How Our View of the Universe Can Change

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New Ideas in History and Science:

Galileo Conference

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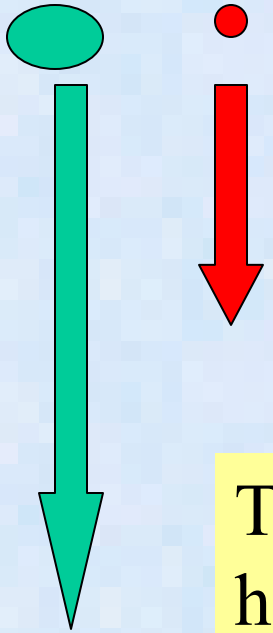
Introduction

- 1609 Galileo was the first person to use a telescope to study stars (including our Sun) and planets → other talks later today
- clearly changed our view of the universe
  - the Earth is not the center even of the Solar System
  - there are many more stars
- Galileo also studied many fundamental physics questions on the nature of motion, forces and mass
- understanding of these basic physics questions also change our view of the universe → this talk will explore a few simple items whose understanding may have profound implications

Galileo and Motion and Gravity

- Galileo and many of his contemporaries developed the concept of motion
  - velocity and acceleration
  - importance of friction
- Galileo used inclined planes
- and (perhaps) the Leaning Tower in Pisa

Speed vs Mass

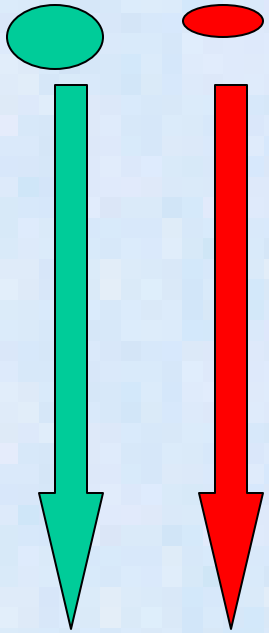


according to Aristotle, heavier objects fall faster then light objects

The heavier (green) ball will hit the ground before the lighter (red) ball

Experiments showed Aristotle was wrong.
"Pure thought" not the best way to do science

Speed vs Mass vs Acceleration



Experiments done by Galileo and others showed that the heavier (green) ball and the lighter (red) ball hit the ground at the same time

Galileo also showed that the gravitational acceleration was a constant

Theories based on experimental observations are best way to do science.

see http://nicadd.niu.edu/~hedin/Galileo.htm for a fake news story and some background on the history

This Talk

- Newton used the experimental results as input to his theory of motion and the force of gravity

- In this spirit, using everyday observations we can look at how mass and forces are understood today and how this may lead to other "changes" in our view of the universe

This Talk

1. Why the difference in particle masses may point to the existence of a MULTIVERSE

2. Why the weakness of gravity may point to the existence of EXTRA DIMENSIONS

Mass

- Most of the mass of ordinary matter is due to the protons and neutrons which make up the nucleus → baryonic matter

Hydrogen

1 proton + 1 electron

mass = 938.8 MeV/c^2

Helium

2 p + 2 neutrons + 2 electrons

mass = 3,728.4 MeV/c^2

$m_p = 1.672 \times 10^{-24} g = 938.3 MeV/c^2$

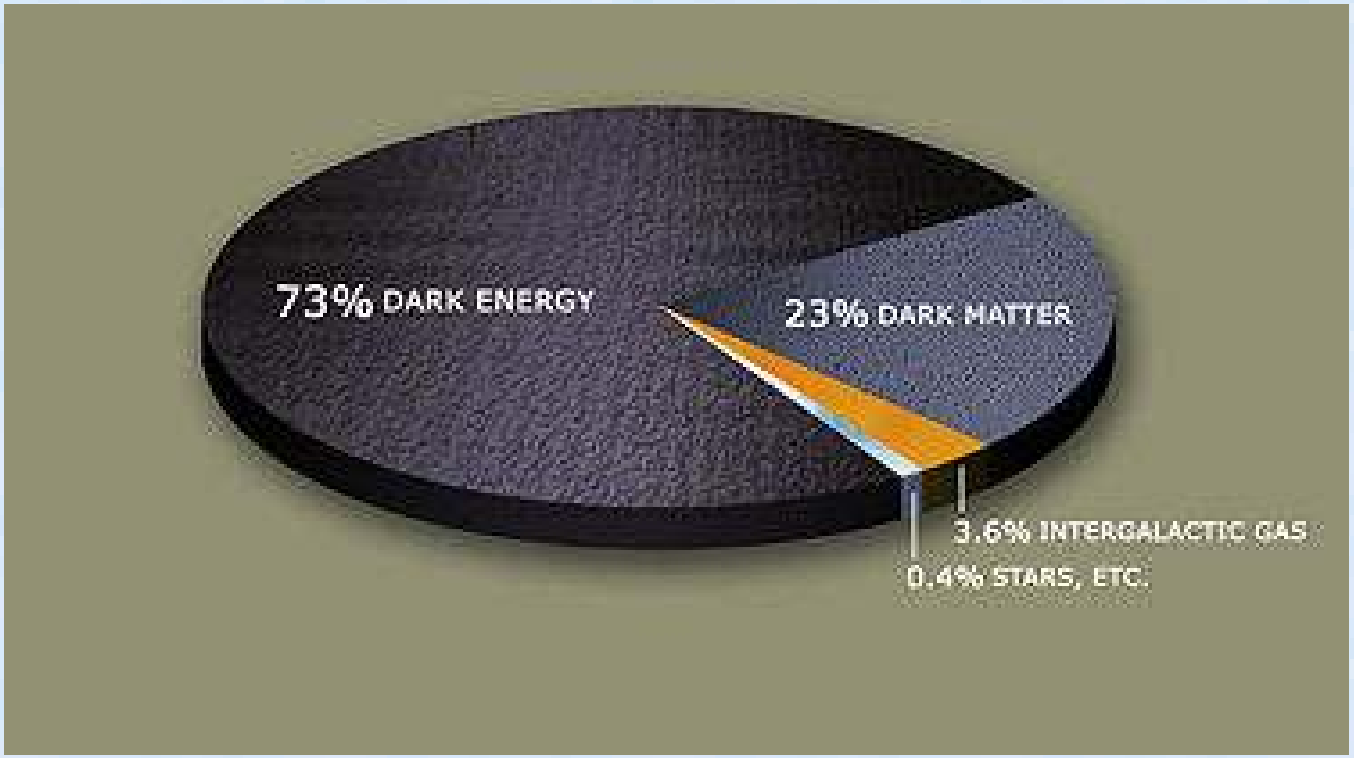
$m_e = 9.1 \times 10^{-28} g = 0.5 MeV/c^2$

$m_p / m_e \approx 2000$

$m_n = 1.675 \times 10^{-24} g = 939.6 MeV/c^2$

Mass + Energy

- In the past 20 years, astrophysicists have determined that ordinary "baryonic" matter makes up only about 4% of the mass/energy of the universe. For today, stick to "easy to understand" normal matter



Neutrons and Protons

- the mass of a neutrons is just a little bit more than a proton's mass → neutrons decay with a lifetime of 15 minutes
- all the protons and neutron were formed in the first minute after the Big Bang. Neutrons either decayed to protons or combined with protons to make Helium. Our Universe is 90% H + 9% He+1%(Carbon+O+…) (with a 7/1 p/n ratio)

$$m_p = 938.3\,MeV/c^2$$
$$m_n = 939.6\,MeV/c^2$$
$$m_e = 0.5\,MeV/c^2$$

$$n \rightarrow p + e^- + \bar{\nu}_e$$

Masses of Neutrons and Protons

- Why are neutrons and protons 2000 times more massive then electrons?
- Why is the neutron heavier than the proton?
- How would our universe look if these masses were different?

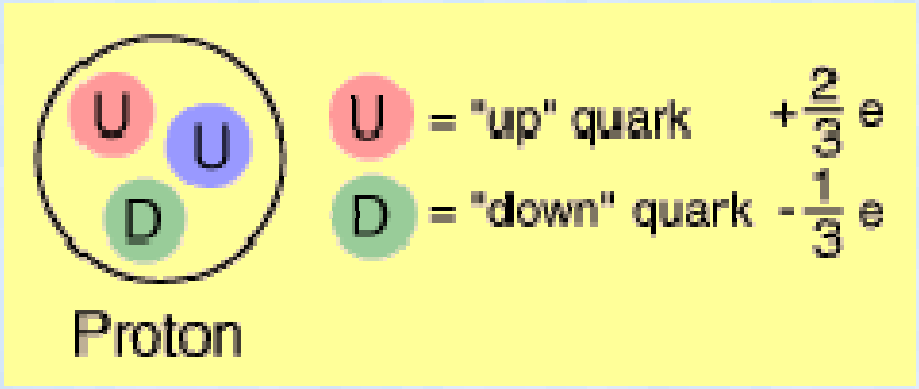
$$m_p = 938.3\,MeV/c^2$$

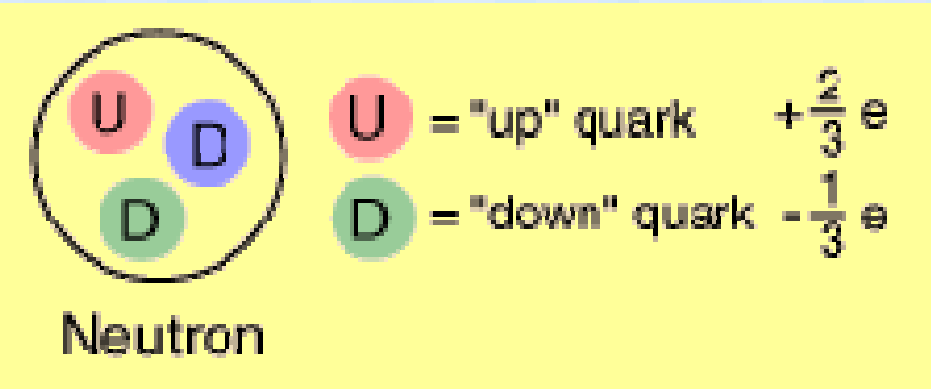
$$m_n = 939.6\,MeV/c^2$$

$$m_e = 0.5\,MeV/c^2$$

Masses of Neutrons and Protons

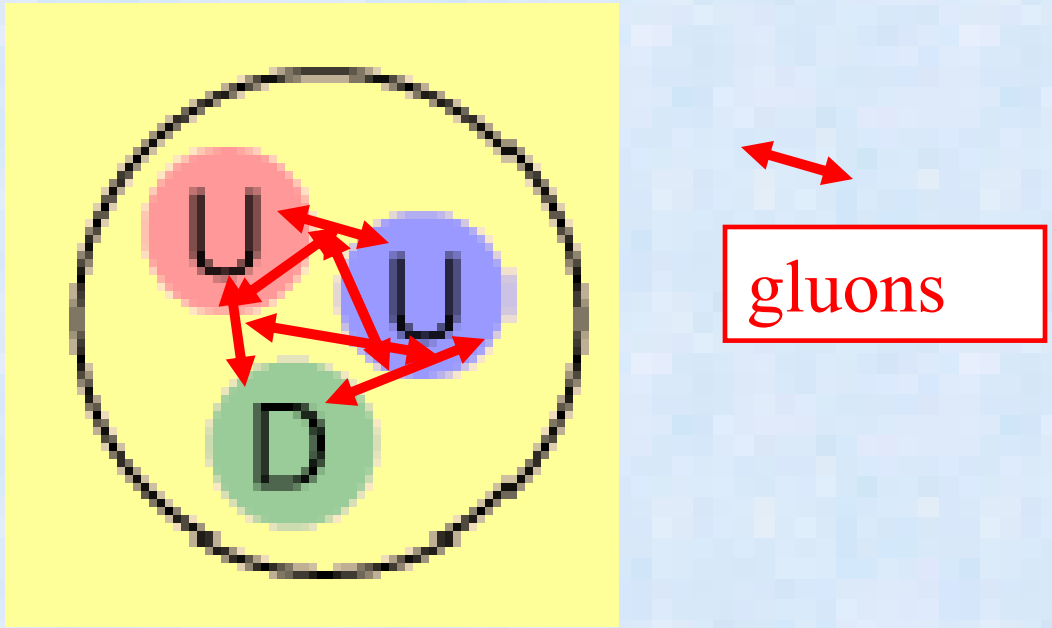
- In the 1960s it was realized the p,n are made from up and down quarks
- bound together by gluons

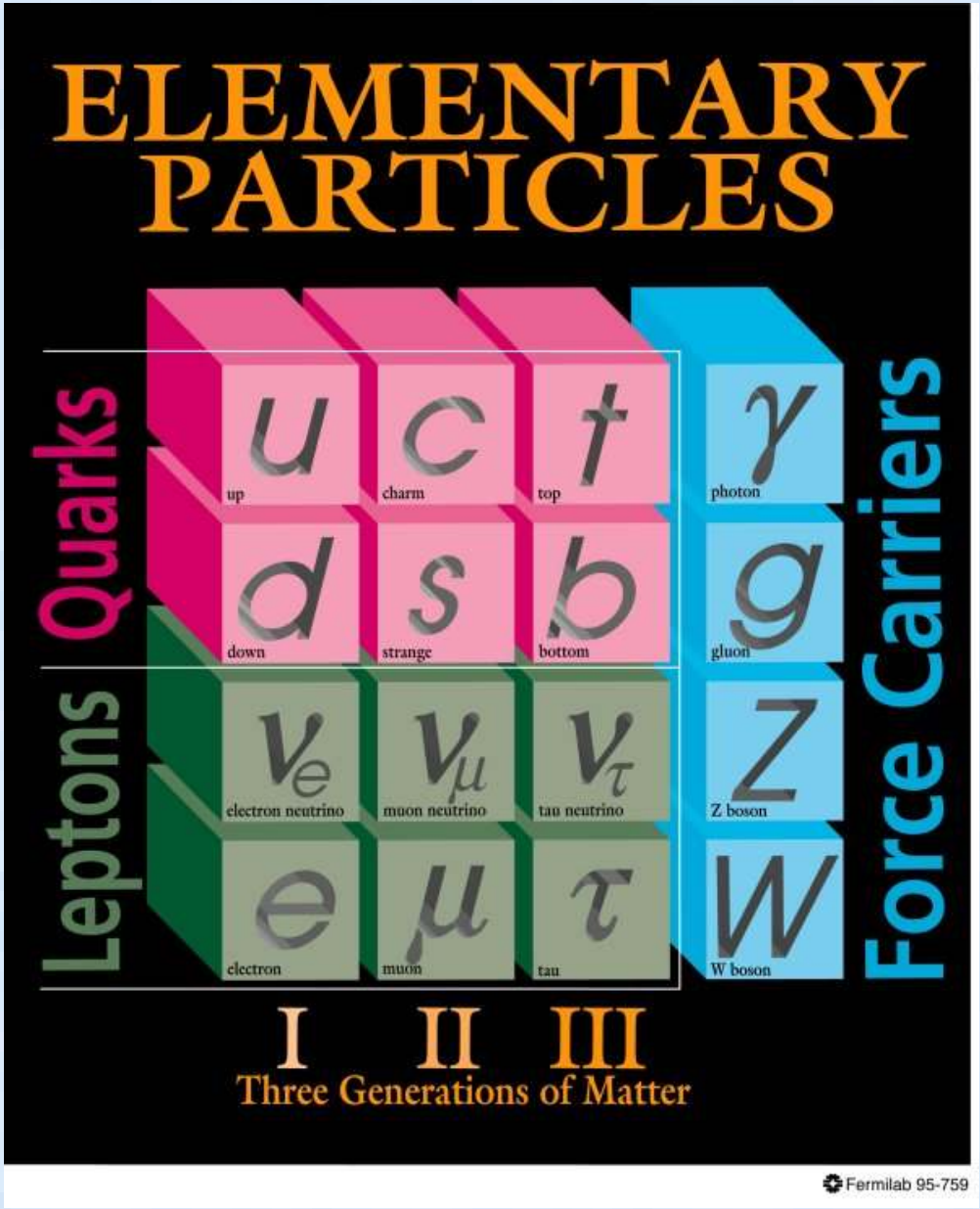




Neutron and Proton Masses

- gluons bind together quarks. Only 3 quark (and quark-antiquark) combinations are stable
- gluons have energy → ~99% of proton mass due to this energy
- about 1% due to "bare" masses of 3 quarks





Also found:

- 6 quarks
- 6 leptons
- 4 force carriers
- + antiparticles → make up known universe

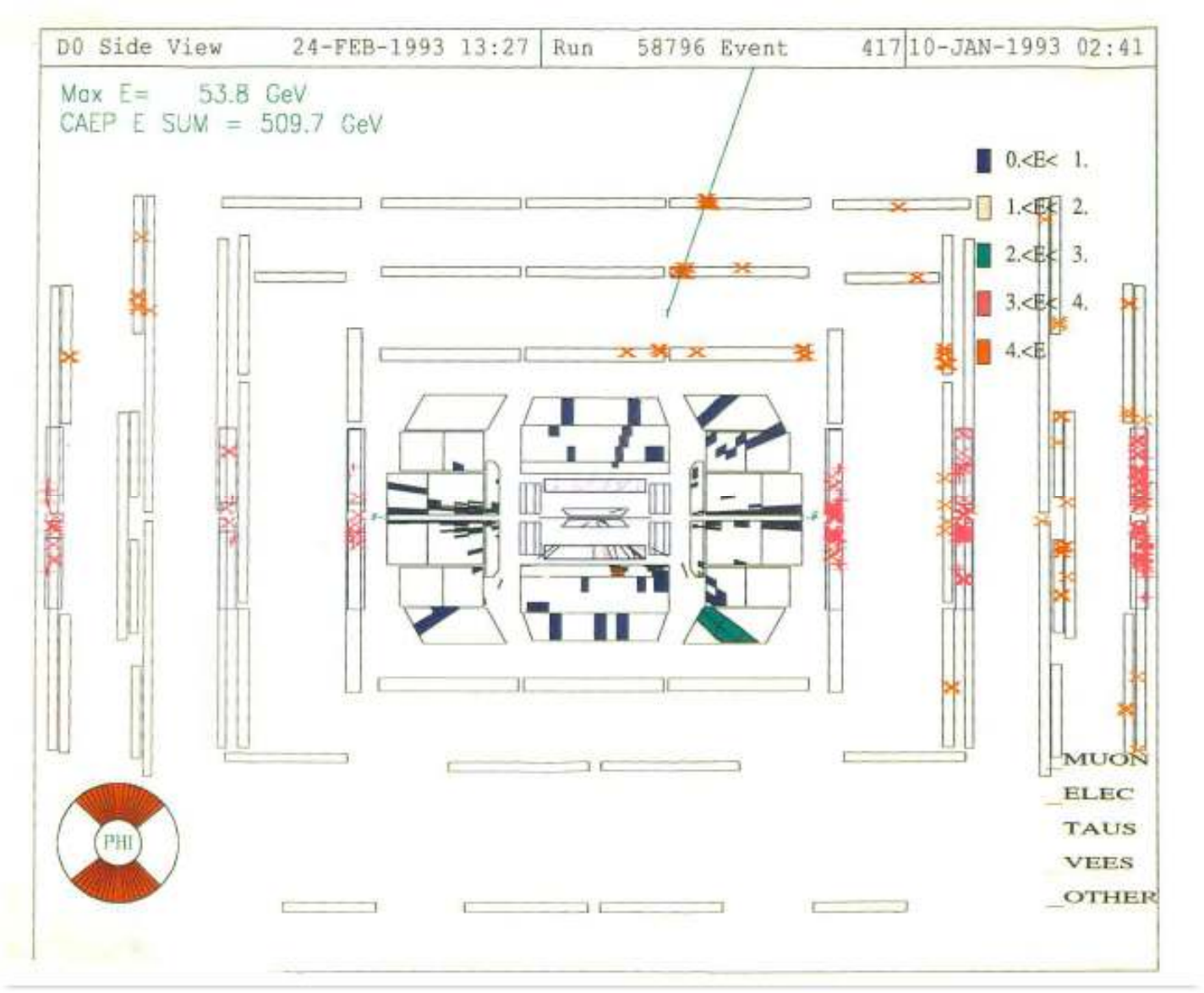
Still searching for what makes up dark matter and energy

When/where discovered

Nobel Prize?

γ	Mostly Europe	1895-1920	Roentgen (sort of)1901
W/Z	Switzerland(CERN)	1983	Rubbia/vanderMeer1984
gluon	Germany (DESY)	1979	NO
electron	Europe	1895-1905	Thomson 1906
muon	Harvard	1937	NO
tau	Stanford (SLAC)	1975	Perl 1995
ν_e	US	1953	Reines/Cowan 1995
ν_μ	NY (BNL)	1962	Schwartz/Lederman/Steinberger 1988
ν_τ	Fermilab	2000	NO
u,d	Stanford	1960s	Friedman/Kendall/Taylor 1990
s	mostly US	1950s	NO
c	SLAC/BNL	1974	Richter/Ting 1976
b	Fermilab	1978	NO (Lederman)
t	Fermilab	1995	NO

Fist top quark ever observed



D0 experiment

Fermilab

1993

Quark Masses – in MeV/c^2

charge 1/3	d	s	b
	6	125	4,200
charge 2/3	u	c	t
	4	1,200	175,000

- first generation lightest
- in second/third charge 2/3 heavier but in first charge 1/3 is heavier ????????

proton and neutron masses vs Quark Masses

- as the neutron is made from up-down-down and the proton from up-up-down quarks
- and the down quark is slightly heavier than the up quark

→ neutron slightly heavier than the proton

Quark Masses

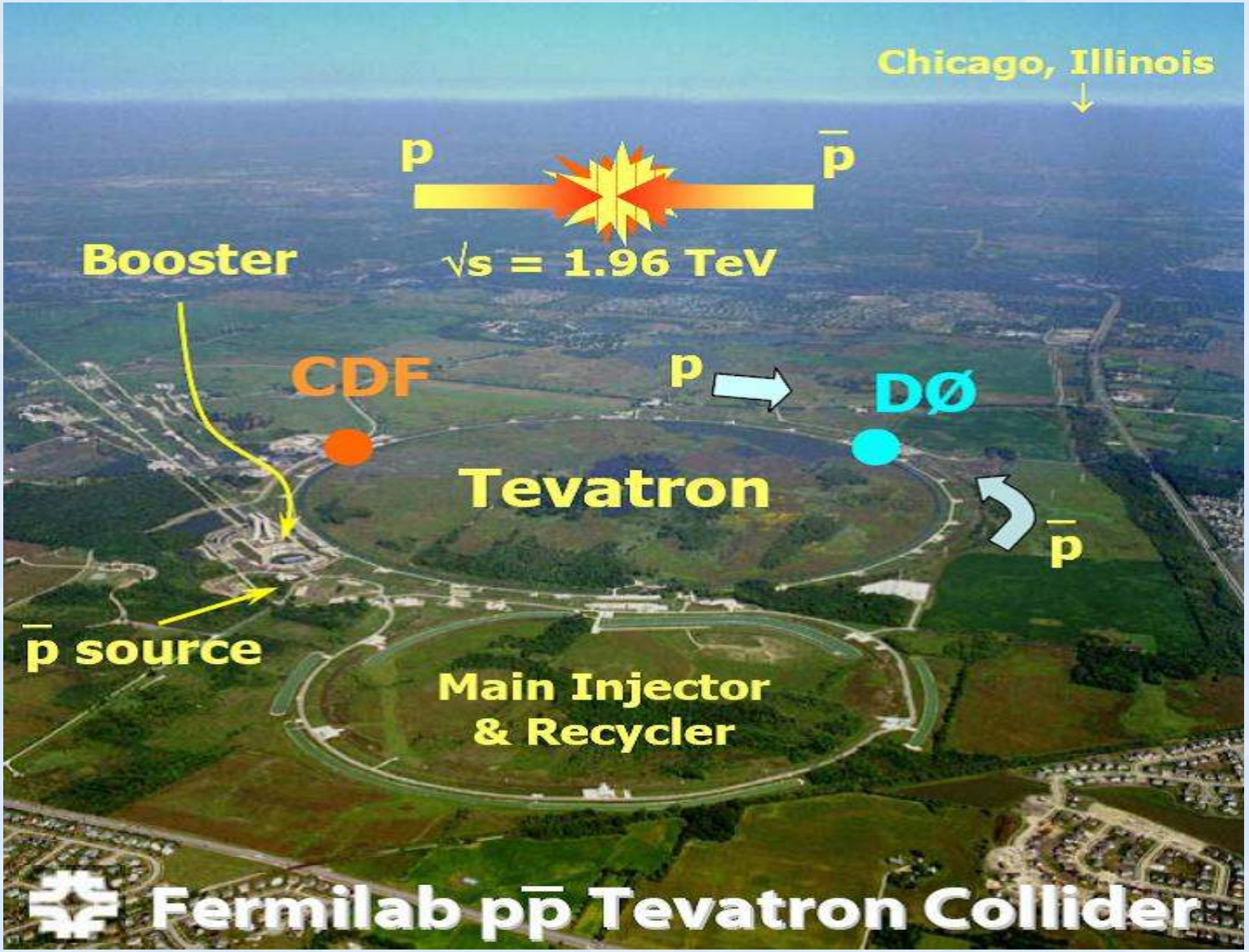
- No understanding of why quarks have different masses

- Due to the mechanism of a yet to be discovered theory?

- Or set by the random conditions at the very beginning of the Universe??

- will finding the Higgs Boson at Fermilab or CERN help figure this out?

Higgs Boson search ongoing at Fermilab



What if??

- quark masses depend on conditions in the early universe
- many different universes exist

→ each forms its own space
→ each has own starting conditions and possibly different physics

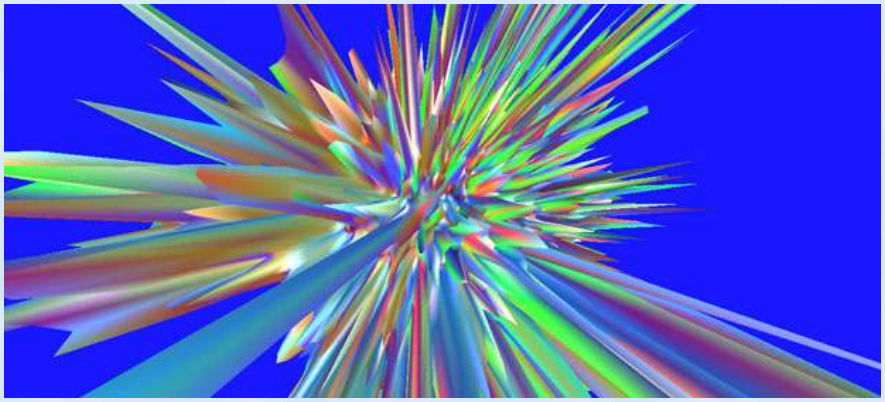
MULTIVERSE

Snowflakes

- each snowflake is unique do to the slight variations in the conditions when they formed

What if Multiverse

- many (infinite??) universes in a multiverse
- not really "next" to each other. "nothingness" separates
- no communication between universes



two artist conceptions – mostly meaningless

What if in different universe 1

- up quark mass greater than down quark mass

→ proton heavier than neutron

- Two possibilities

if $|m_{proton} - m_{neutron}| < m_{electron}$ → both protons and neutrons are stable

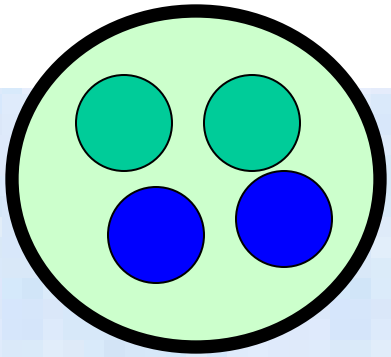
if $m_p - m_n > m_e$ → proton is unstable and decays into neutrons

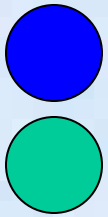
what if in a different universe 2

- proton and neutron are both stable
- most p and n combine into Helium (2p+2n)

→ have Hydrogen but it is rare.
DH guess fraction H/He ~ 1%

Helium



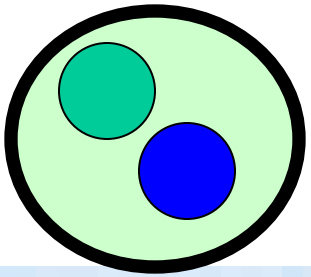


= neutron

= proton

What if in different universe 3

- proton is unstable and decays to neutrons
- still have stable heavy Hydrogen (Deuterium pn nucleus) but is very rare. DH guess D/He~.0005
- in early universe, He forms and then extra neutrons easily attach to He and then decay making Li, Be, B, C
- some free neutrons remain



Deuterium

What if in different universe 4

- in either case with stable neutron

- very small amount of Hydrogen

→ different type of Stars and planets but with little water and Hydrogen : needed for biochemistry (proton bonds, DNA, etc)

→ no life

Anthropic Principle and Multiverse

• intelligent life in our universe depends on having the physics "just right". Why?

→ anthropic principle holds that with an infinite number of universes, there is a non-zero probability that one is "just right"

→ That's ours where the masses of the up quark, down quark and the electron, and the strengths of the forces are "just right"

Goldilocks and the Three Bears

This universe has the matter-antimatter variation too small

This universe has the proton mass too large

This universe has the strong nuclear force too strong

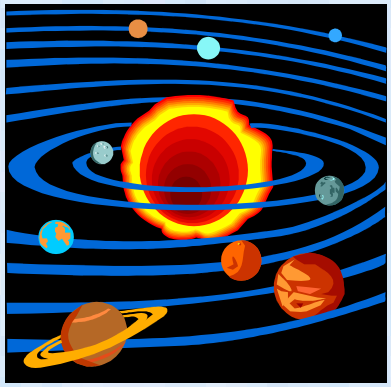
This universe has the electron mass too small

This universe has the W/Z mass too small

Our Universe is just right

Gravity and Extra Dimensions

- the first force to be understood was gravity
- Newton used results from Galileo, Kepler and others on motion on Earth's surface and orbits of the planets
- gave simple relationship for gravitational force between 2 objects separated by distance R



$$F = G\frac{mass_1 mass_2}{R^2}$$

Four Forces

- other forces: electromagnetism, strong nuclear, and weak nuclear

- understood in 20th century using quantum mechanics

- all have roughly the same strength at Fermilab energies

- all much stronger than gravity

Gravity vs Electric Force

- electric force dominates daily life

→ all senses

→ all chemistry

- easy to observe much stronger then gravity

→ floor prevents us from falling to Earth's center

→ can stick a balloon to the wall

→ levitating magnets

Gravity vs Electric Force

static electricity demo

easy source of cat fur

Gravity vs Electric Force

- electric and gravitational forces →same form
- compare strengths for electron and proton in Hydrogen

$$F_{gravity} = G\frac{mass_1 mass_2}{R^2}$$

$$F_{electric} = E\frac{ch\arg e_1 ch\arg e_2}{R^2}$$

$$\frac{F_{gravity}}{F_{electric}}(Hydrogen) = 10^{-39}$$

$$= 0.00000000000000000000000000000000000001$$

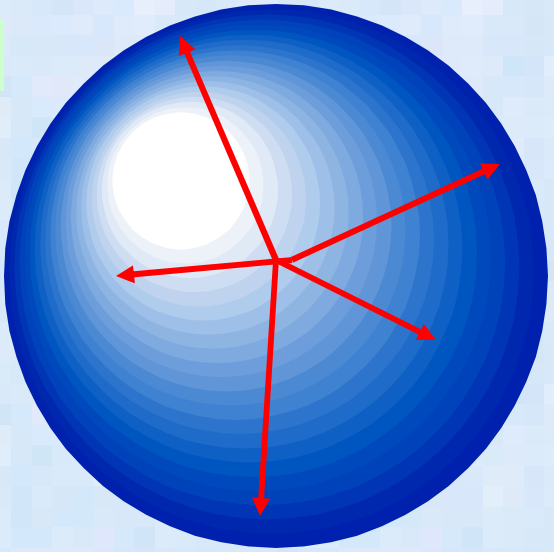
Gravity + Electric Force:Geometry

- the $1/R^2$ is due to the area of a surface of the sphere
- the force carriers (photon or graviton) are spread out over this surface

$$F_{gravity} = G\frac{mass_1 mass_2}{R^2}$$

$$F_{electric} = E\frac{ch\arg e_1 ch\arg e_2}{R^2}$$

$$Area = 4\pi R^2$$

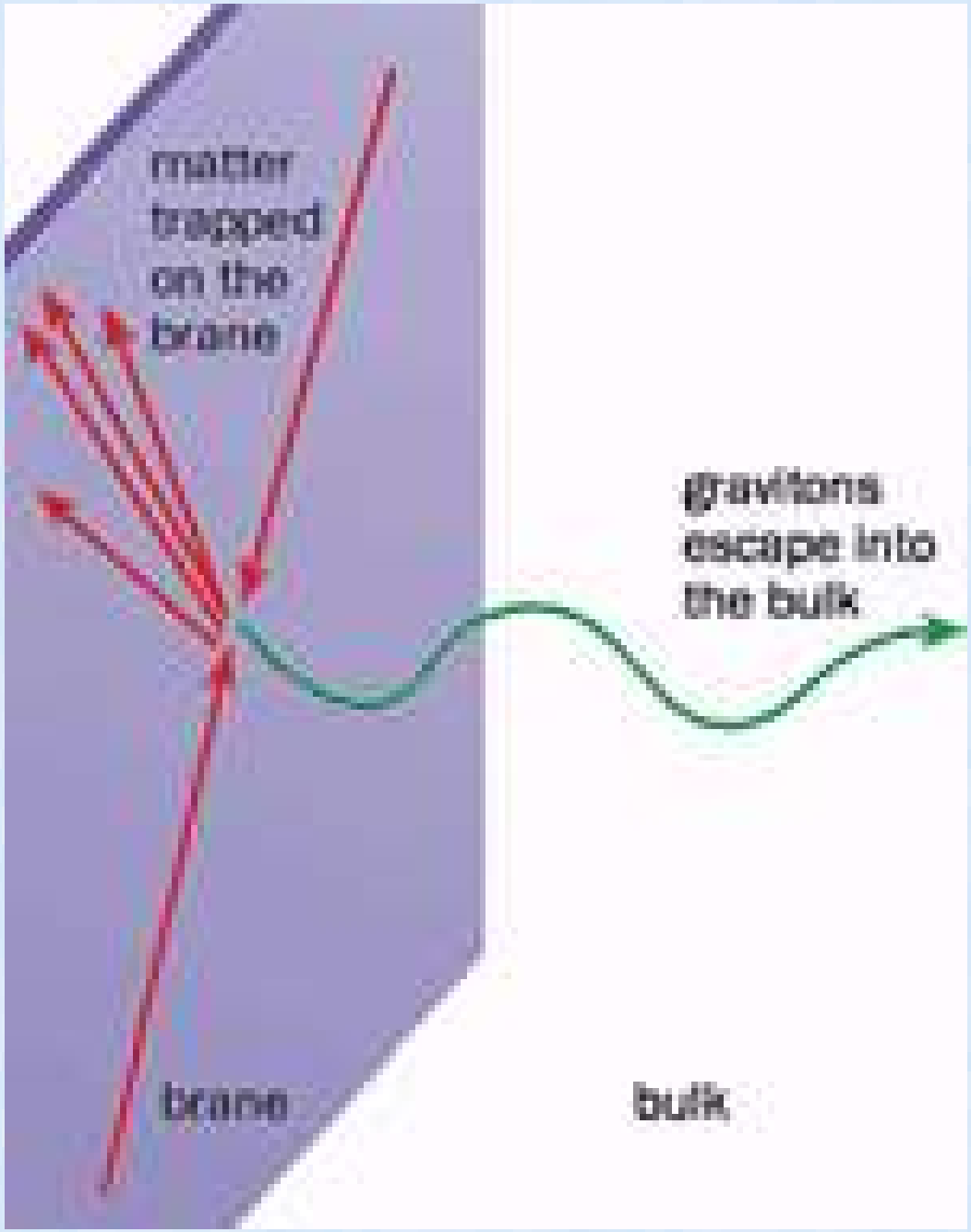


What if – Extra Dimensions

- assume that the force carrier for the electric force (photon) is confined to "normal" 3D space
- but there exists extra dimensions that the force carrier for gravity (graviton) can exist in
- gravity then spreads itself out over more dimensions then the electric force → appears weaker in the normal 3D space

brane = "normal" 3D space

bulk = extra dimensions

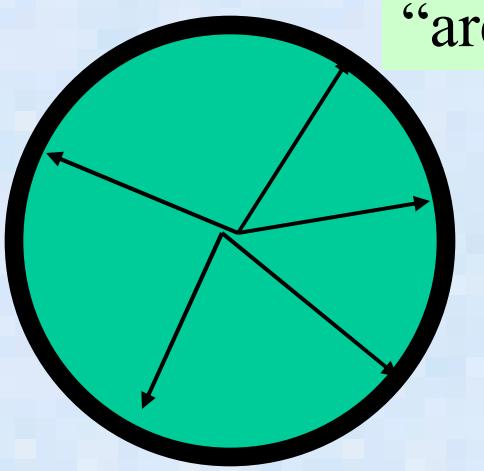


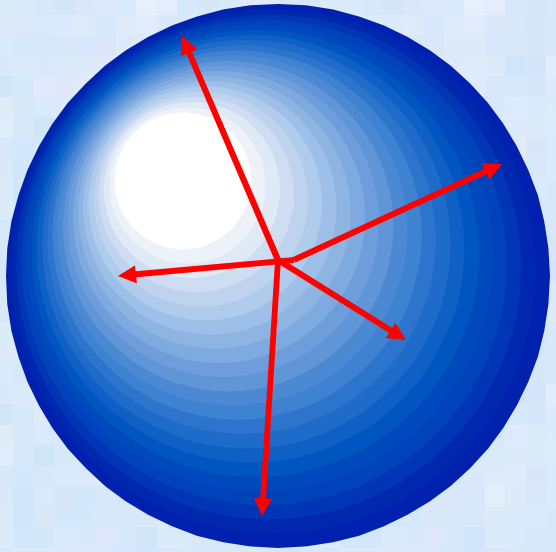
Extra Dimensions -- Geometry

- normal 3D space → $1/R^2$
- 2D space → $1/R$
- 3 extra dimensions → $1/R^5$

3D space
area=πR^2

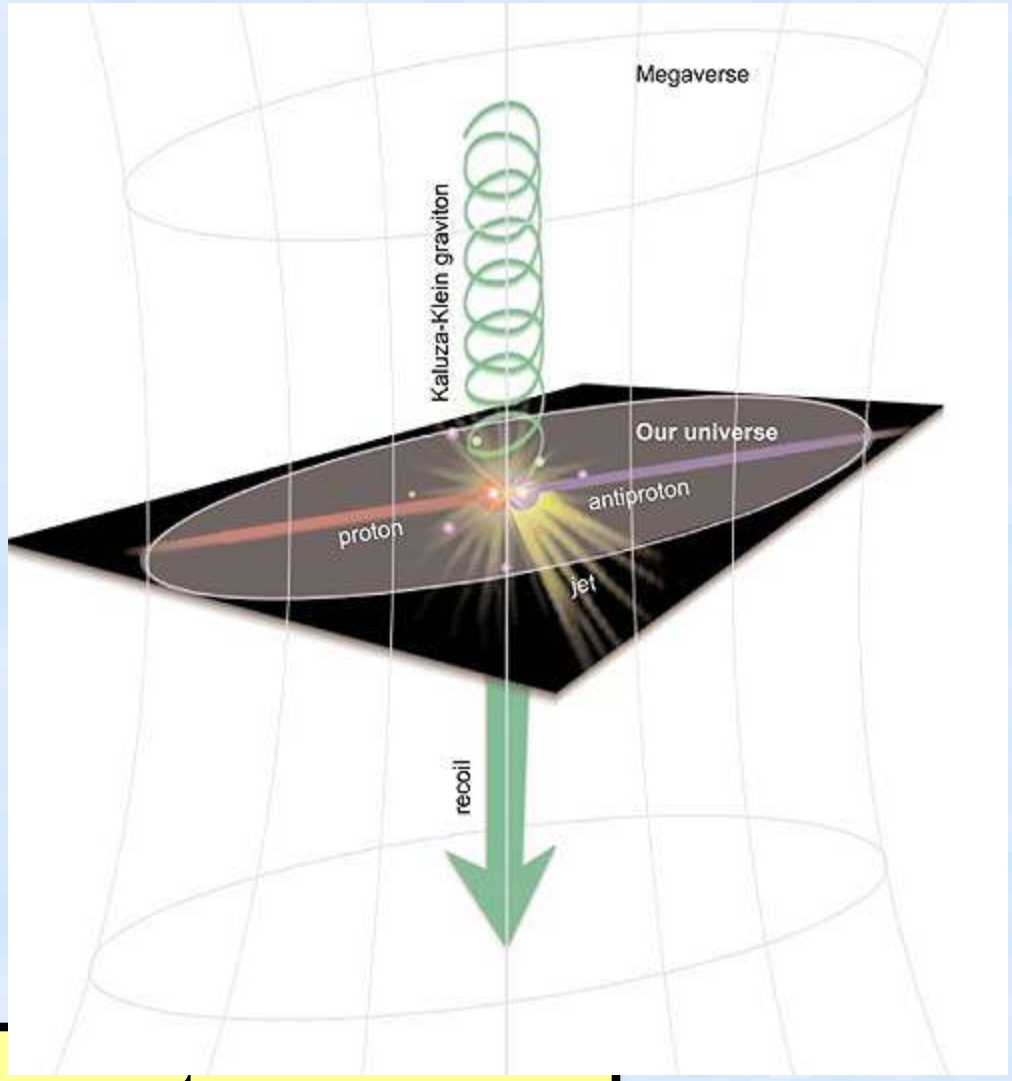
2D space
"area"=$2\pi R$





brane = our universe = "normal" 3D space

Megaverse = 3D plus extra dimensions



can look for interactions at Fermilab+CERN which have particles which go into extra dimensions

Conclusions

- even after 400 years, the origin of some very basic properties of the Universe - particle masses and the strength of forces - are not understood

- Both the existence of other universes and of extra dimensions in our own universe have been proposed

- experiments are looking for any evidence which can support (or refute) these theories

Conclusions

- It would be interesting to have Galileo's view on MULTIVERSES and MEGAVERSES and other new theories and experiments
- He would undoubtedly be fascinated with expanding our view of the Universe into these new realms

web location

nicadd.niu.edu/~hedin/galileotalk.ppt

nicadd.niu.edu/~hedin/galileotalk.pdf