Physics 100 - November 12, 2007

- Exam Wednesday
- Q + A Session Tuesday 4:30–6:00
  B+L 208
- Presentation group meeting

Fundamental Particles

Quarks

u, d, c, s, t, b

fract. electric chg

Bind by St. interaction

(qqq) Baryons

Proton, neutron

(q$\bar{q}$) Mesons

π, K

Leptons

e, μ, τ

ν_e, ν_μ, ν_τ

Gauge Bosons

mediate forces

$\gamma, W^{+/-}, Z$, g (gluon), G (graviton)

Higgs

Fundamental Forces

gravitation

Graviton

Strong

gluon

range is self-limiting

Weak

$W^{+/-}, Z$

10^{-18}m range

Electromagnetism

γ

infinite range

Strength

gravitation: $\sim 10^{-40}$

Strong: 30

Weak: 1

Electromagnetism: 1

Quantum Field Theory

Weak   EM   Strong   No mass in theory

Weak + EM + Higgs

↓

Mass

W, Z, γ predicted

} STANDARD Model

something does what the Higgs does

Let's move from inner space to outer space

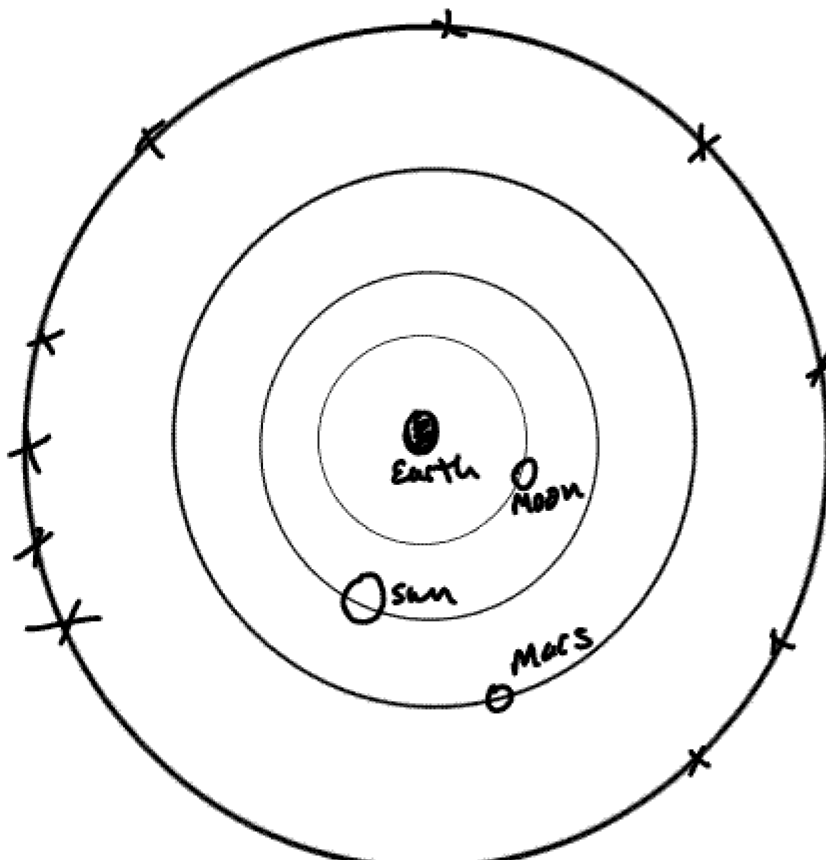
Views of Earth's place in the cosmos ...

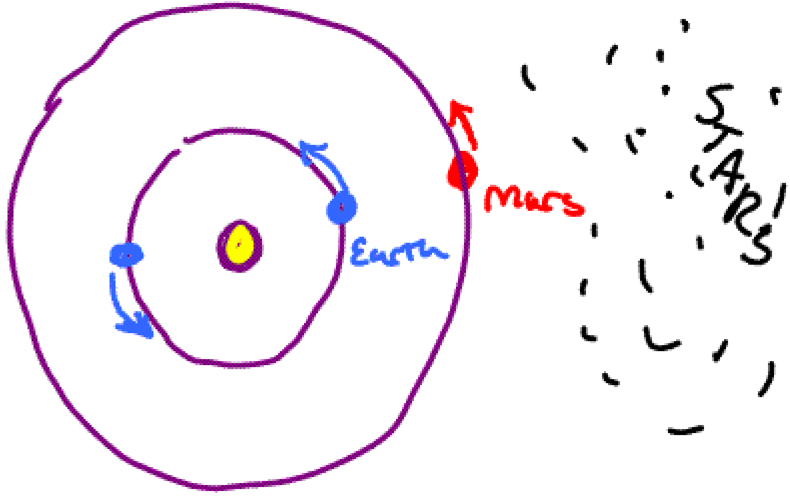
Pythagorian theory

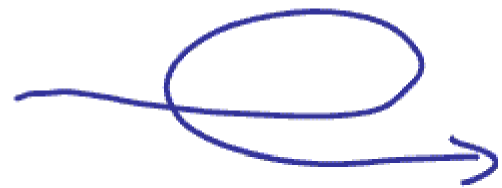
Early Greek view of the universe

Pythagoras of Samos

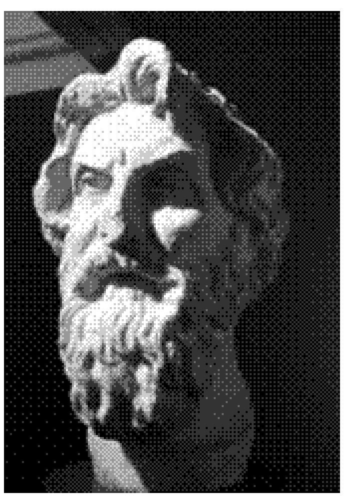
~500BC







Plato ~400 BC ~ Multiple spheres

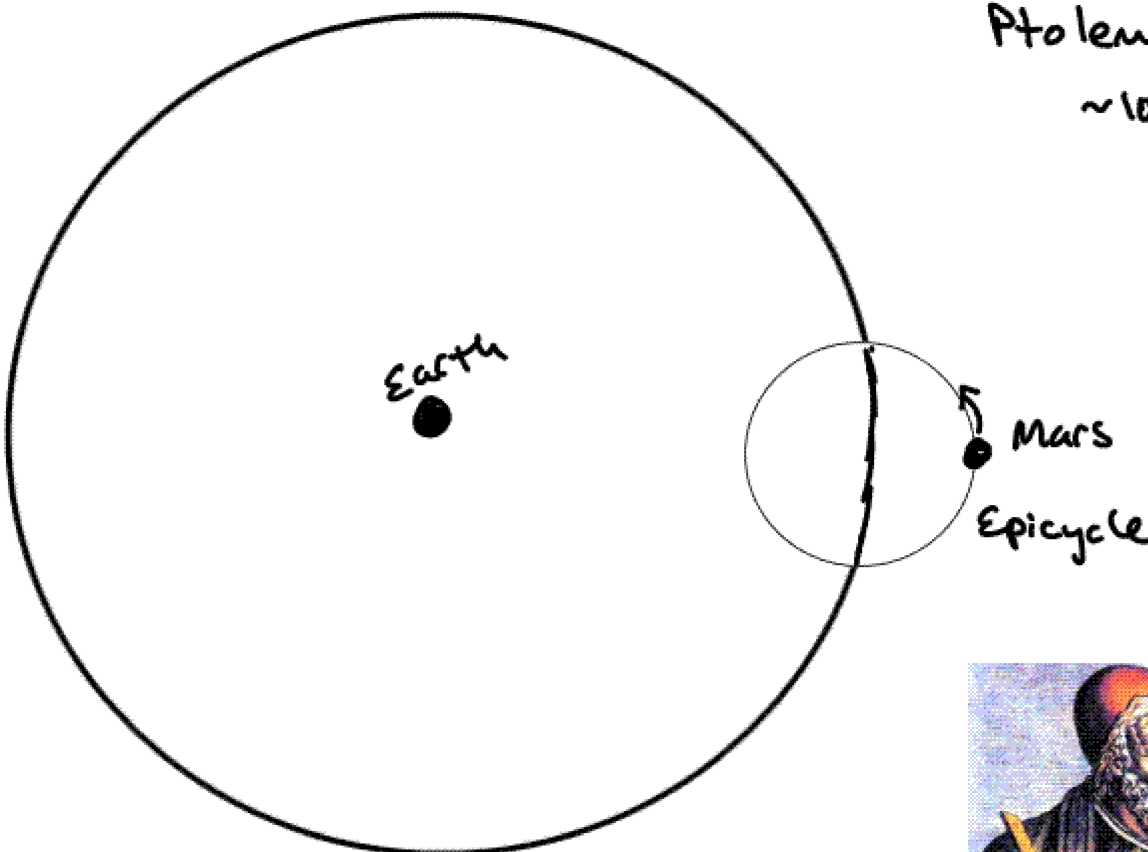


Aristarchus ~310 - 230 BC
(Greek)

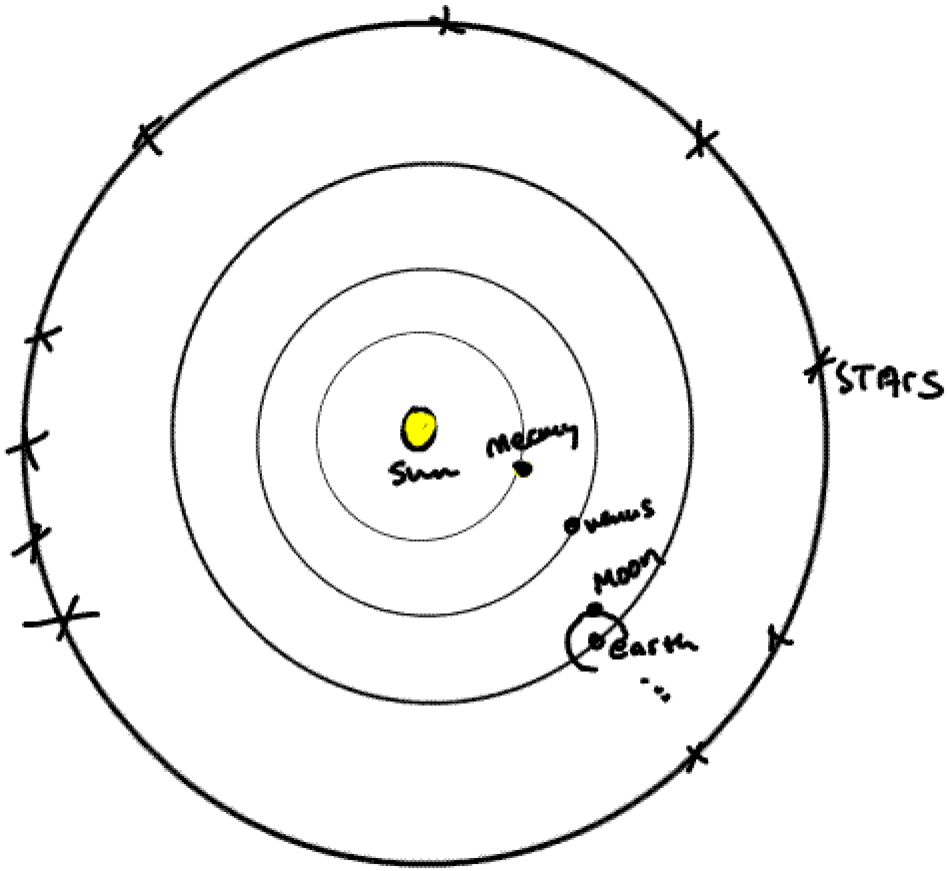
Proposed sun-centered universe
→ rejected

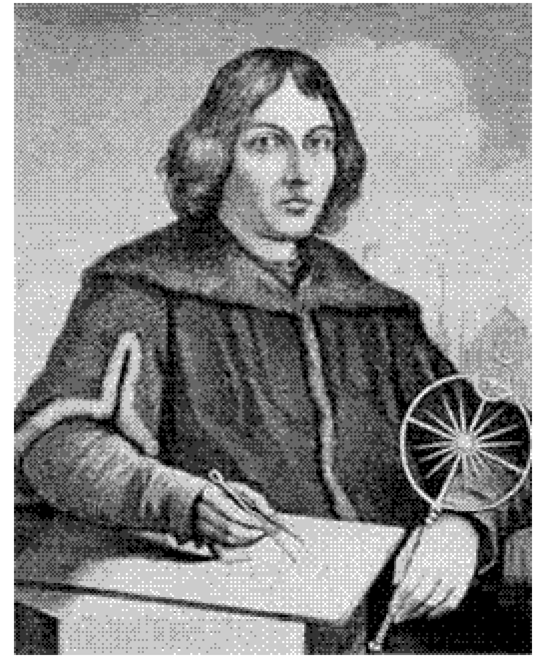
Ptolemy

~100 AD



Sun centered universe





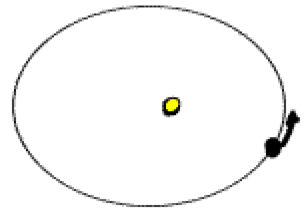
Nicolaus Copernicus
1473-1543
(Poland)

On the Revolutions of the Heavenly Spheres

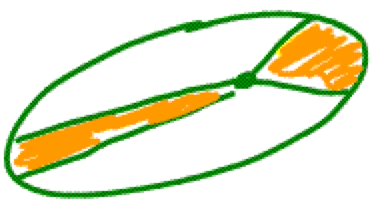
Brahe's data did NOT fit perfectly with Copernicus' theory

Tycho Brahe
1546 - 1601
(Dane)
careful observations
of positions
of Sun, Moon, planets

Johannes Kepler
1571 - 1630
(German)



⇒ Elliptical orbits
fits the data!



Determined 3 laws
that mathematically
describe orbits seen –
relate periods, areas, axes ....

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

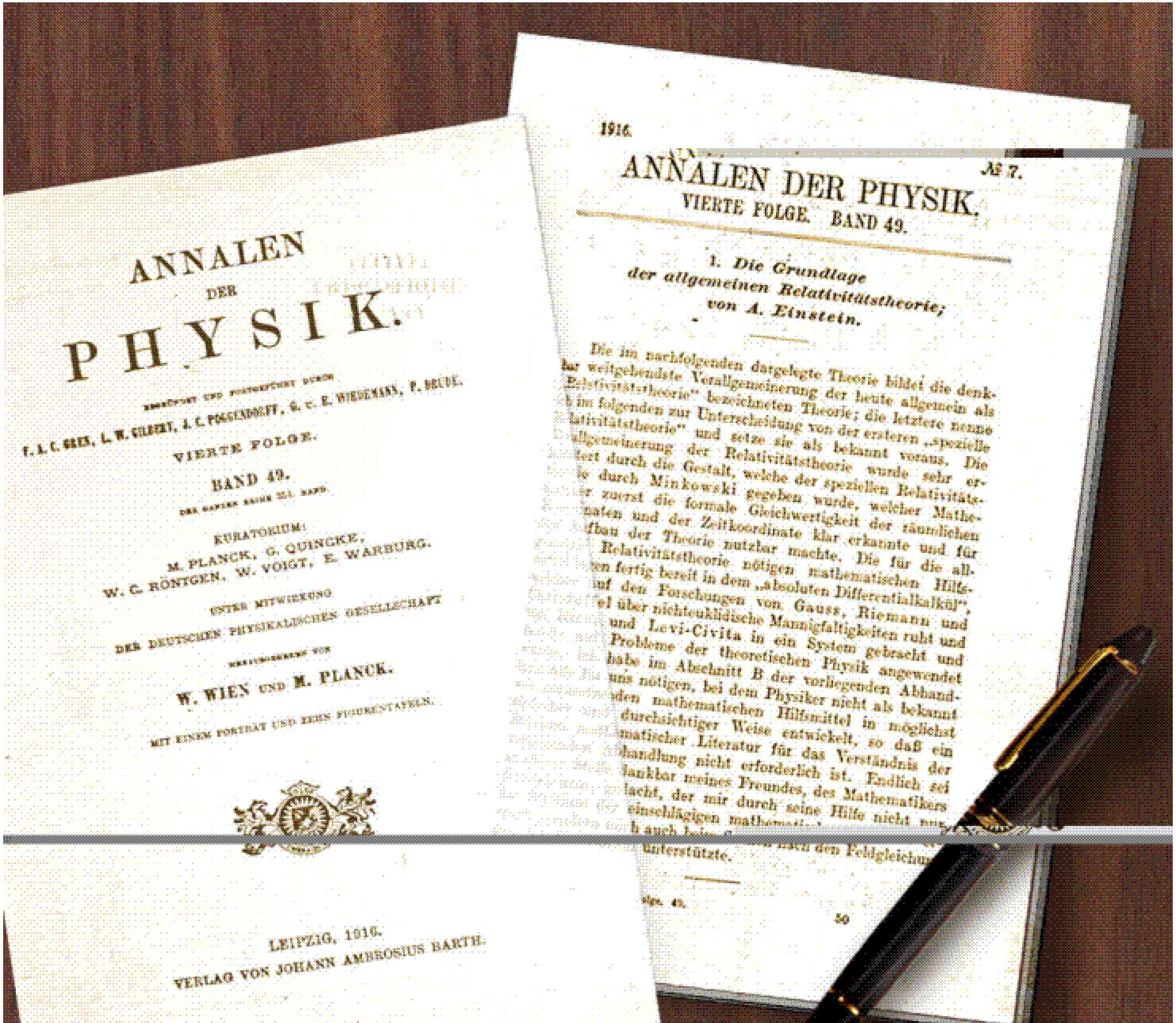
$$F = \frac{G M_1 M_2}{r^2}$$

+

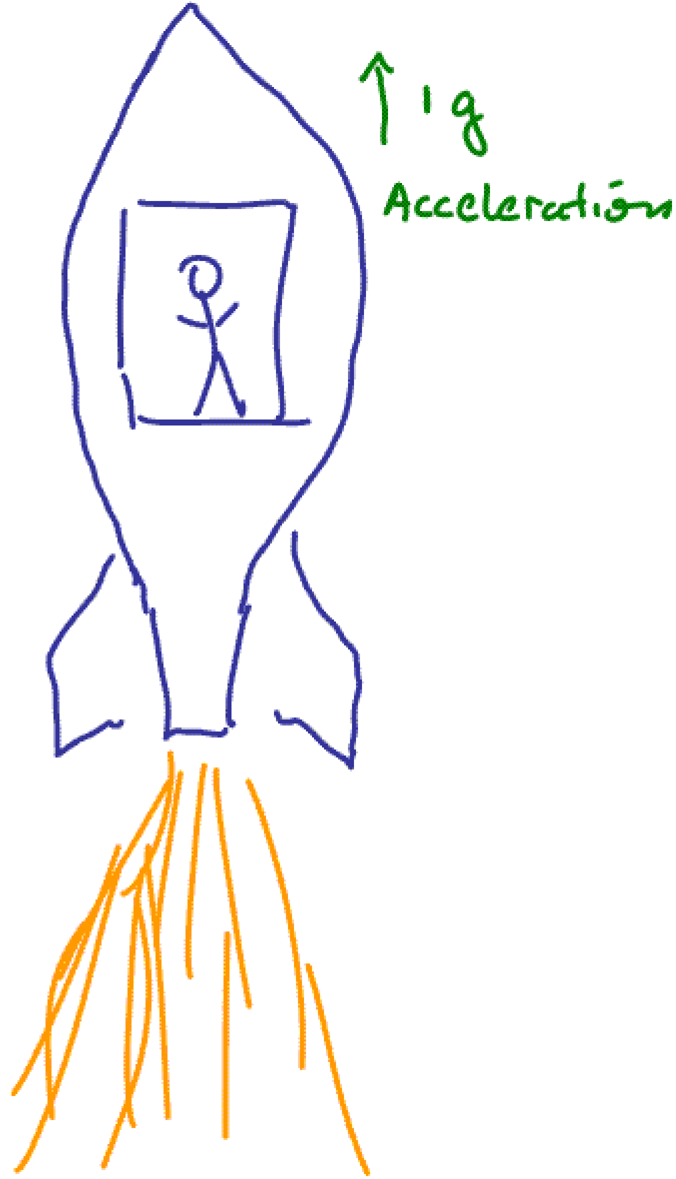
Laws of Motion

⟹ derived Kepler's 3 laws of planetary motion

The Theory of General Relativity – Einstein 1916



Vs



accelerated reference frames

≡

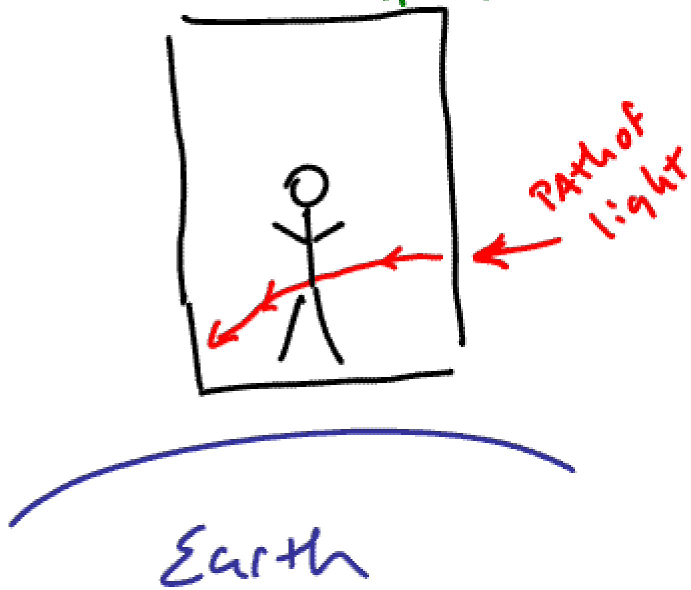
gravitational field

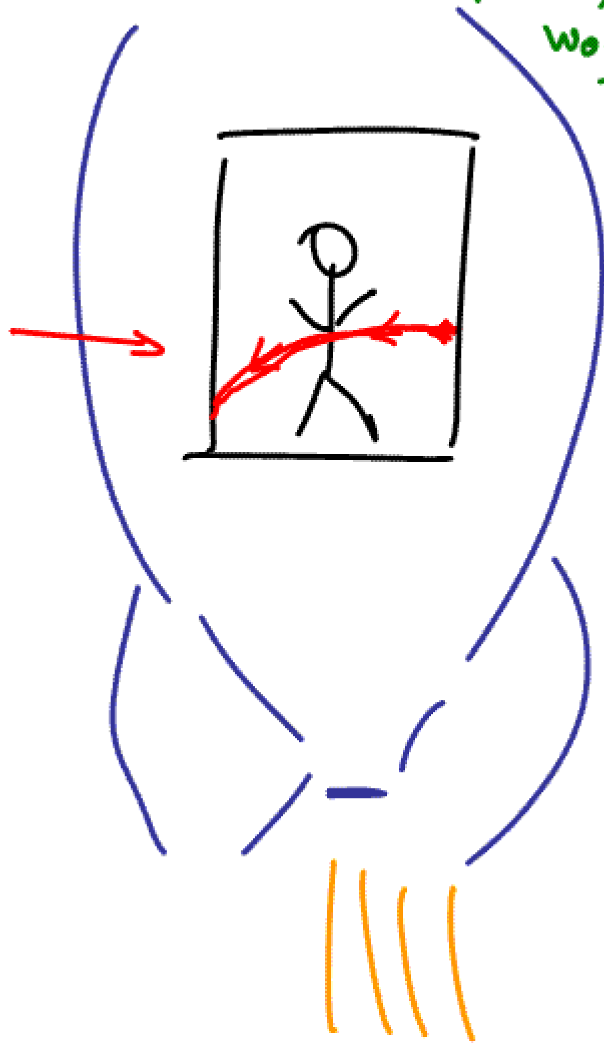
If you are in a closed box —

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

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

Means grav. field must curve spacetime





Accel.
↑ 1g

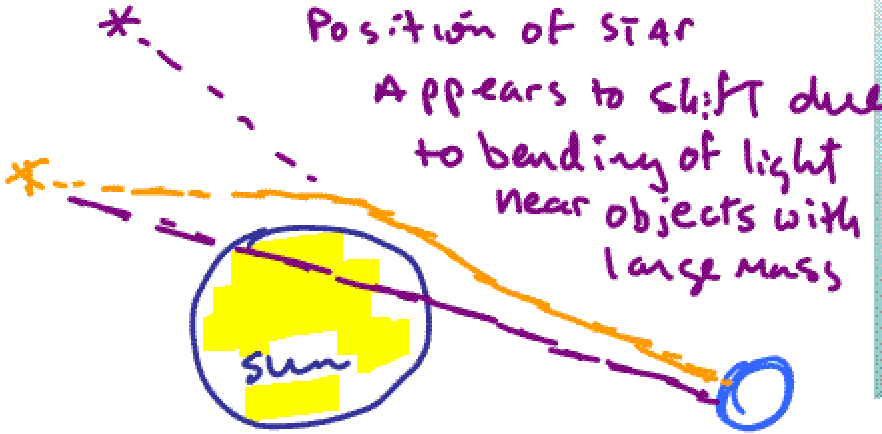
grav ≡ Accel. frame

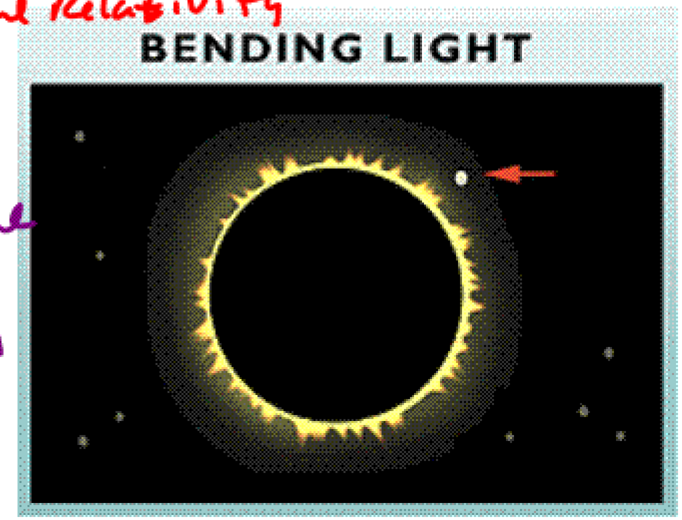
light moves on a geodesic

↑ shortest dist. between two points

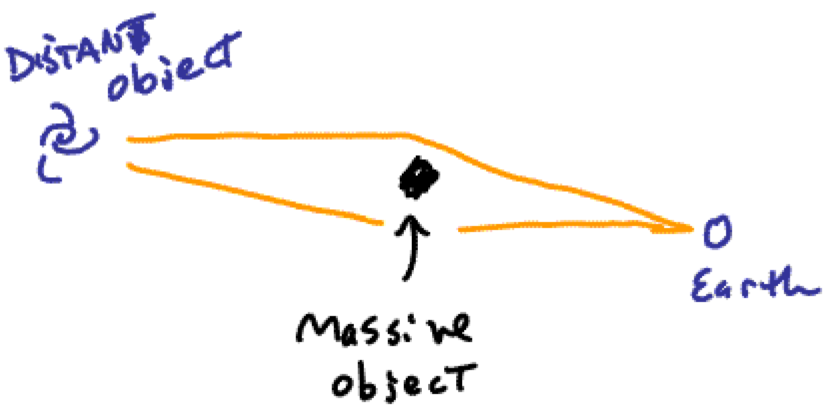
So, Einstein interprets gravitation as a <u>curvature of spacetime</u>

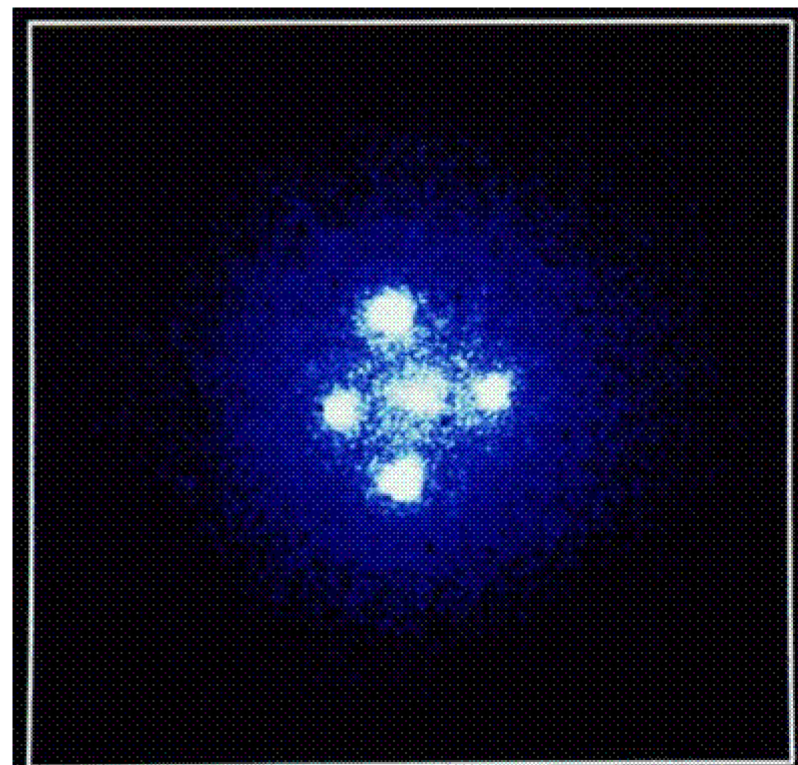
Experimental evidence supporting General Relativity

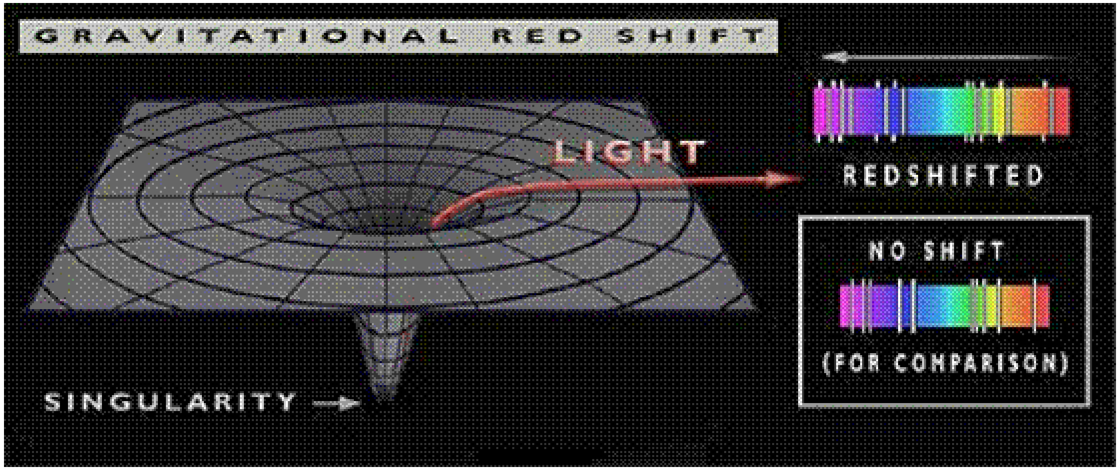




Gravitational Lensing




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

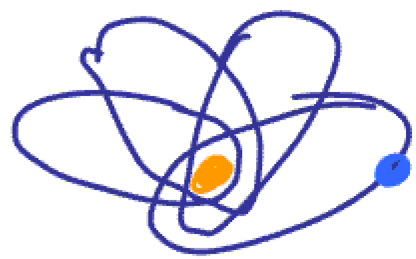
wavelength becomes longer

Stronger gravity → more of a redshift

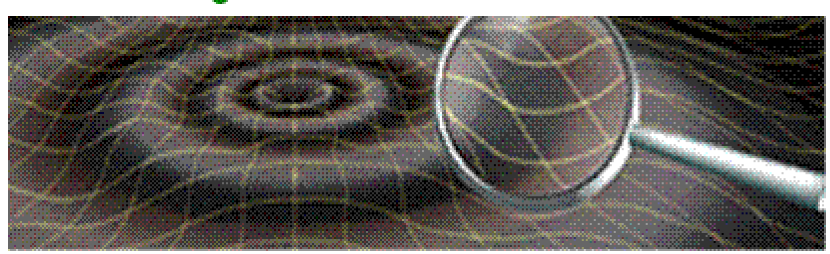
G.R. needed to understand fine details of planetary orbits

Perihelion Advance of Mercury

(show animation)



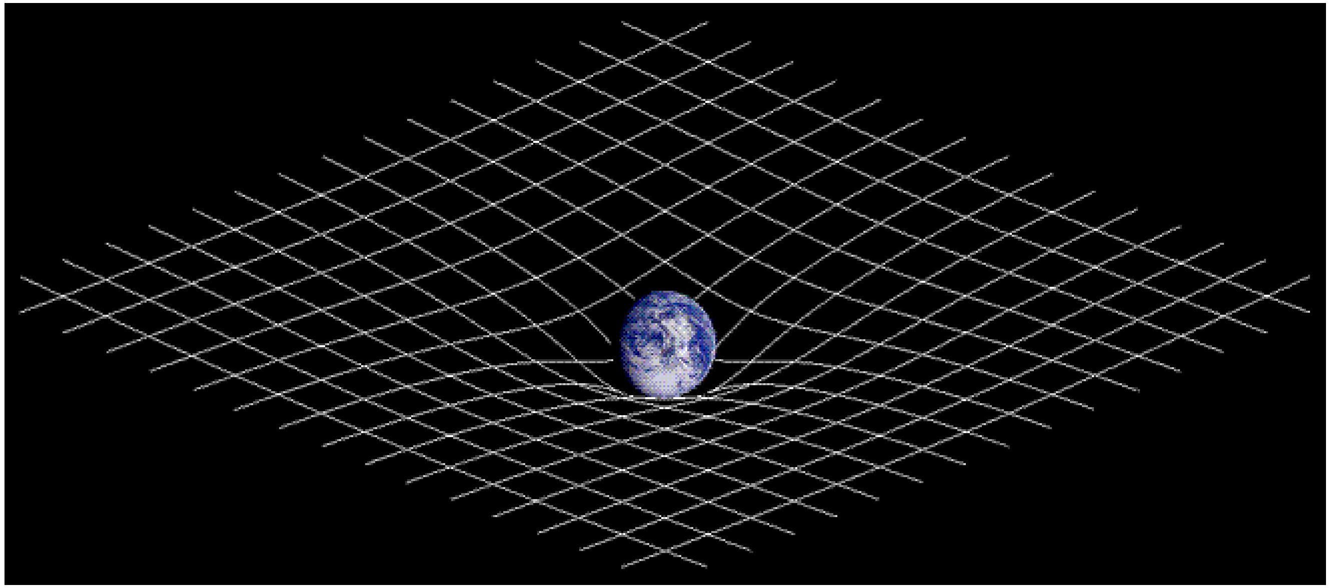
G.R. predicts existence of waves traveling in the fabric of spacetime → gravitational waves

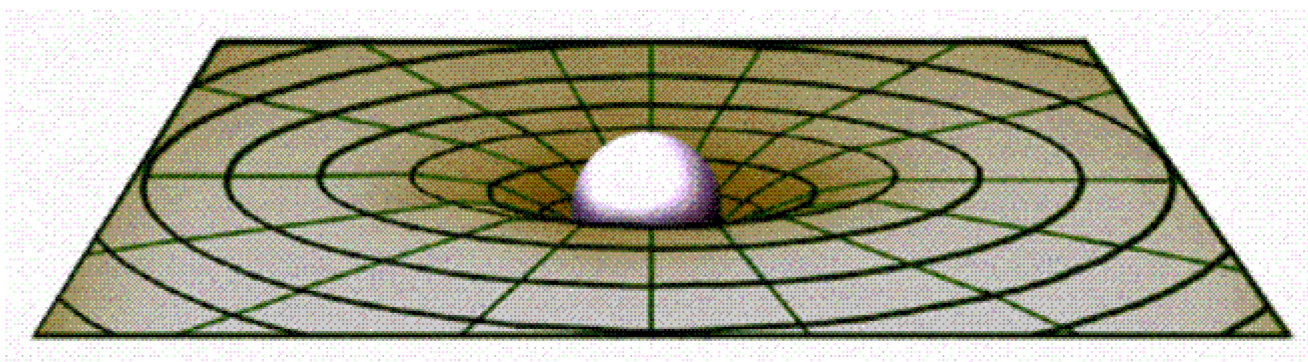


grav. waves would be very small distortions in spacetime traveling at speed of light from large gravitational disturbances

gravitational waves

major experiment aiming to detect grav. waves → LIGO





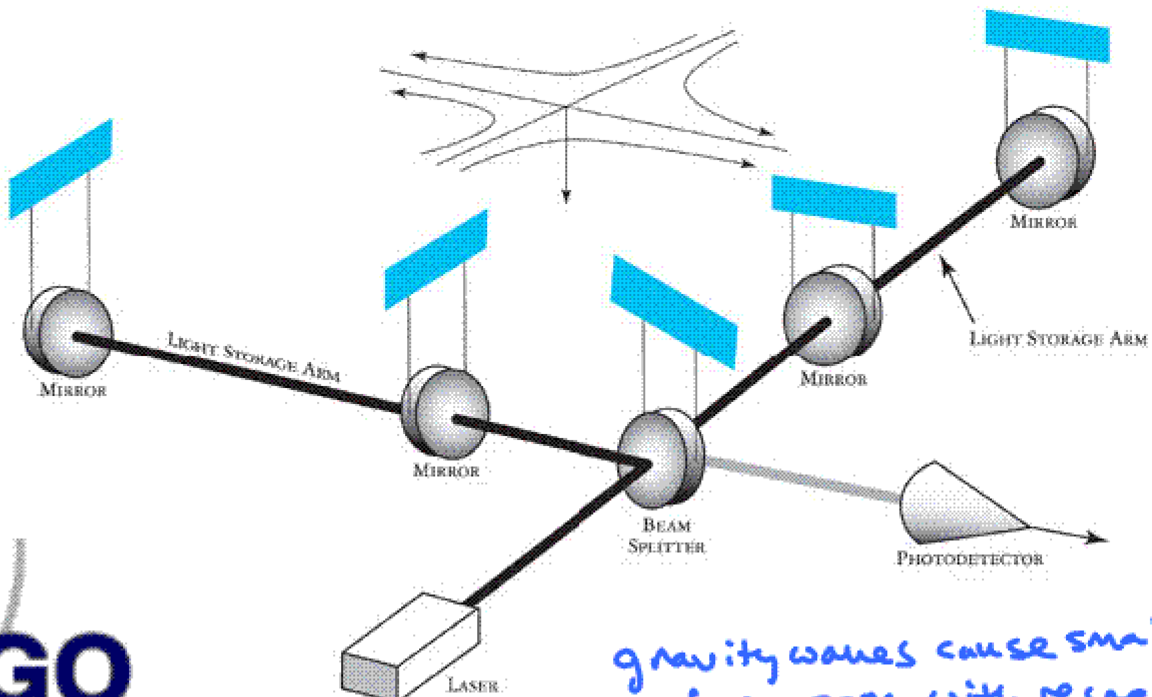
Imagine that mass causes curvature / depression in the fabric of spacetime ... is it true??

LIGO - Laser Interferometer Gravitational Wave Observatory

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

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

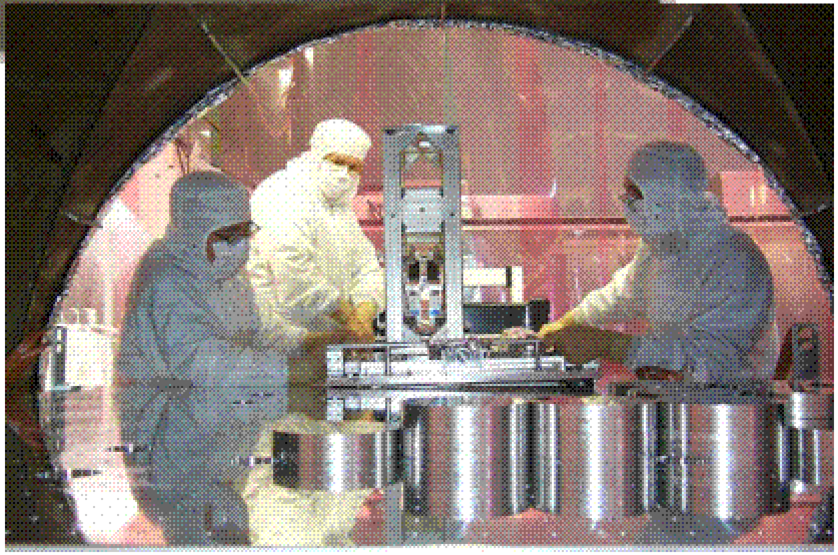
Arms ~4 km in length



LIGO

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

LIGO Site in Hanford, WA
Also one in Louisiana

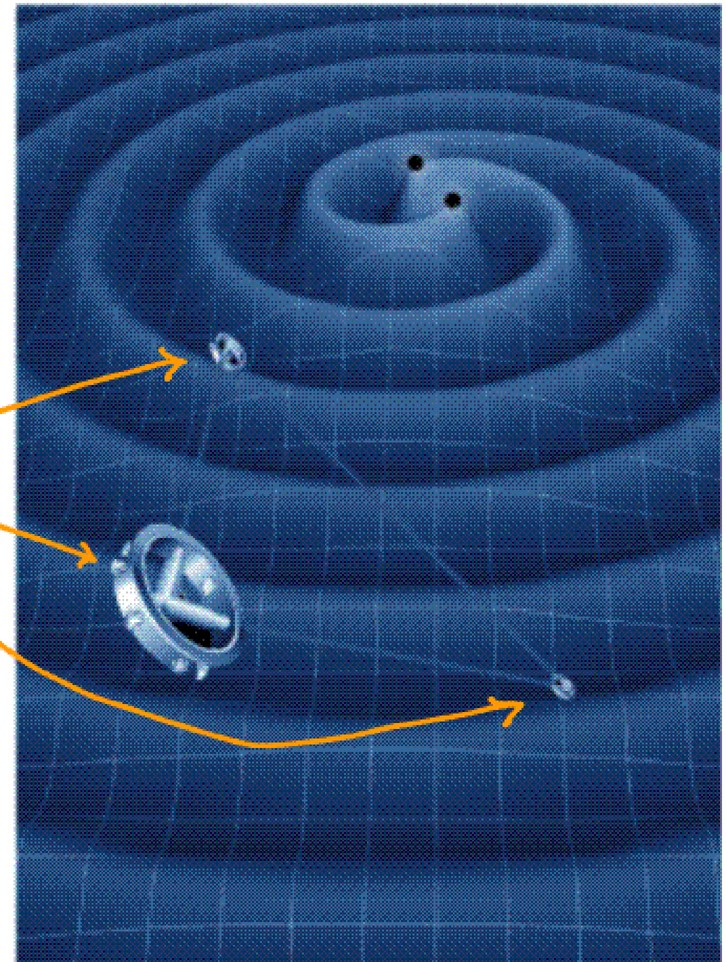


There are other projects ...

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