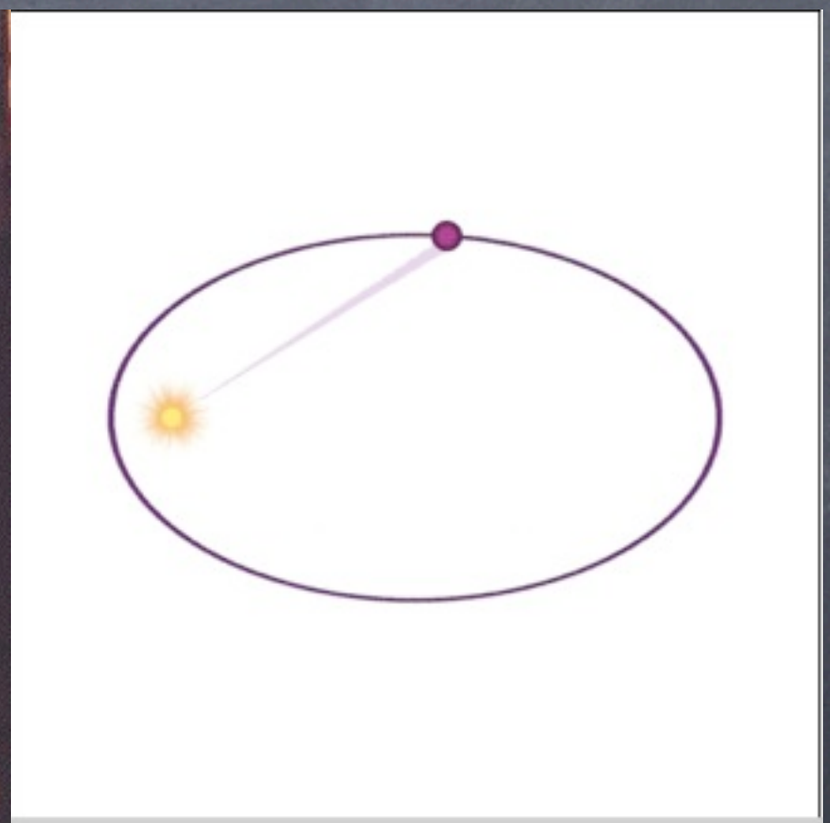
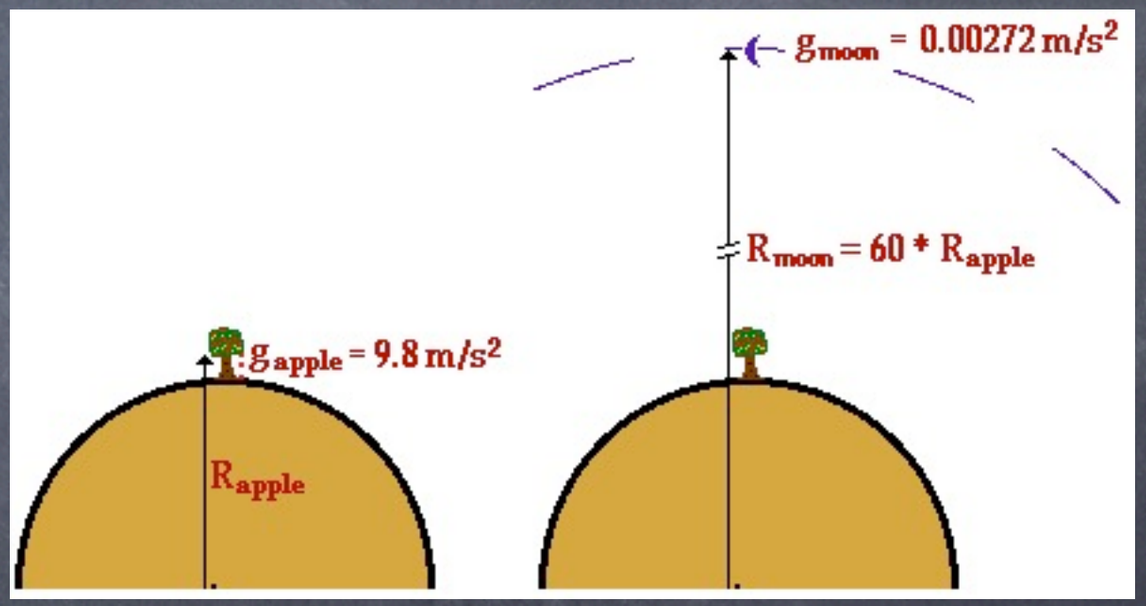
Chapter 4:
Theoretical Physics

Tycho Brahe and Kepler



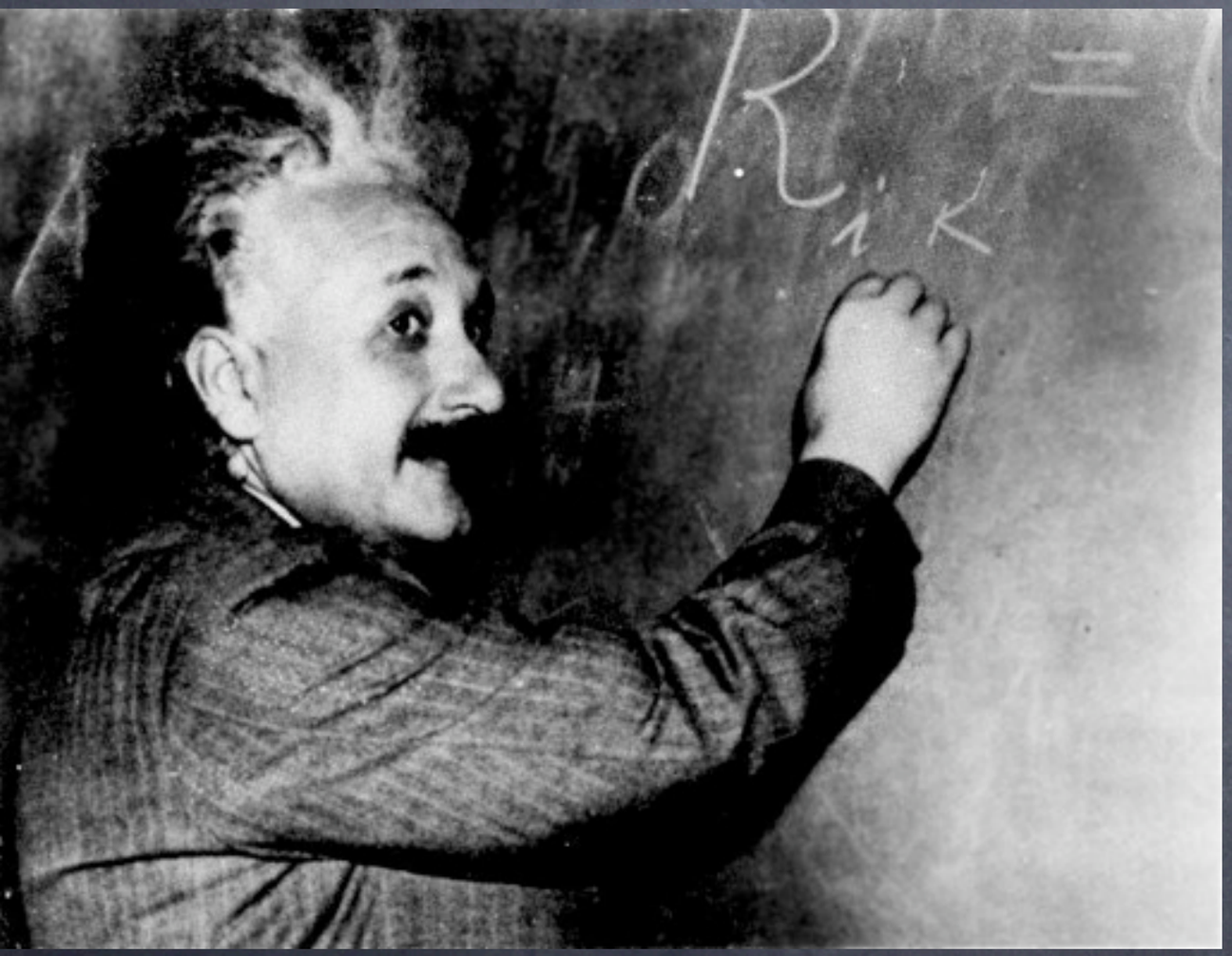
Newton



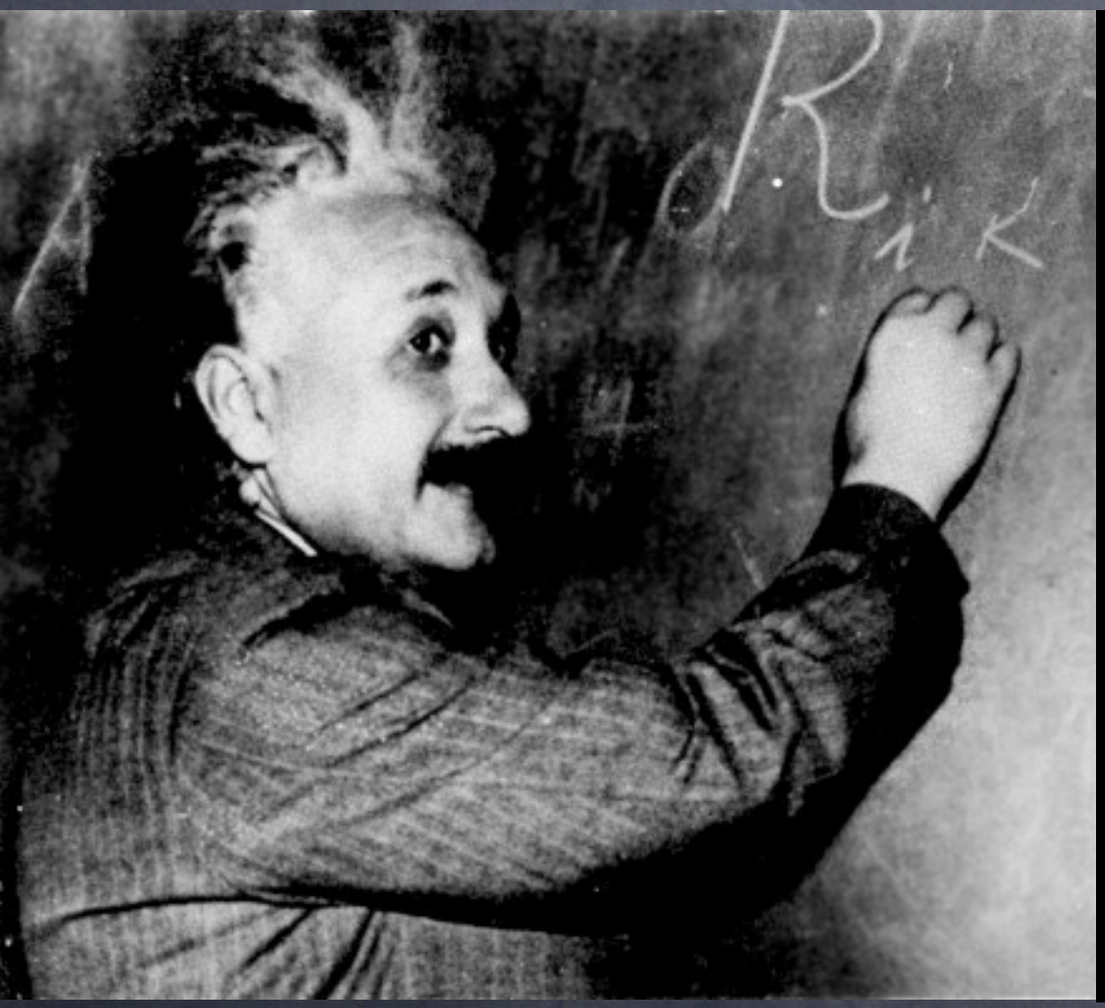
Einstein: Superstar

"They cheer me because they all understand me,
and they cheer you because no one understands you."
– Chaplin to Einstein

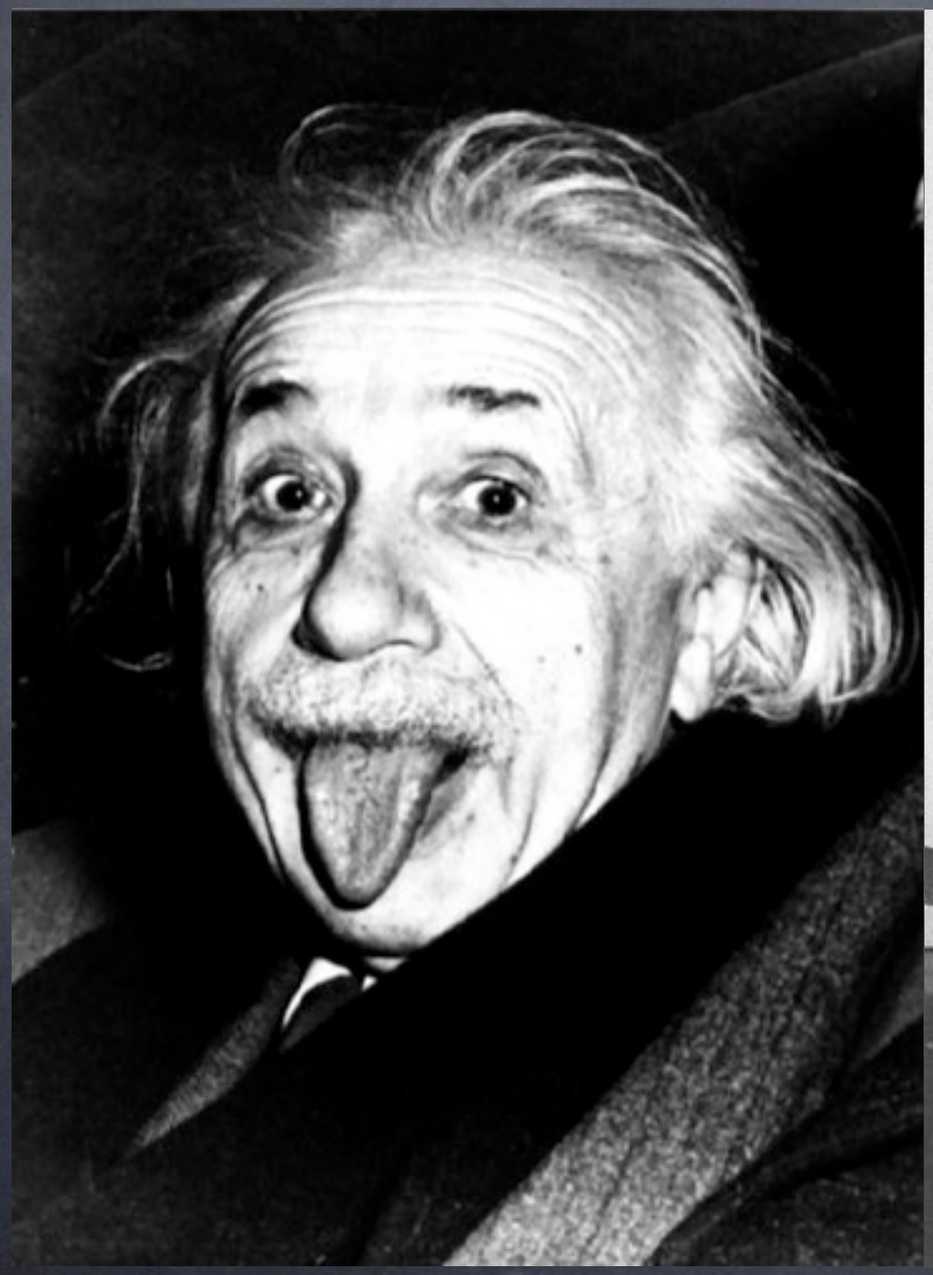
Fourth Dimension



Fourth Dimension

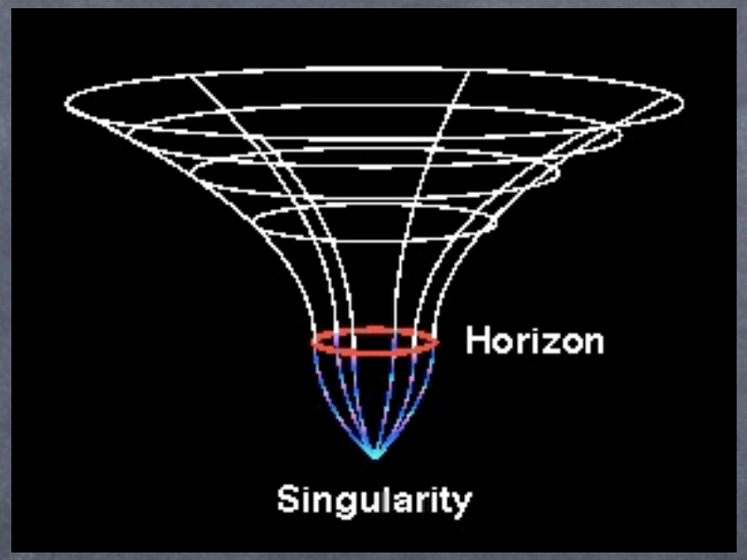


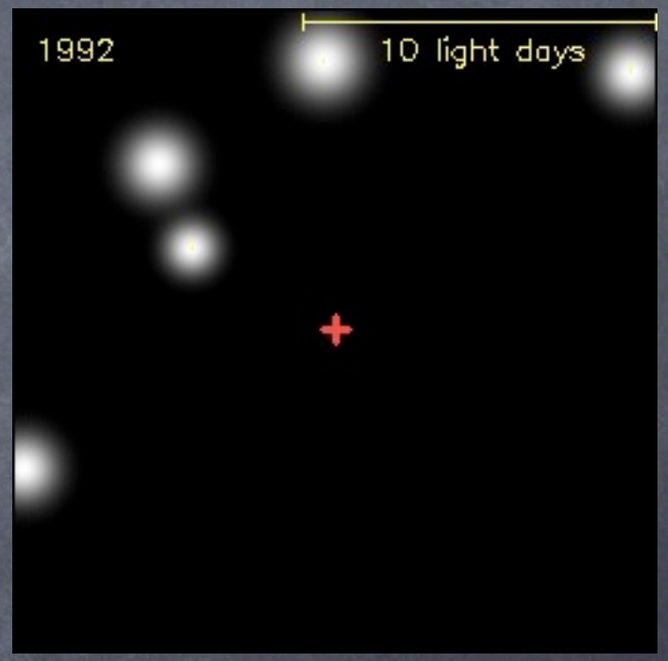
Old versus Young



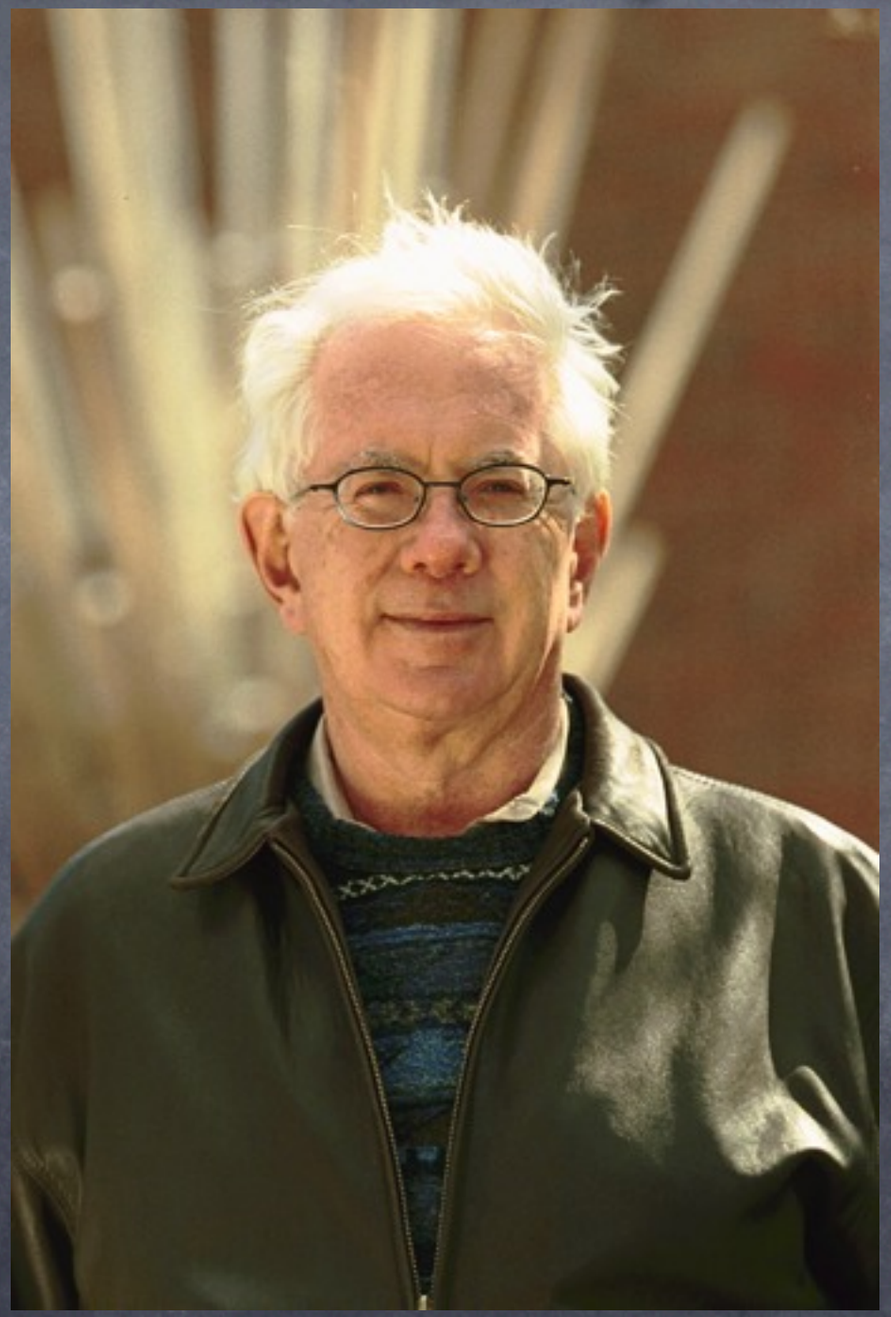
Black Holes

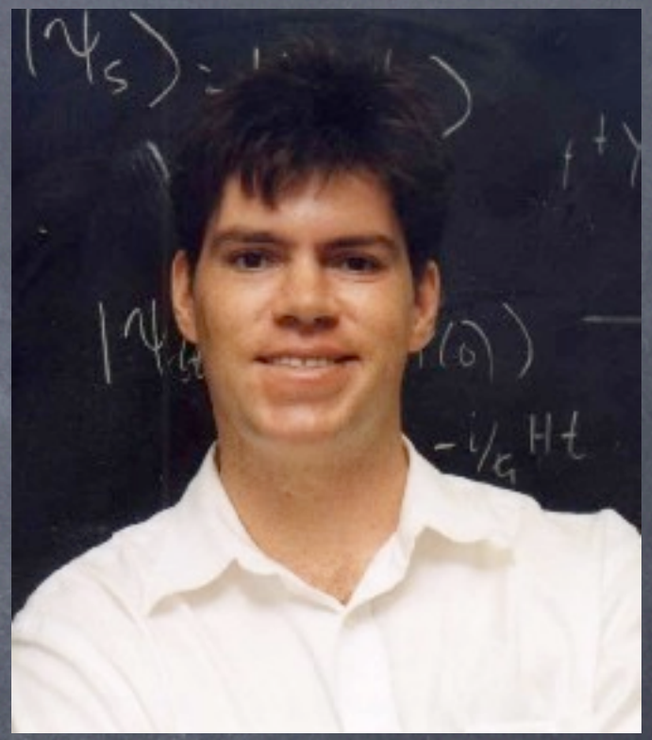
Schwarzschild





Georgi, Glashow, Lawrence

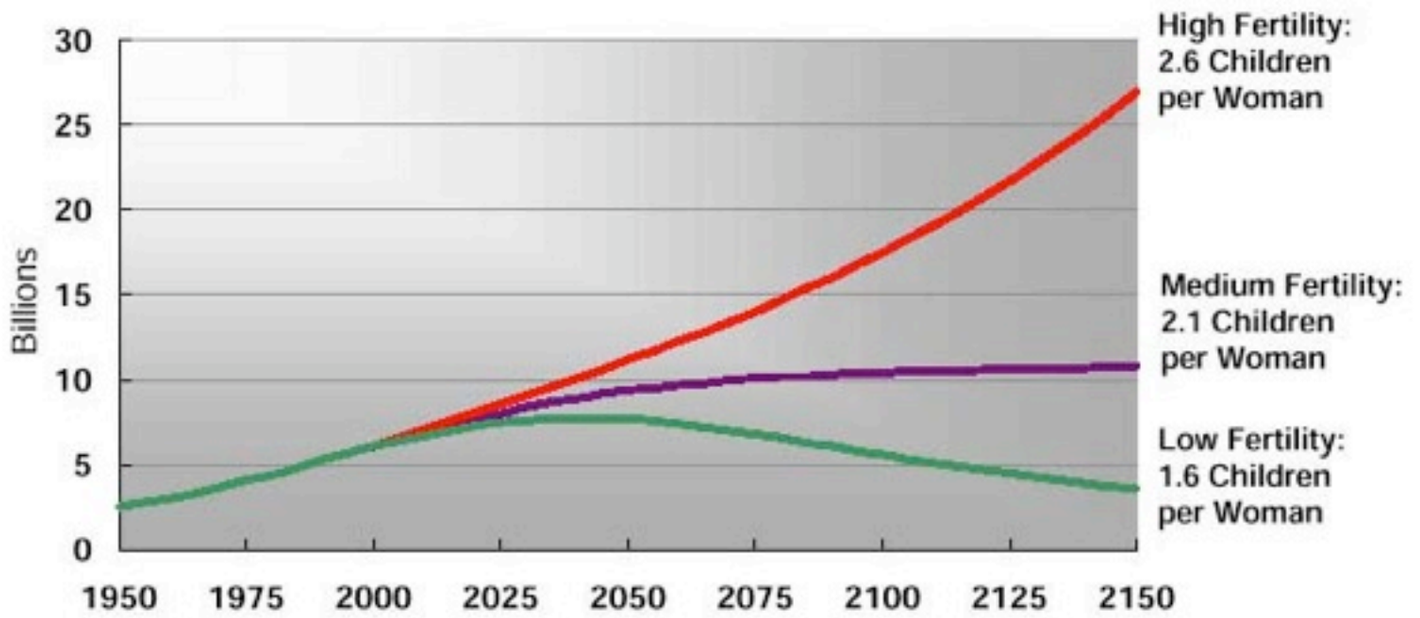




Extrapolation

Projected World Population to 2150

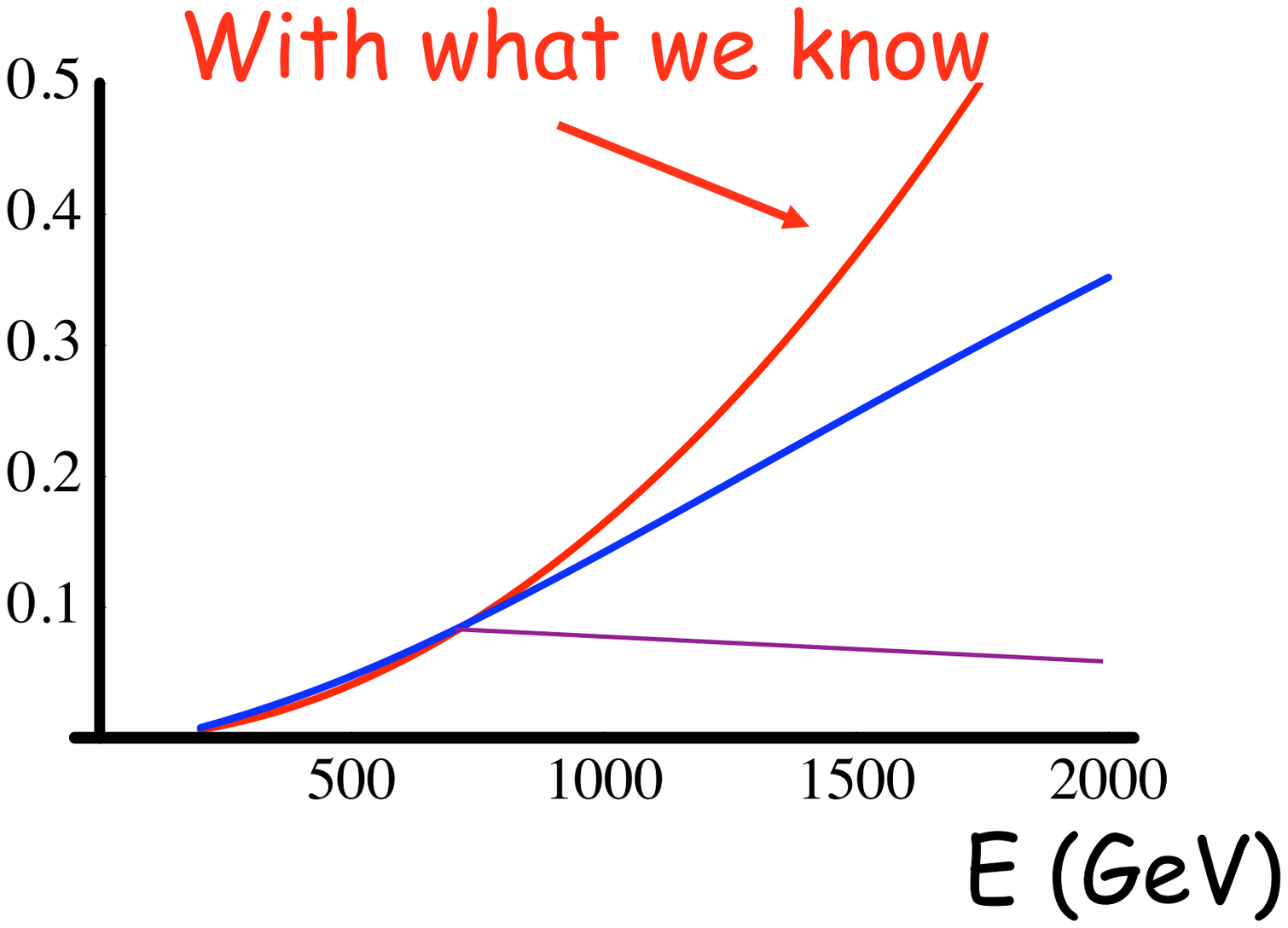
Three scenarios



Source: UN, *World Population Projections to 2150*, 1998.

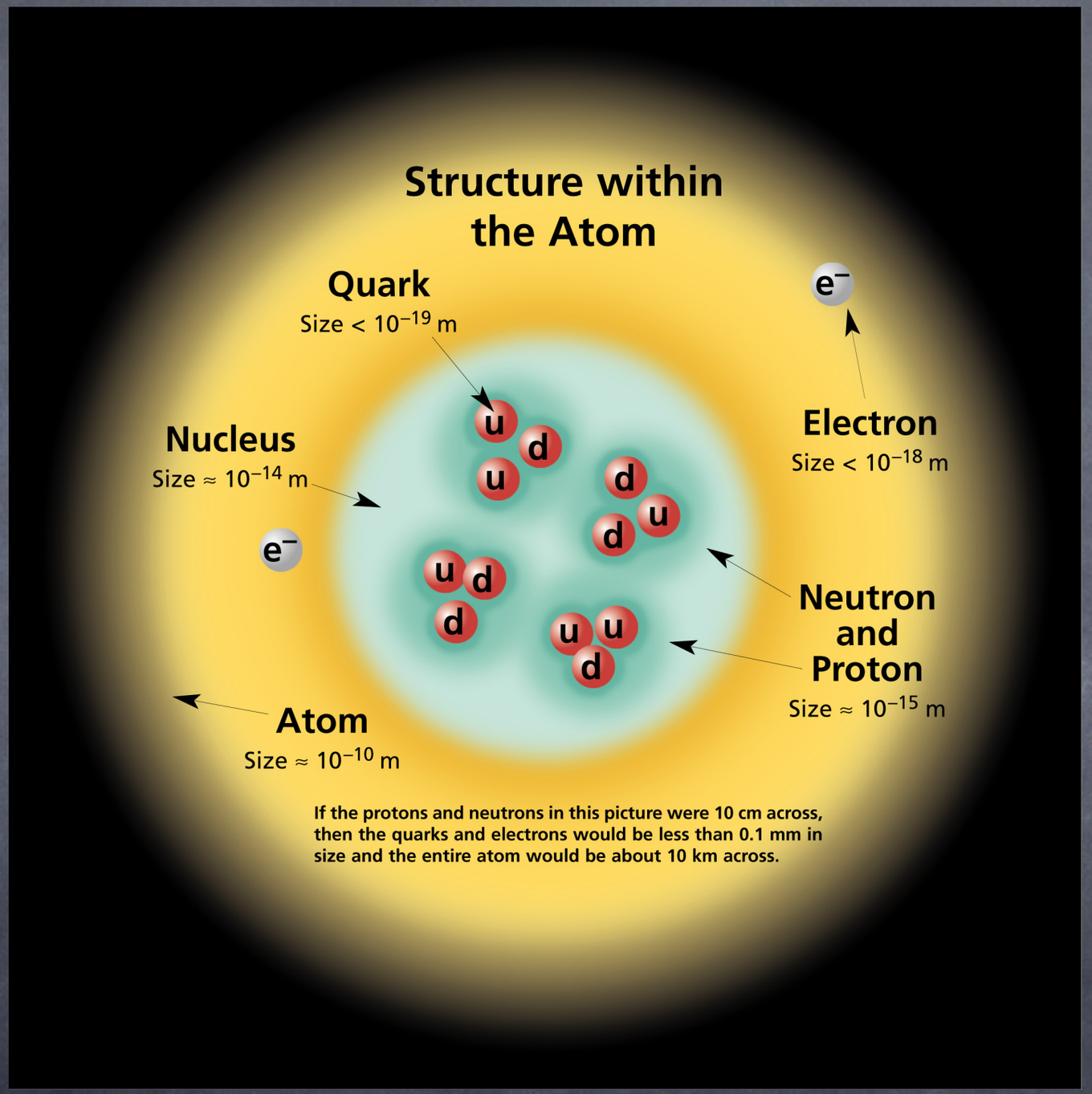
PRB

WW Scattering Amplitude



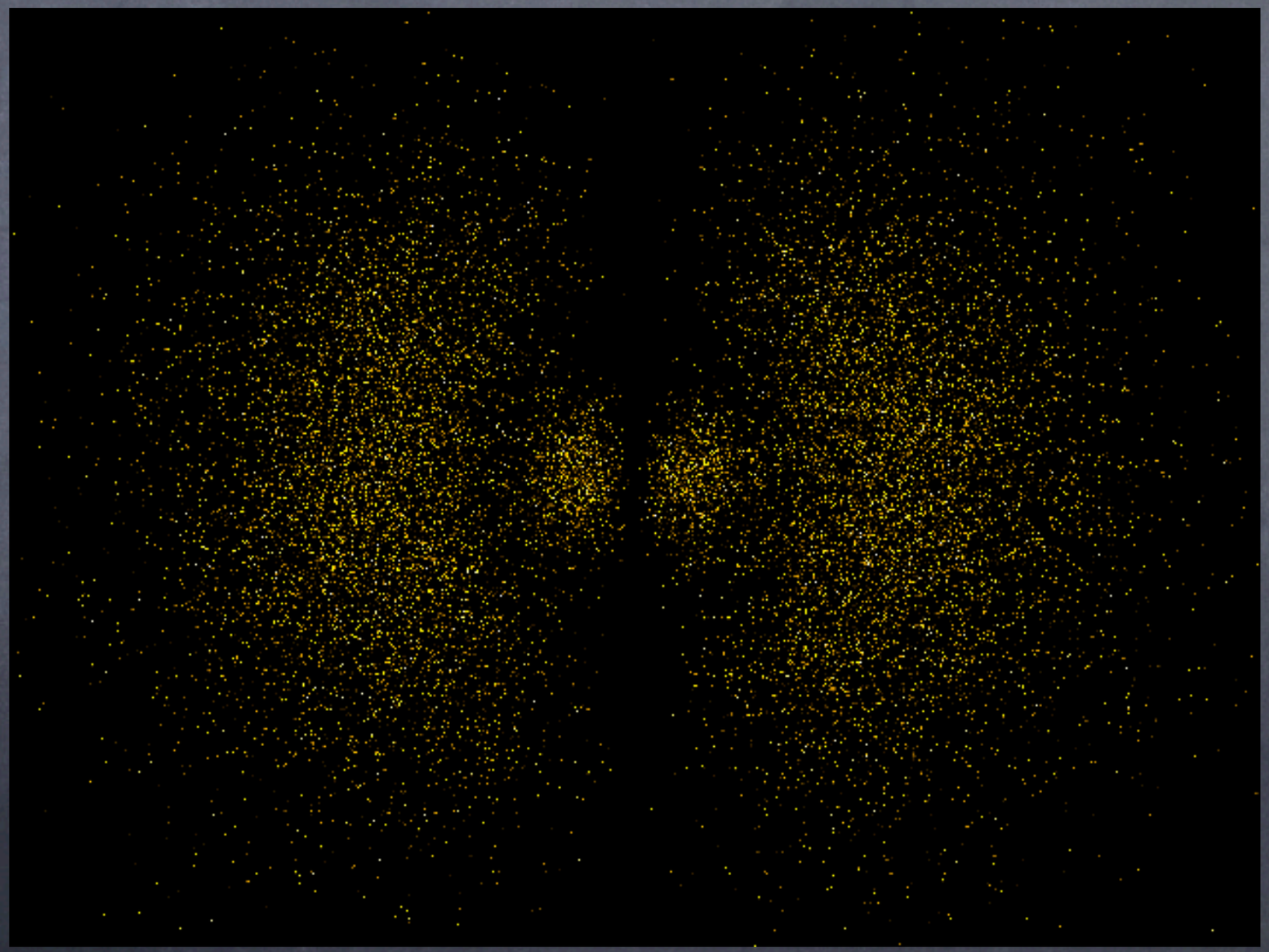
Weinberg

Nobel Prize 1979

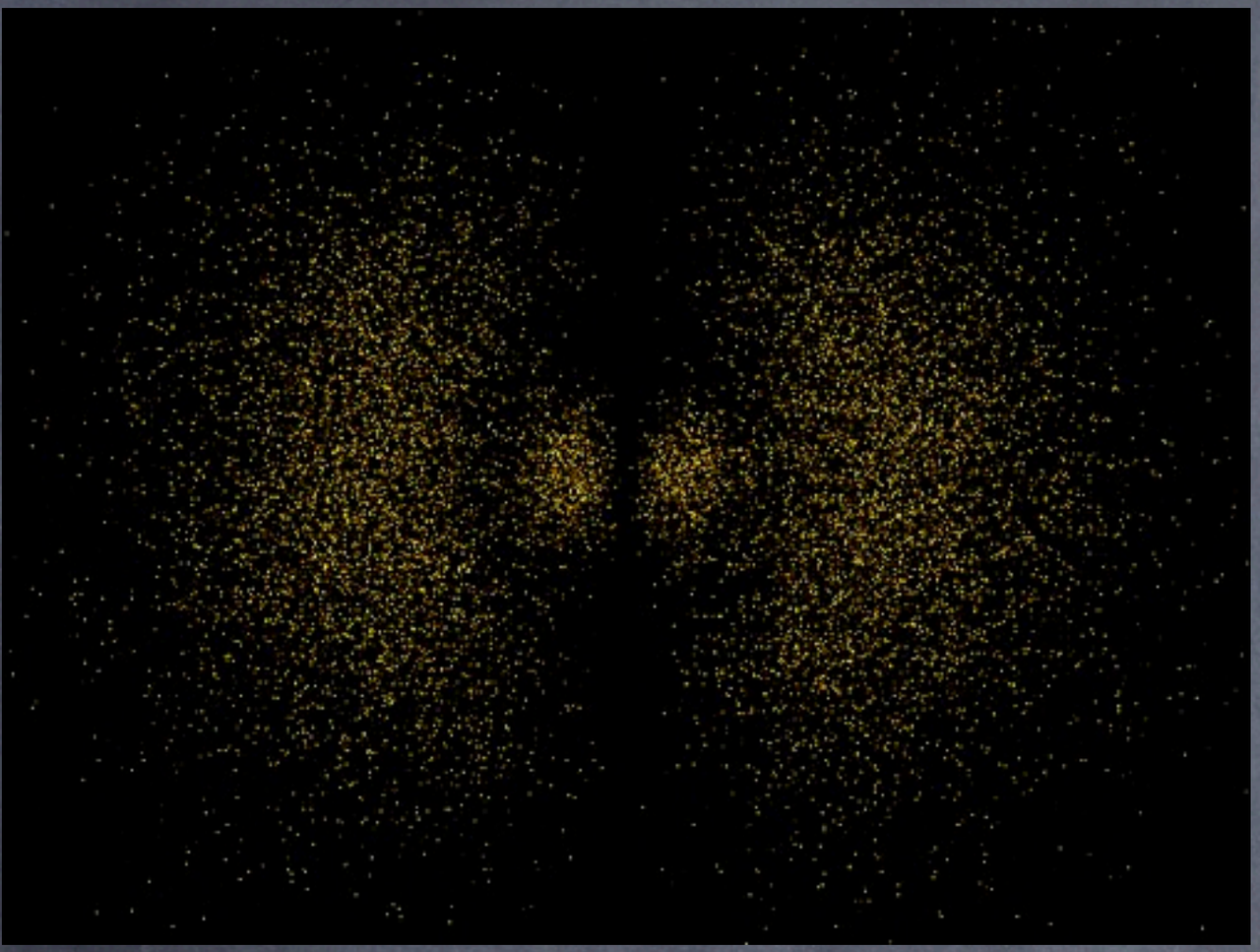


If the protons and neutrons in this picture were 10 cm across, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

Probability Cloud for Electron in Hydrogen



Charges



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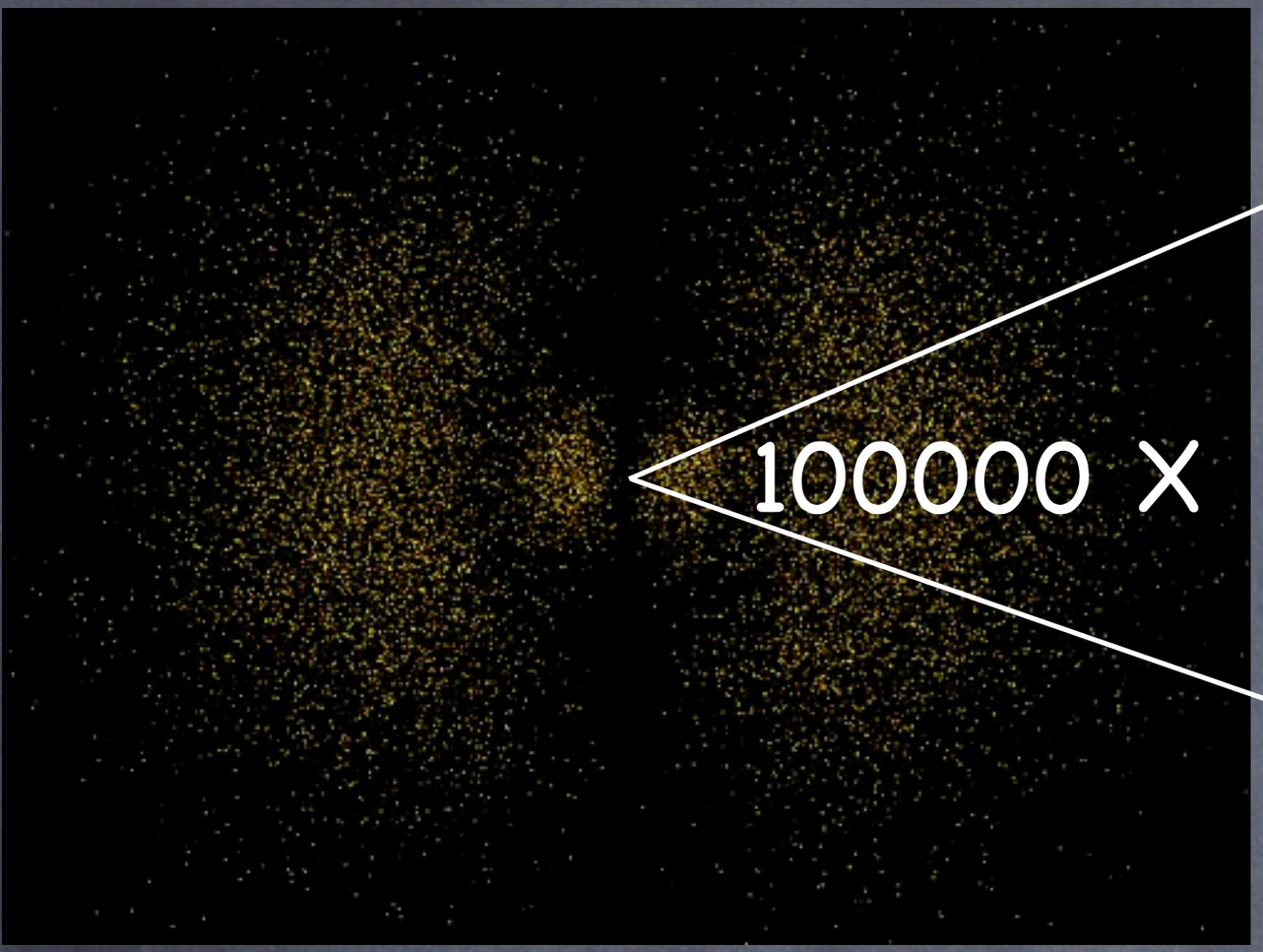
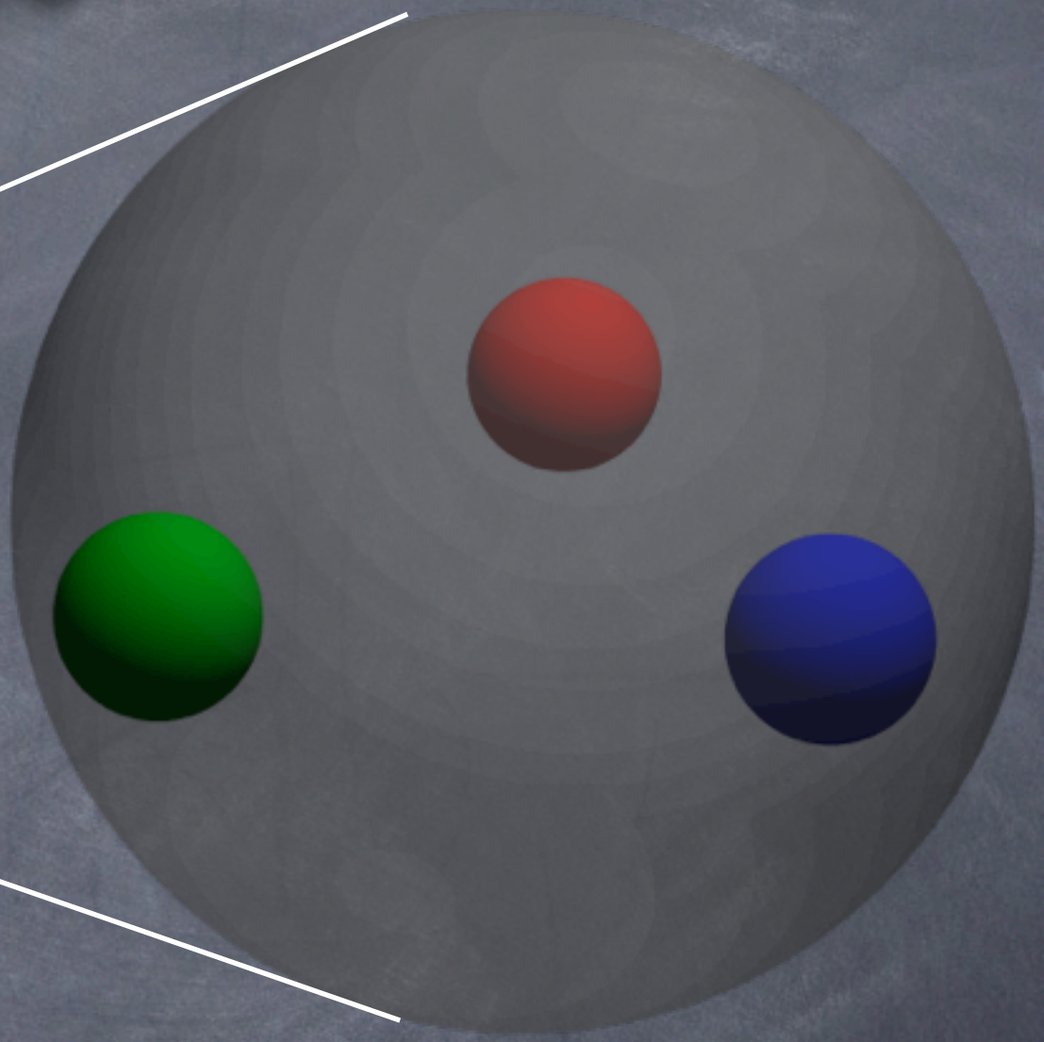
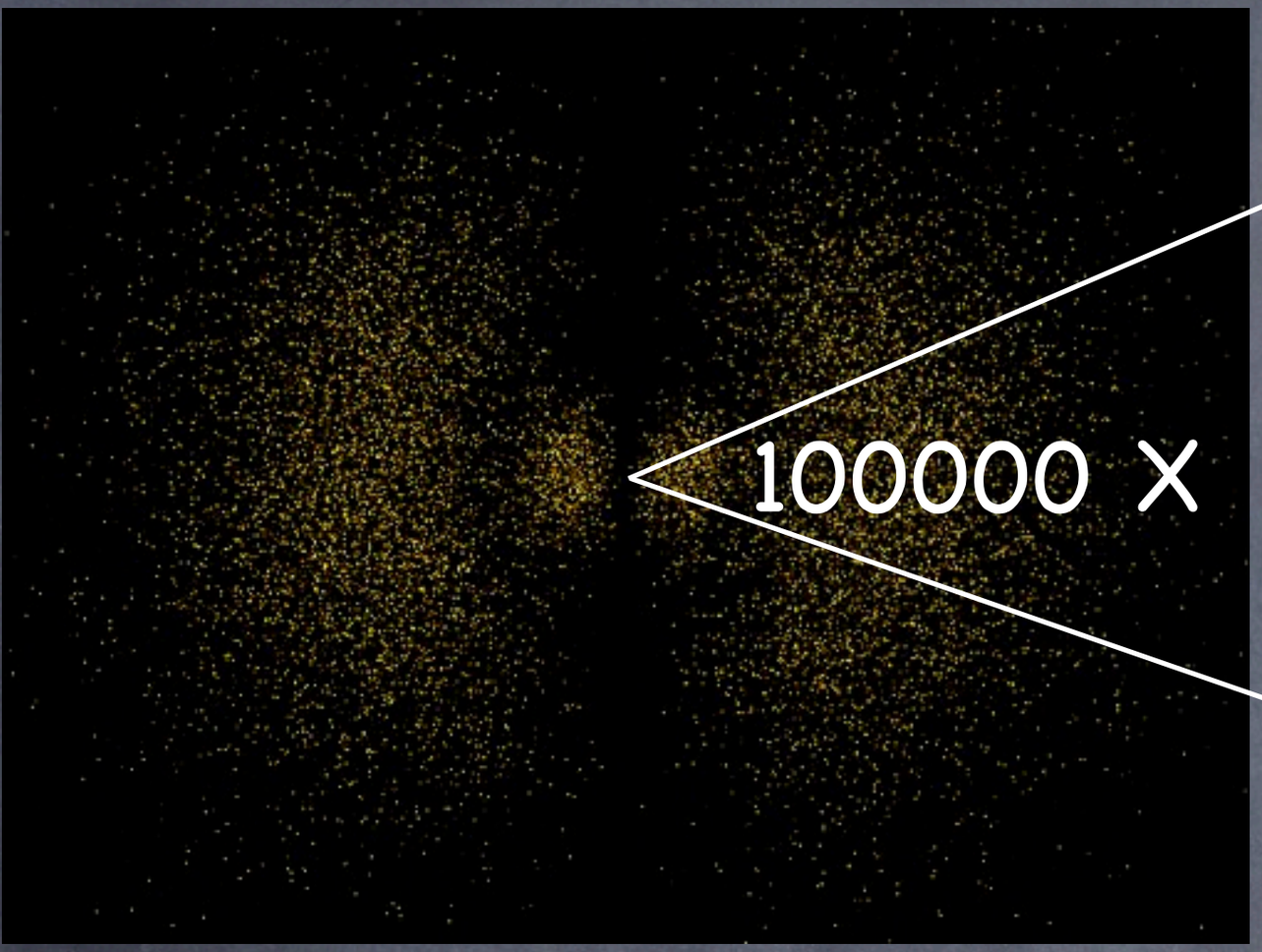


100000 X



Charges



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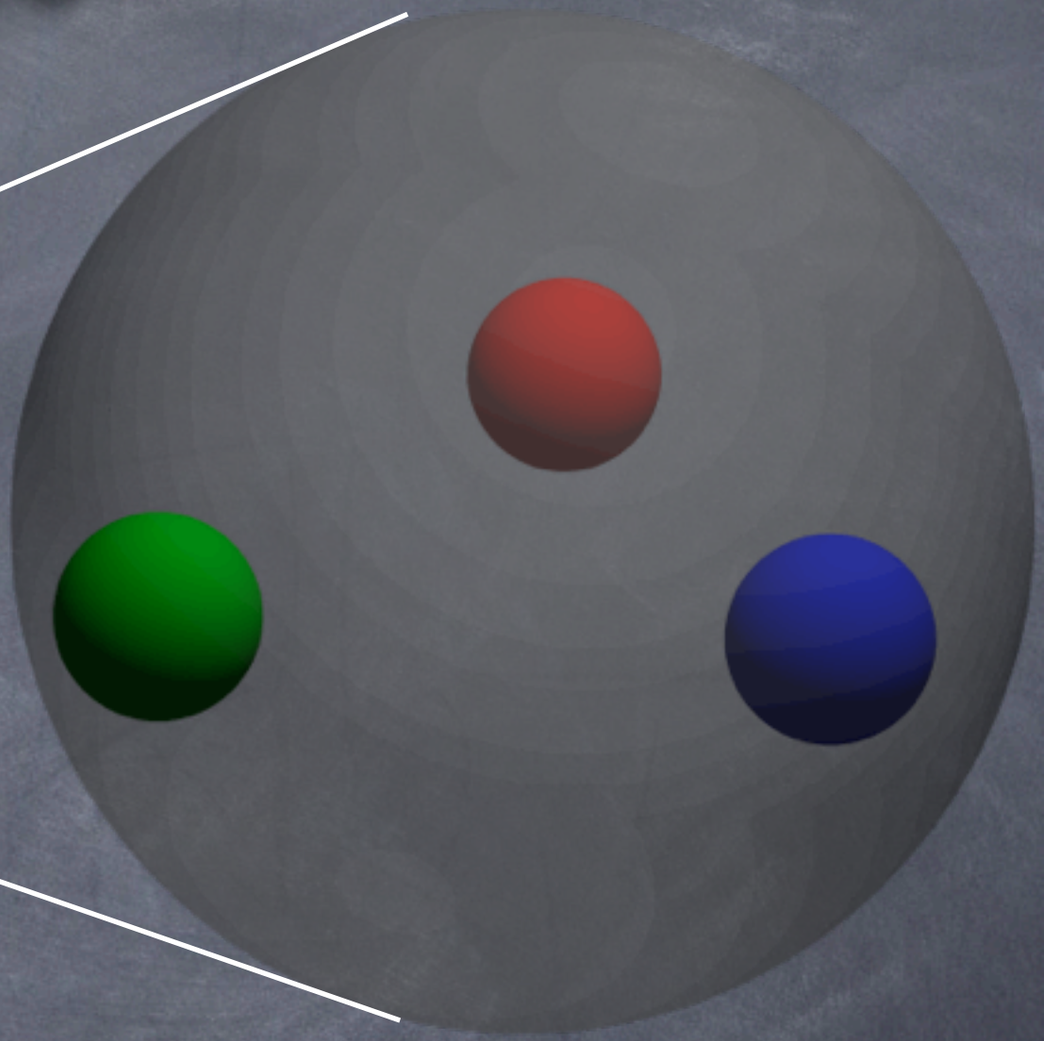
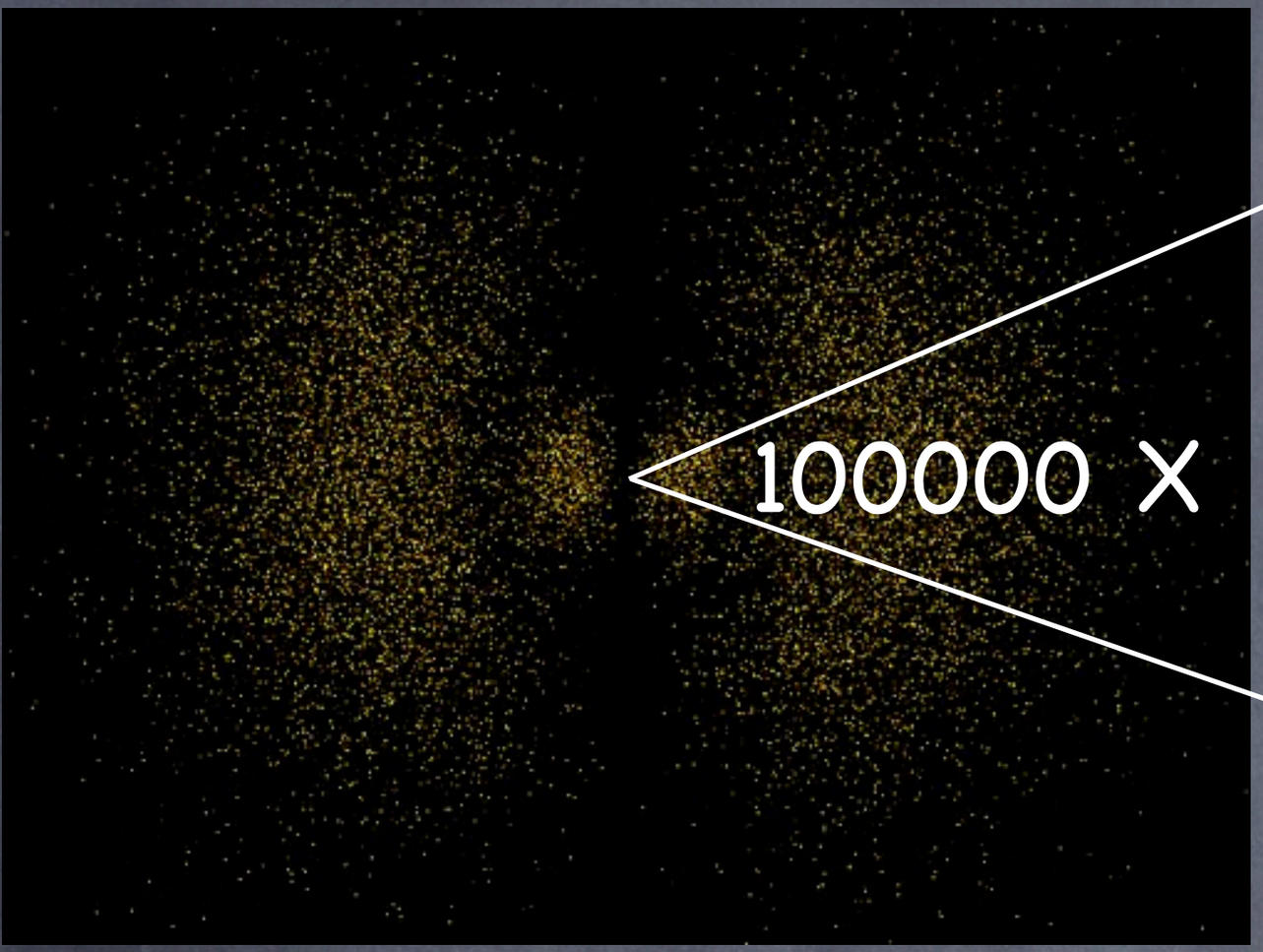
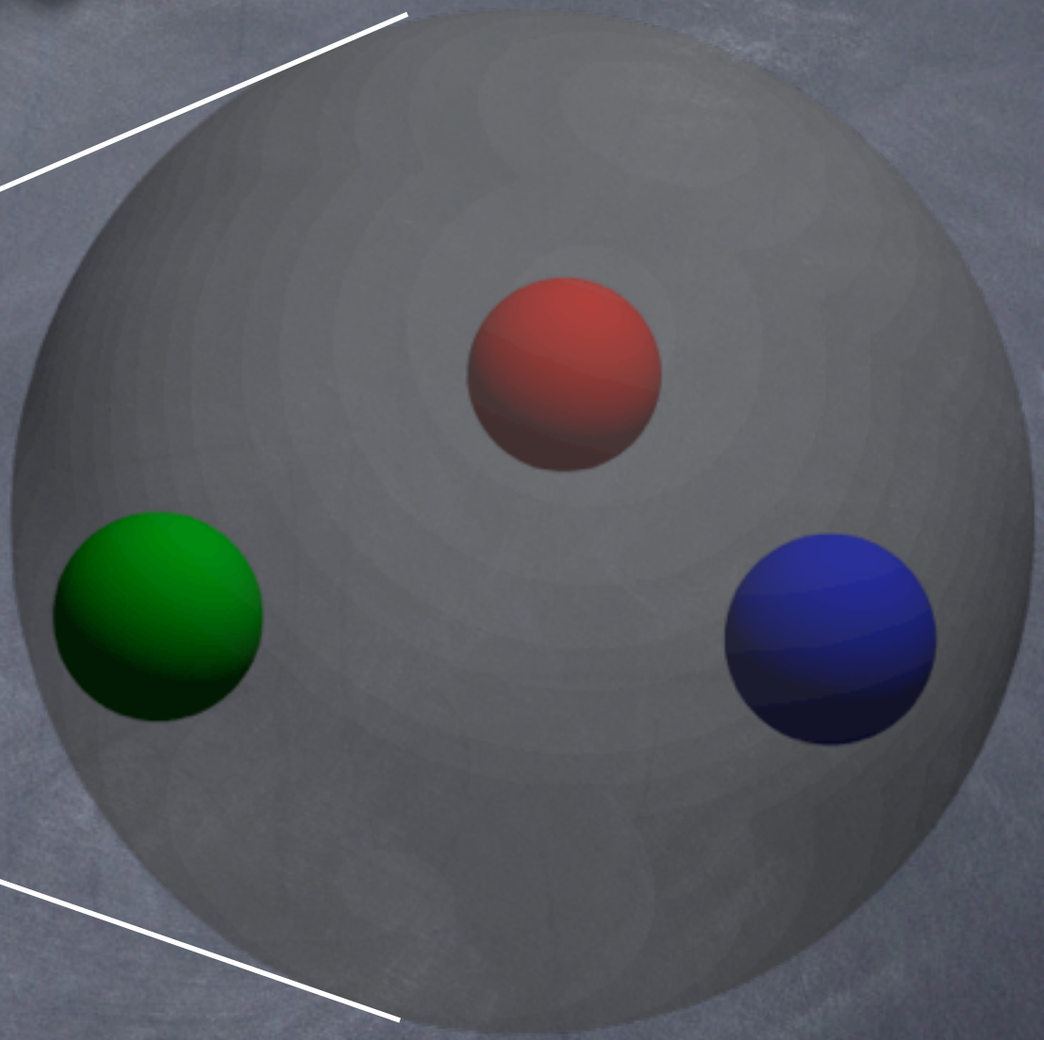


electrons have
electric charge
QED: photon

Charges





electrons have
electric charge
QED: photon

quarks also
have "color" charge
QCD: 8 gluons

Standard Model

FERMIONS

matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2

Flavor	Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	–1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	–1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	–1

Quarks spin = 1/2

Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	2/3
d down	0.006	–1/3
c charm	1.3	2/3
s strange	0.1	–1/3
t top	175	2/3
b bottom	4.3	–1/3

BOSONS

force carriers
spin = 0, 1, 2, ...

Unified Electroweak spin = 1

Name	Mass GeV/c^2	Electric charge
γ photon	0	0
W^-	80.4	–1
W^+	80.4	+1
Z^0	91.187	0

Strong (color) spin = 1

Name	Mass GeV/c^2	Electric charge
g gluon	0	0

Why so many particles?

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Why so many particles?

With such weird masses?