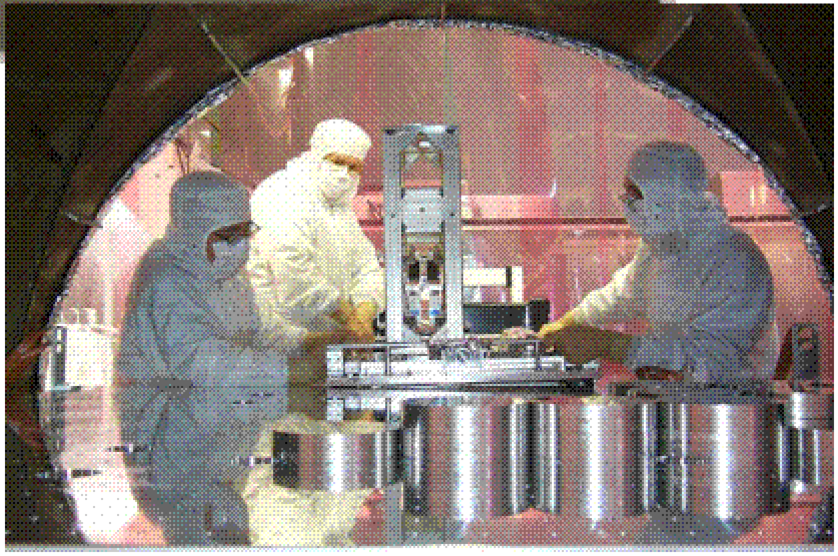
Distortions $\sim 10^{-16}$ m

Arms ~ 4 km in length



gravity waves cause small distortions of one arm with respect to the other.

LIGO Site in Hanford, WA
Also one in Louisiana

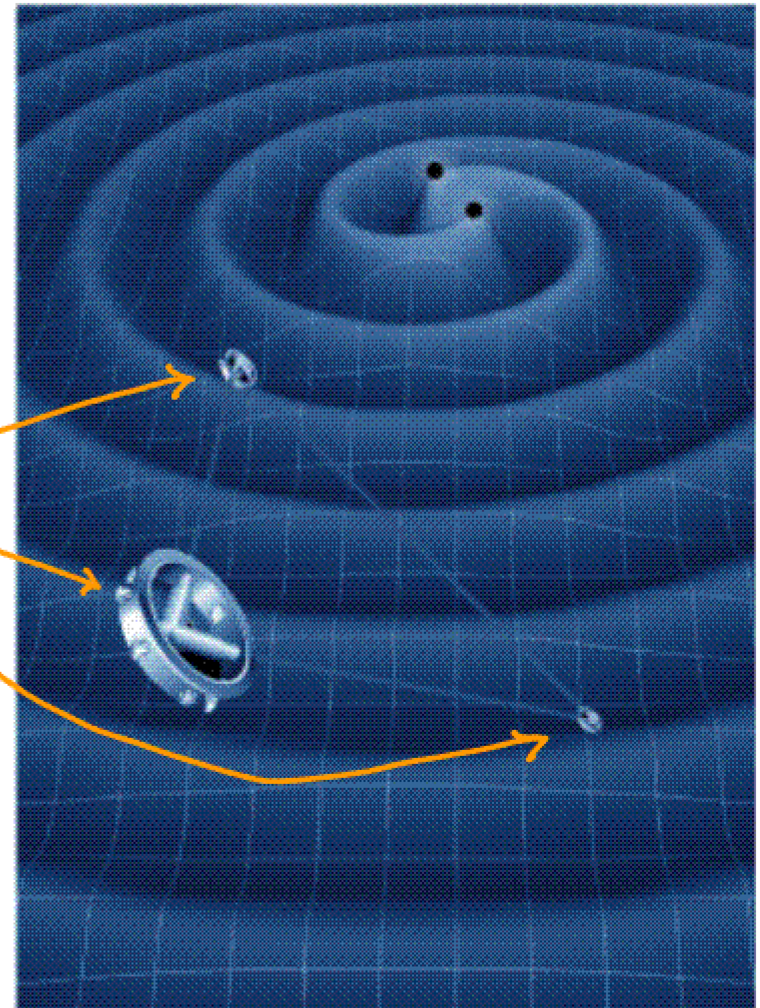


There are other projects ...

LISA

Laser Interferometer
Space antenna

ESA + NASA



3 satellites widely separated in space —

idea is to watch how the distance between them varies as the gravitational wave passes by

perhaps someday we will be able to study astrophysical objects by observing emitted grav. waves → gravitational wave astronomy

Places to learn more:
Particle and nuclear physics links

http://pdg.lbl.gov

http://particleadventure.org

http://www.slac.stanford.edu/gen/edu/aboutslac.html

http://www.bnl.gov/bnlweb/sciindex.html

http://www.bnl.gov/rhic/

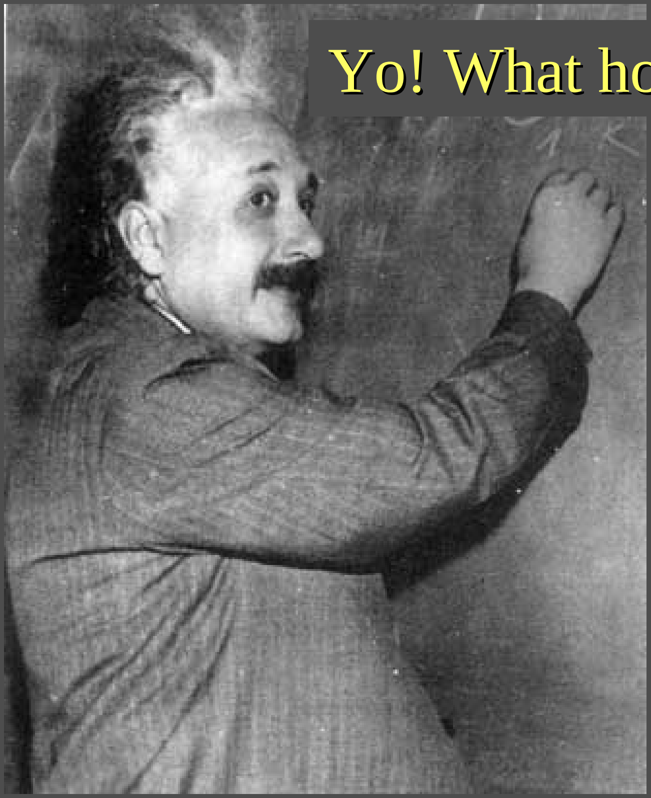
http://public.web.cern.ch/public/

http://www.fnal.gov/

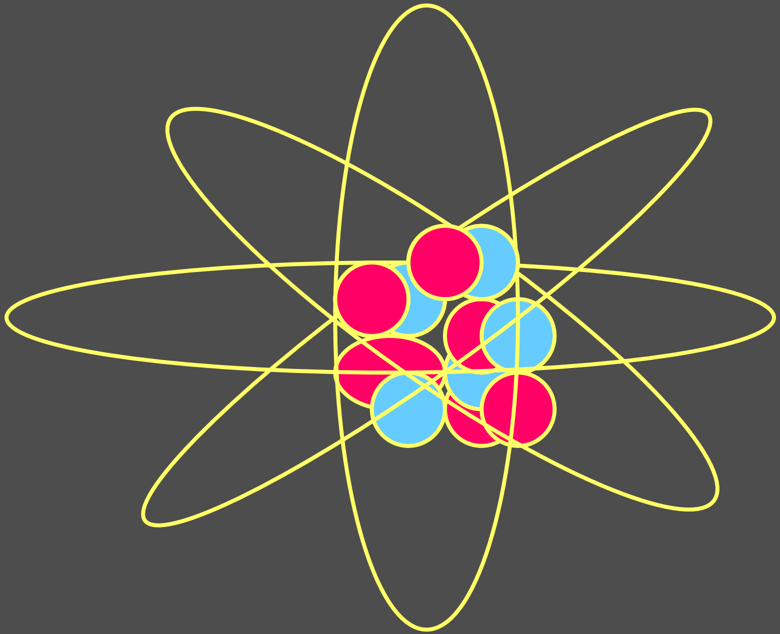
http://www.er.doe.gov/production/henp/np/index.html

http://www.science.doe.gov/hep/index.shtm

Inquiring minds want to know ...



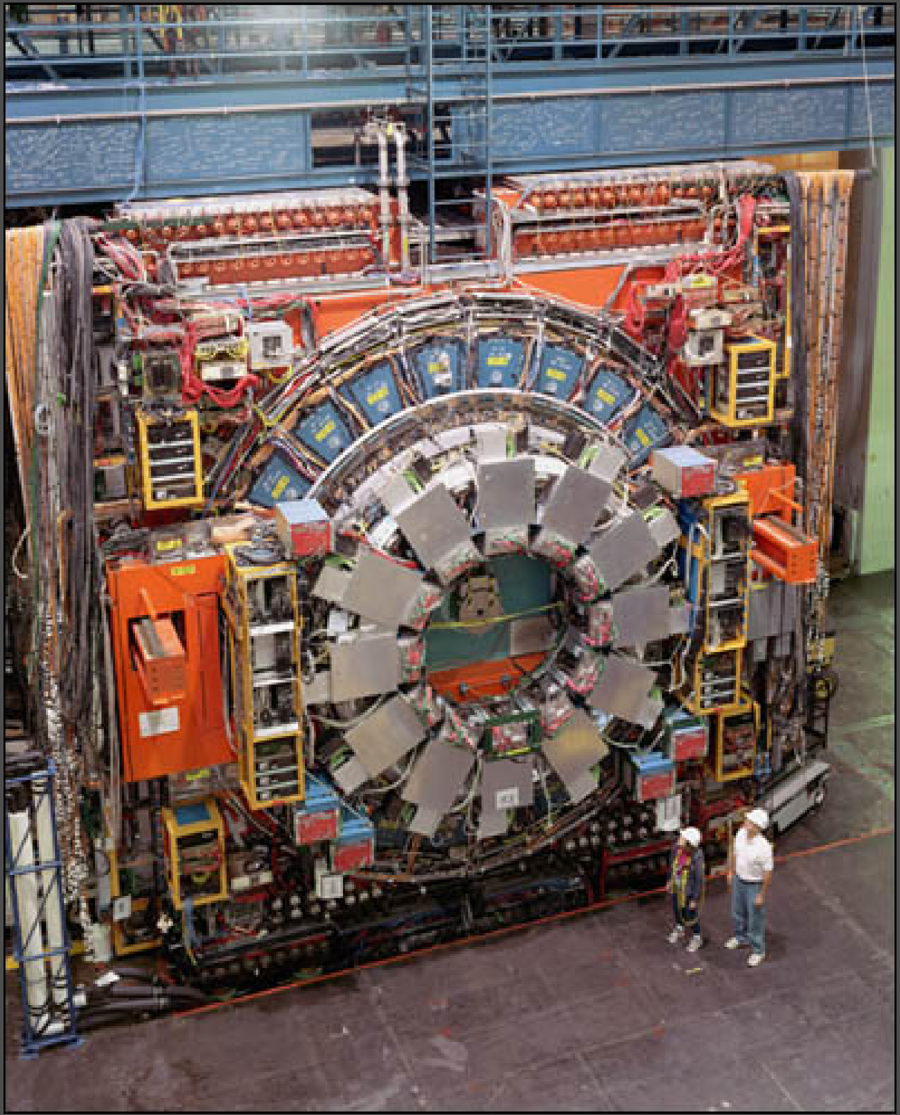
Yo! What holds it together?




52
46
ACXIOM
27
HASTINGS

Fermi National Accelerator Laboratory (near Chicago)

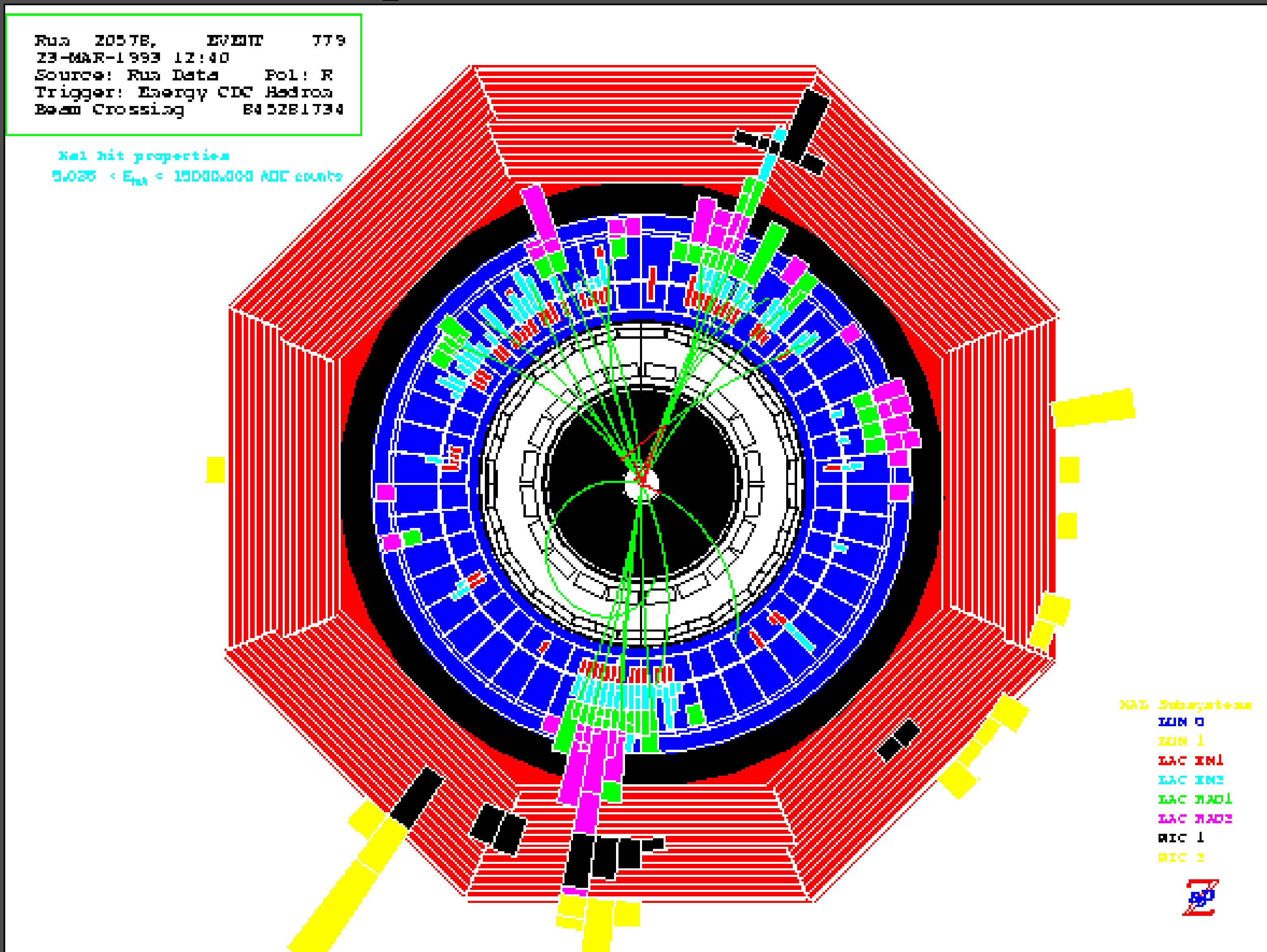
CDF



Minos

Stanford Linear Accelerator Center

Event display from the SLD experiment at SLAC



π^0

$I^G(J^{PC}) = 1^-(0^{-+})$

Mass $m = 134.9766 \pm 0.0006$ MeV (S = 1.1)

$m_{\pi^\pm} - m_{\pi^0} = 4.5936 \pm 0.0005$ MeV

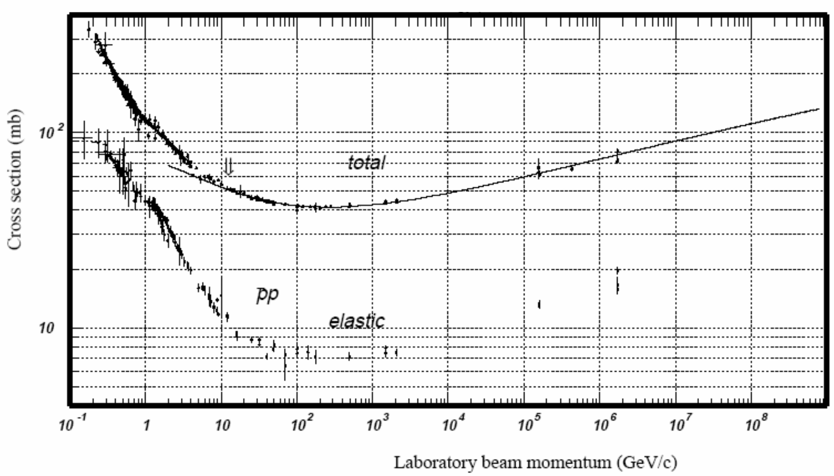
Mean life $\tau = (8.4 \pm 0.6) \times 10^{-17}$ s (S = 3.0)

$c\tau = 25.1$ nm

For decay limits to particles which are not established, see the appropriate Search sections (A^0 (axion), and Other Light Boson (X^0) Searches, etc.).

π^0 DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
2γ		(98.798 ± 0.032) %	S=1.1	67
$e^+ e^- \gamma$		(1.198 ± 0.032) %	S=1.1	67
γ positronium		$(1.82 \pm 0.29) \times 10^{-9}$		67
$e^+ e^+ e^- e^-$		$(3.14 \pm 0.30) \times 10^{-5}$		67
$e^+ e^-$		$(6.2 \pm 0.5) \times 10^{-8}$		67
4γ		$< 2 \times 10^{-8}$	CL=90%	67
$\nu\bar{\nu}$	[a]	$< 8.3 \times 10^{-7}$	CL=90%	67
$\nu_e \bar{\nu}_e$		$< 1.7 \times 10^{-6}$	CL=90%	67
$\nu_\mu \bar{\nu}_\mu$		$< 3.1 \times 10^{-6}$	CL=90%	67
$\nu_\tau \bar{\nu}_\tau$		$< 2.1 \times 10^{-6}$	CL=90%	67
$\gamma \nu \bar{\nu}$		$< 6 \times 10^{-4}$	CL=90%	–
Charge conjugation (C) or Lepton Family number (LF) violating modes				
3γ	C	$< 3.1 \times 10^{-8}$	CL=90%	67
$\mu^+ e^-$	LF	$< 3.8 \times 10^{-10}$	CL=90%	26
$\mu^- e^+$	LF	$< 3.4 \times 10^{-9}$	CL=90%	–
$\mu^+ e^- + \mu^- e^+$	LF	$< 1.72 \times 10^{-8}$	CL=90%	26

Cross section (mb)



week ending
4 JUNE 2004

→ $\omega\Upsilon(1S)$

E. Coan,[2] Y. S. Gao,[2] F. Liu,[2]
Dorjkhaidav,[3] R. Mountain,[3]
. Mahmood,[4] S. E. Csorna,[5]
pas.[7] A. Shapiro.[7] W. M. Sun.[7]

.S 30 MARCH 1998

ass

mendolia,[27] D. Amidei,[20] J. Antos,[33]
[8] M. Atac,[7] P. Azzi-Bacchetta,[25]

1 MARCH 1999

ıe Measurement
miokande

Itow,[1] T. Kajita,[1] J. Kameda,[1]

26 MAY 1975

e ψ(3095)†

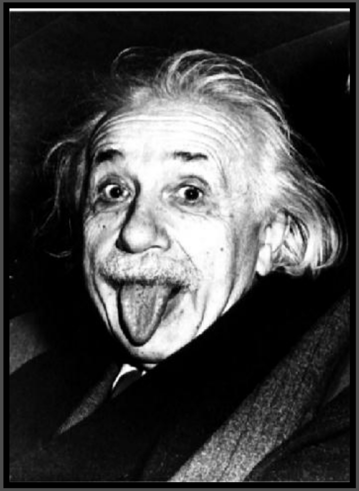
ischer, D. Fryberger, G. Hanson,
, D. Lyon, C. C. Morehouse,
R. F. Schwitters,
ford, California 94305

G. Golhaber, J. A. Kadyk,
Trilling, J. S. Whitaker,
ılifornia, Berkeley, California 94720

near 3095 MeV. The

What forces exist in nature?

What is a force?



How do they interact?

How do forces change with energy or temperature?

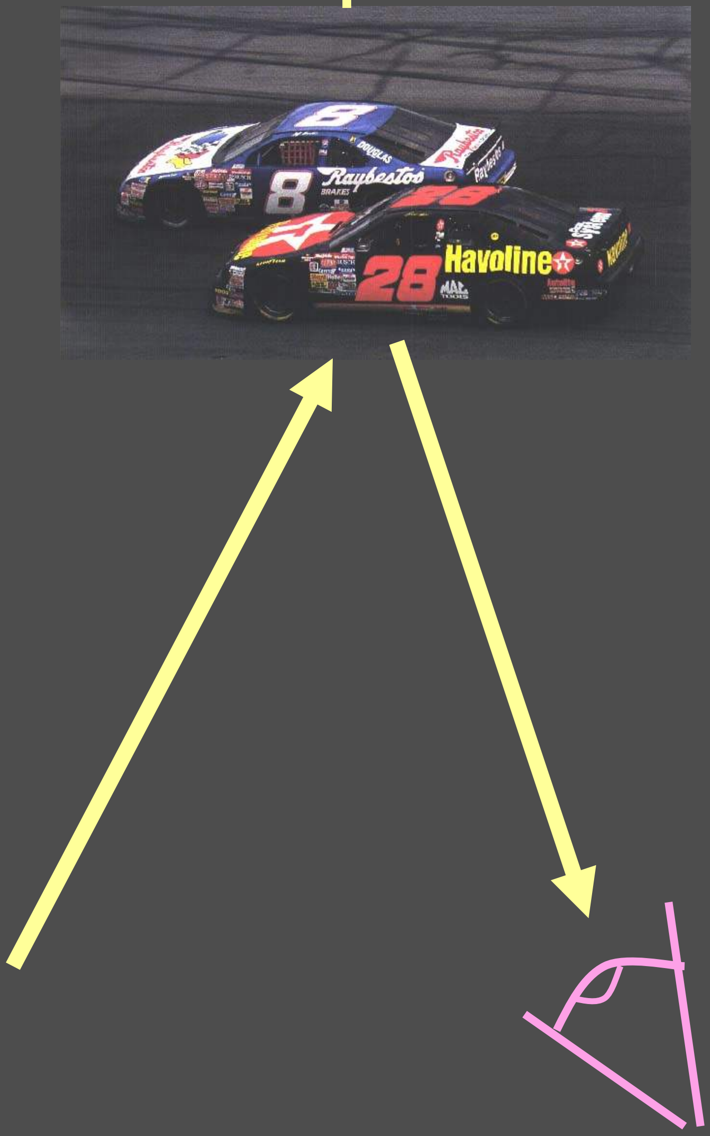
How has the universe evolved?

Mini-Ph.D. – Quantum Mechanics 101

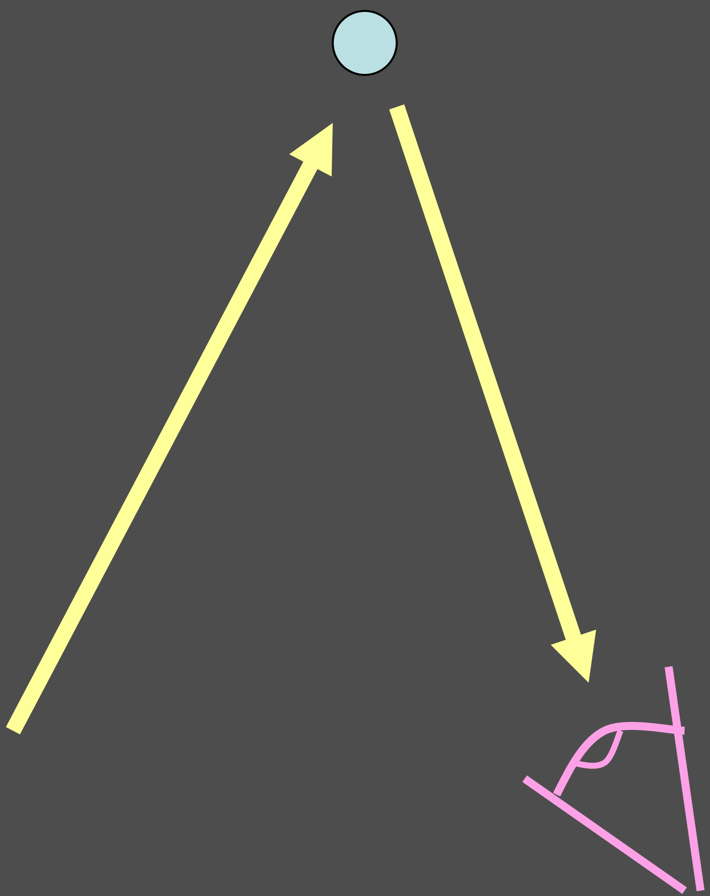
Lesson 1:

Size actually does matter.

Determine the postion and velocity of a car … no problem

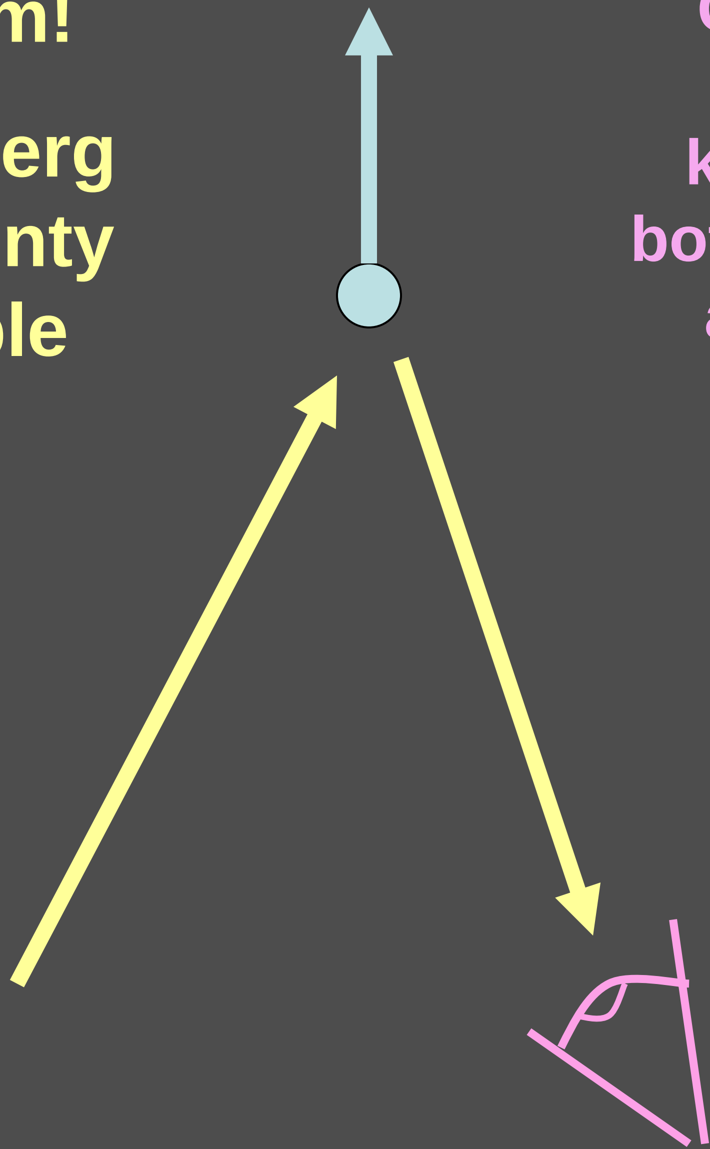


Determine the postion and velocity of a small particle … no problem



Problem!

Heisenberg uncertainty principle



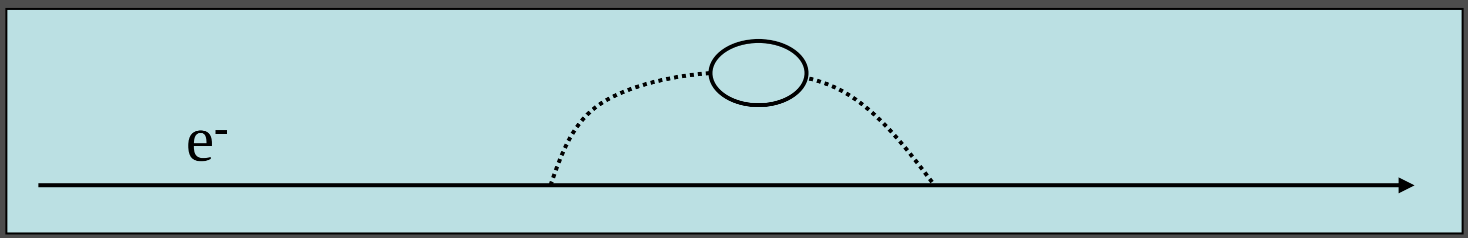
Cannot have perfect knowledge of both the position and velocity

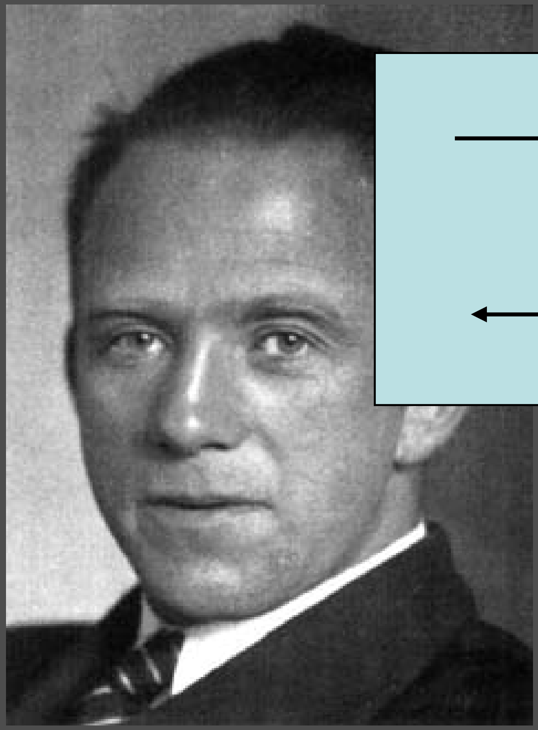
Heisenberg

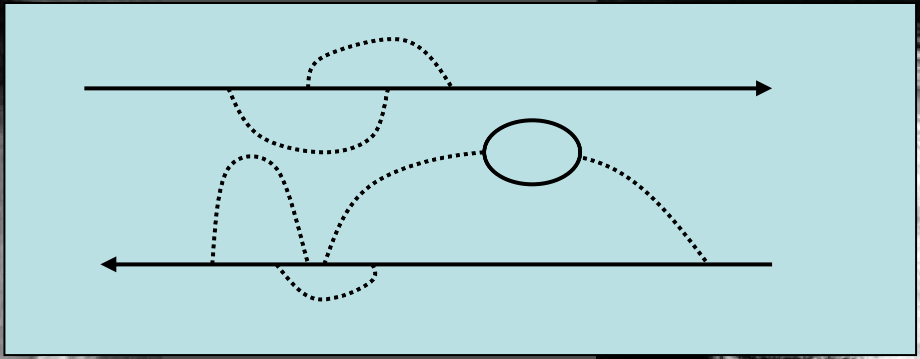
The fundamental nature of forces: virtual particles

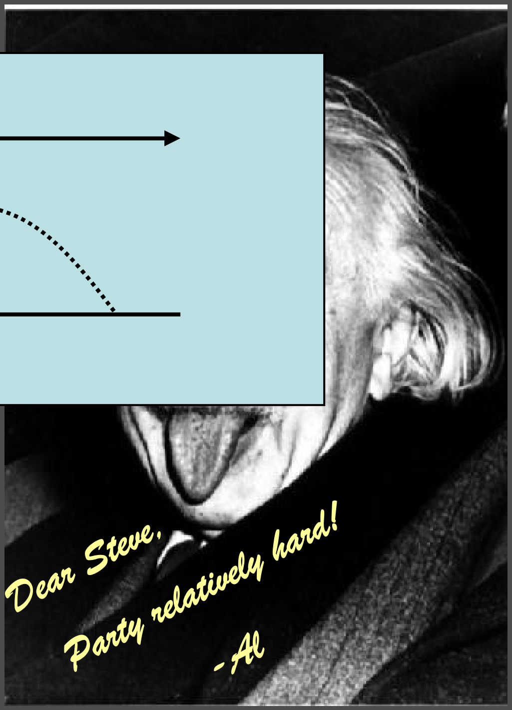
$\Delta E \Delta t \approx h$ Heisenberg

$E = mc^2$ Einstein



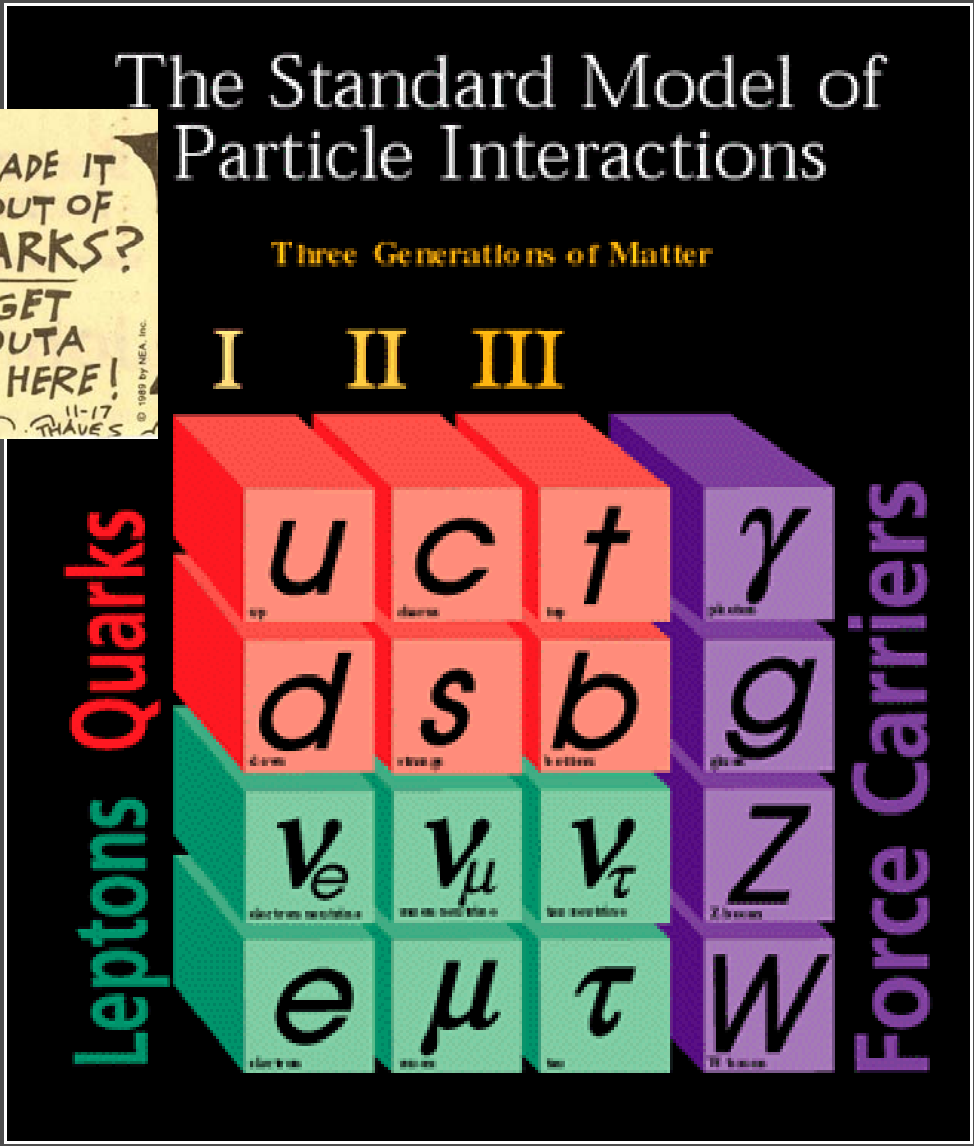






Force	***Source***	***Range***	***Strength***
Gravitation	mass	infinite	10^{-39}
Electromagnetism	Electric charge	infinite	10^{-2}
Strong nuclear	Color charge	10^{-15} m	1
Weak nuclear	Weak charge	10^{-18} m	10^{-5}


Frank and Ernest
YOU MADE IT ALL OUT OF QUARKS?
--GET OUTA HERE!
11-17
THAVES
© 1989 by NEA, Inc.


The Standard Model of Particle Interactions
Three Generations of Matter
I
II
III
Quarks
u c t
d s b
Leptons
ν_e ν_μ ν_τ
e μ τ
Force Carriers
γ
g
Z
W