Physics 100 - November 28, 2007

- Presentations
  - Dec. 3 — GPS
  - Dec. 5 — Nucl. Terrorism; Asteroids
  - Dec. 10 — History; CMB
  - Dec. 12 — Music; Nucl. Bombs
- check out additional nonrequired reading on cosmology on class website

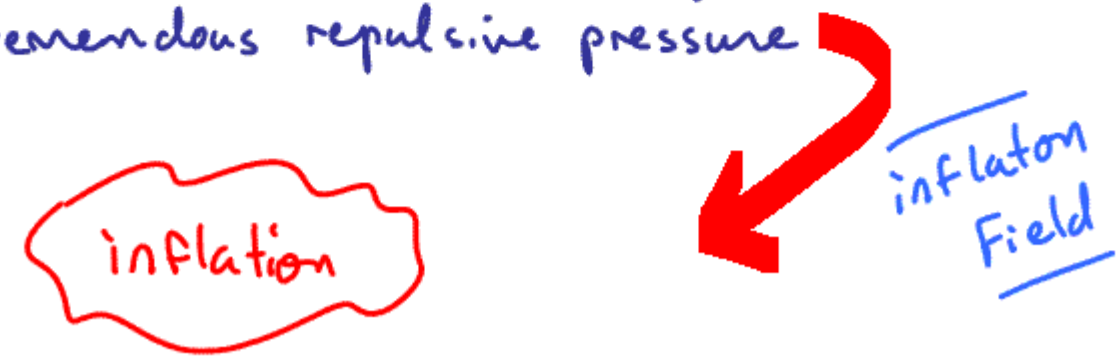
This is your life ... starting at the very beginning

- In the beginning there was ...

- Space-time foam
  - NOT empty space
  - quantum fluctuations
  - Very small $\sim 10^{-33}$ cm possibly

what was there and what exactly caused inflation NOT established yet... models exist

- Fluctuation occurs w/ property that include
  - Tremendous repulsive pressure



- AT $\sim 10^{-43}$ s $\rightarrow 10^{-35}$ s exponential expansion

- How big did inflation make universe by 10^{-35} s ?

Much bigger than observable Universe

at the time

$(10^{-35}\,s)(3\times10^{8}\,m/s)$

or

Bigger than now

Maybe factor of $10^{10^{12}}$

- What was curved ⟶ Now flat

Geometry of Universe flat

- What was small ⟶ Now big

quantum fluctuations become large

density/energy fluctuations

ACTS as nucleus for large-scale structure formation

- As "inflaton field" properties change during inflation, inflation ends

- Energy Driving inflation Dumped into matter and radiation in early universe

- 10^{-35} - 10^{-5} sec

  universe is primordial soup of quark-gluon plasma

  Subatomic particles quarks, Z, W, γ, gluons ...

- 10^{-5} sec quarks bound into Baryons ⟶ Protons, neutrons Mesons

- $t = 3$ minutes — light nuclei form

  Big Bang Nucleosynthesis

- $t = 400{,}000$ years — neutral atoms form

  Universe becomes TRANSPARENT

  light we see from this time called

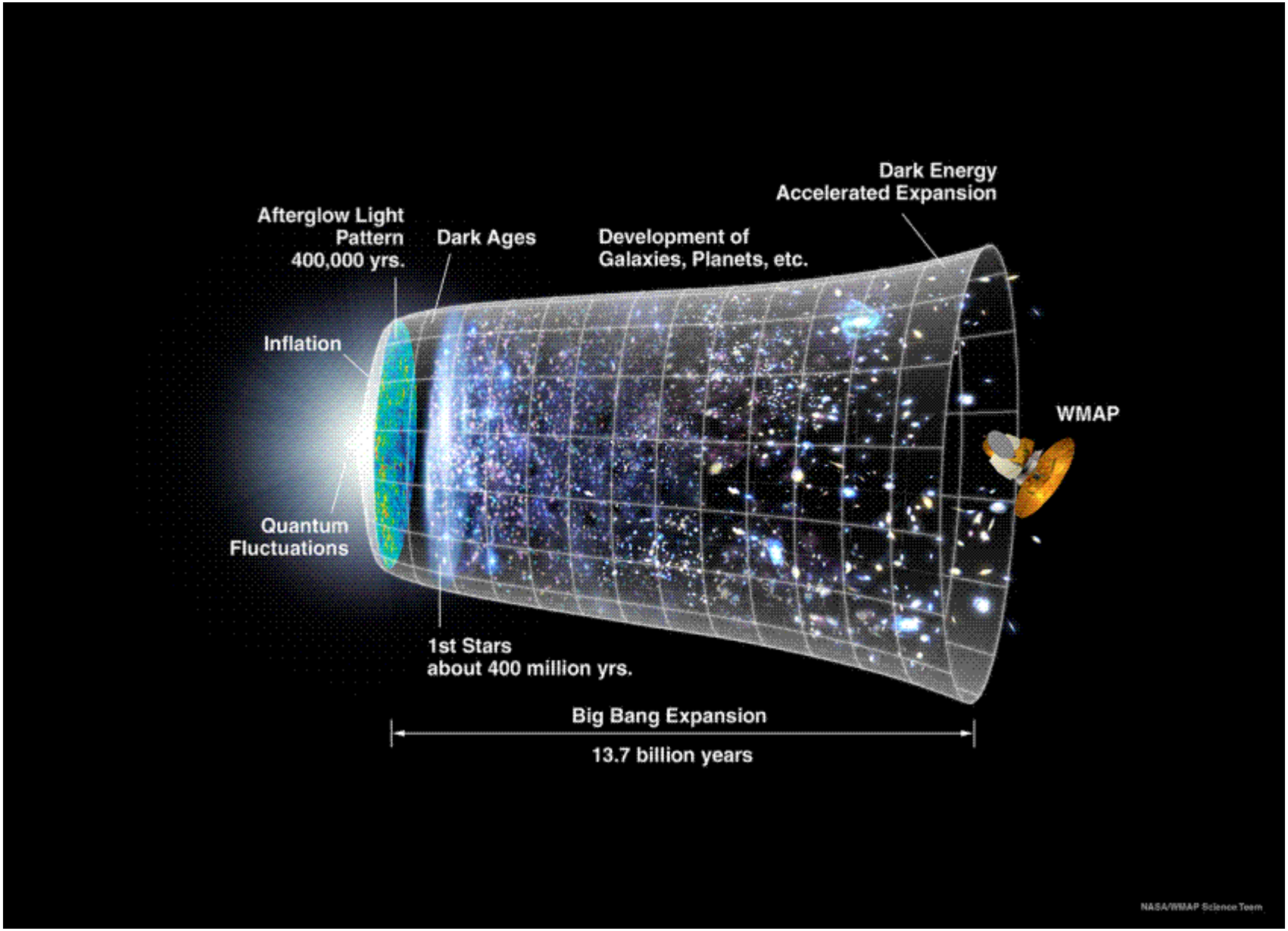
  Cosmic Microwave Background

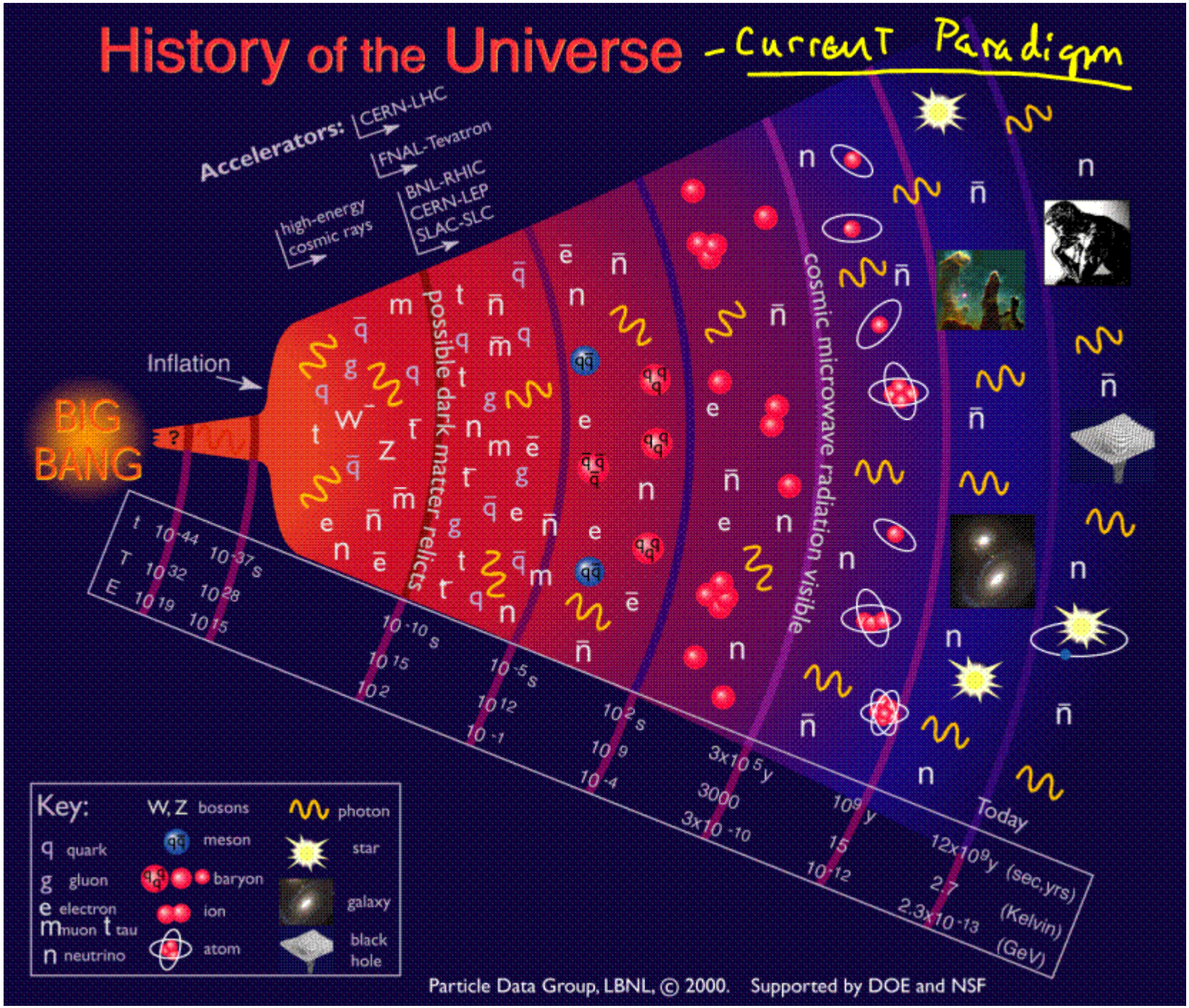
- $t = 400$ Million years — First STARS

- $t = 13.7$ billion years — ~~Buffalo wins Superbowl~~

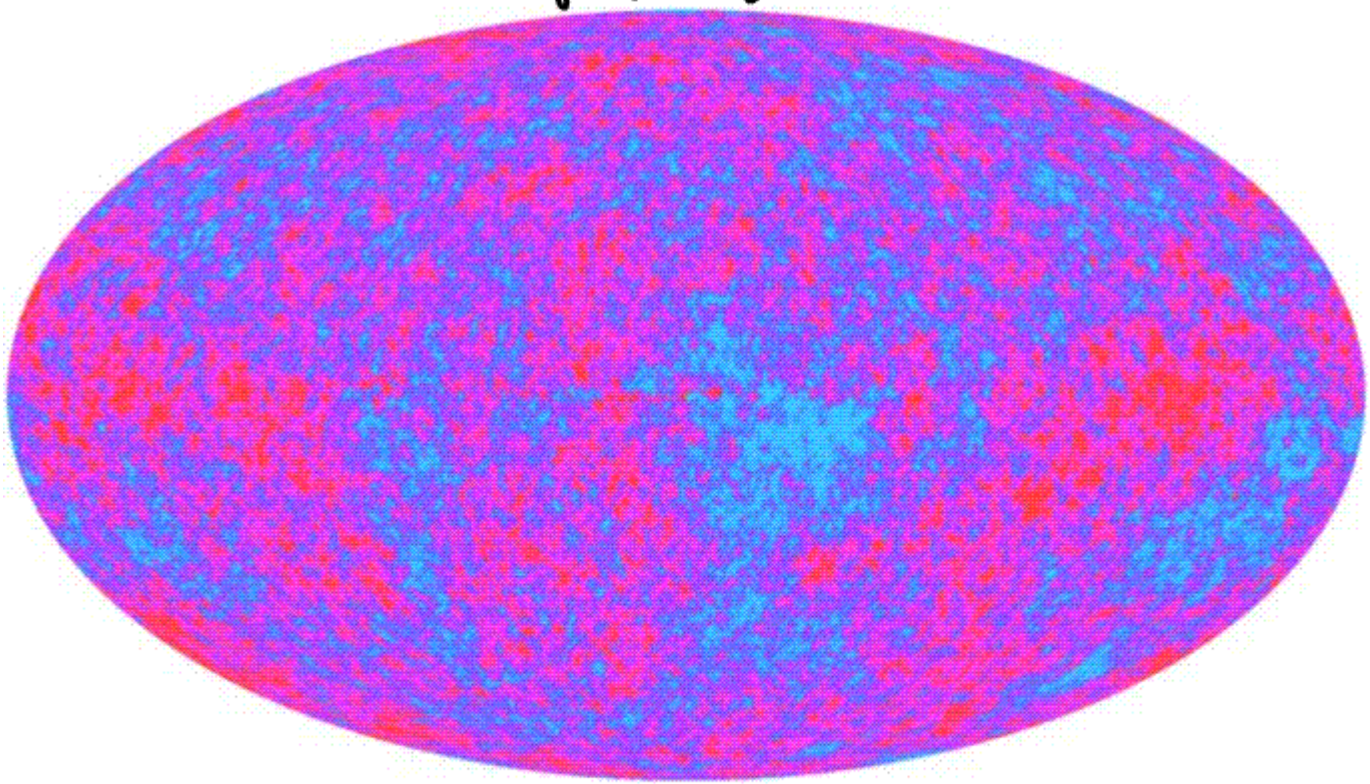
  Now

- Expansion is accelerating


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years
NASA/WMAP Science Team

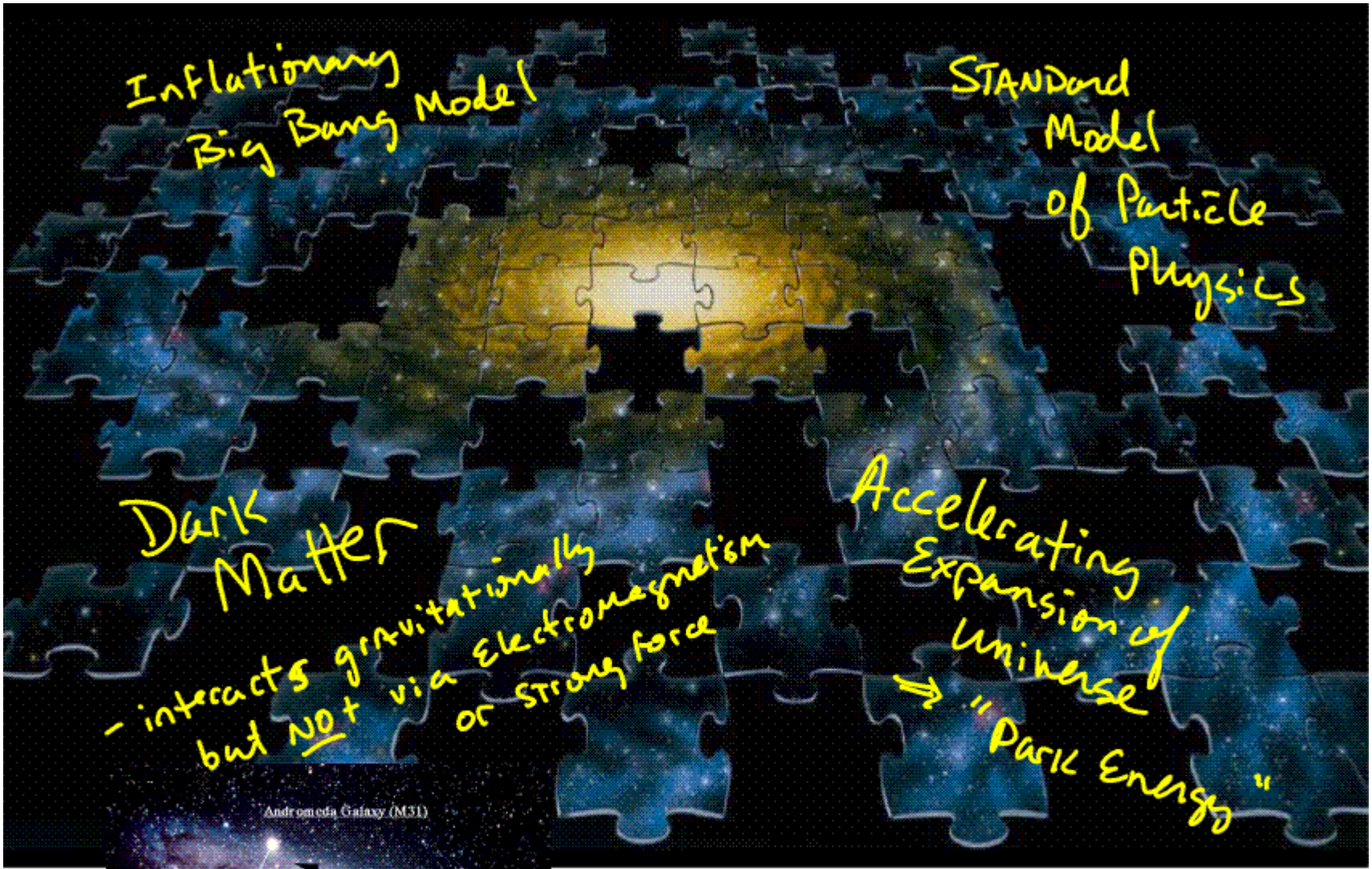

History of the Universe - Current Paradigm
Accelerators:
CERN-LHC
FNAL-Tevatron
BNL-RHIC
CERN-LEP
SLAC-SLC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
Today
t 10-44 10-37 s
T 1032 1028
E 1019 1015
10-10 s
10 15
10 2
10-5 s
10 12
10 -1
102 s
10 9
10 -4
3x10 5 y
3000
3x10 -10
109 y
15
10-12
12x109 y (sec,yrs)
2.7 (Kelvin)
2.3x10 -13 (GeV)
Key:
q quark
g gluon
e electron
m muon t tau
n neutrino
W, Z bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole
Particle Data Group, LBNL, © 2000. Supported by DOE and NSF

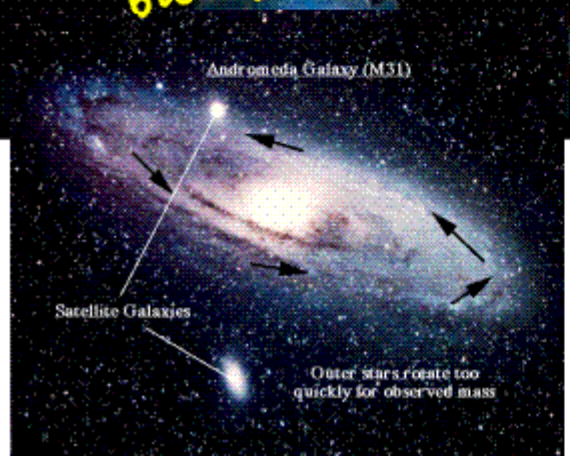
Map of sky unrolled



WMAP "picture" of universe at $t = 400{,}000$ yrs

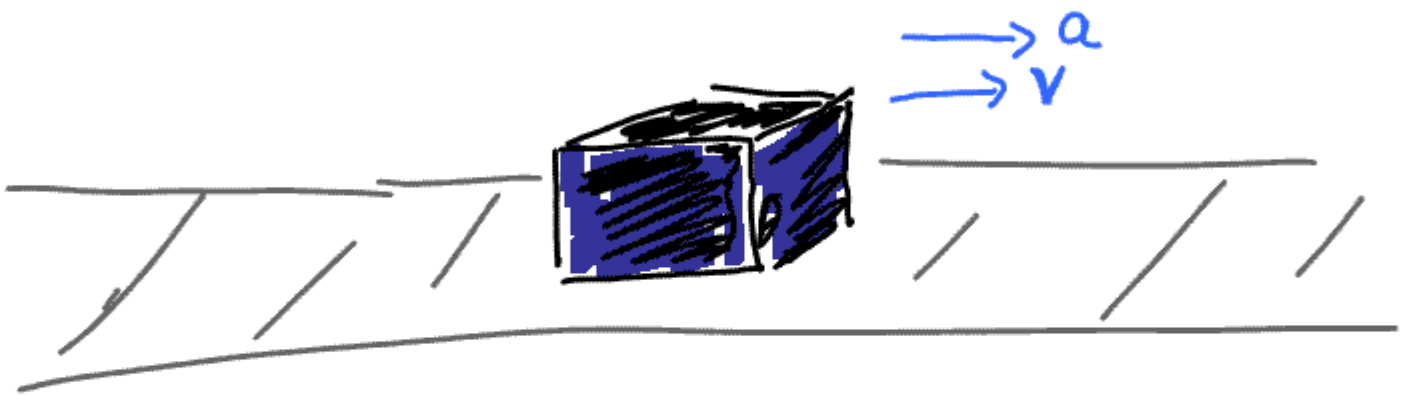
Temperature map of Cosmic Microwave Background





dark energy – sort of an inflation-like pressure (slower) on space expansion – Exact source unknown as yet.

Dark Energy Analogy

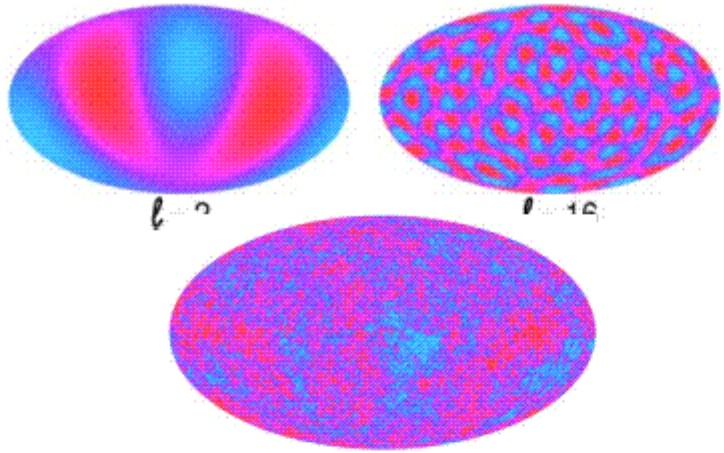


See box accelerating down sidewalk

We Know there is a Force + Source of Energy.

(F)(dist) = work = Energy

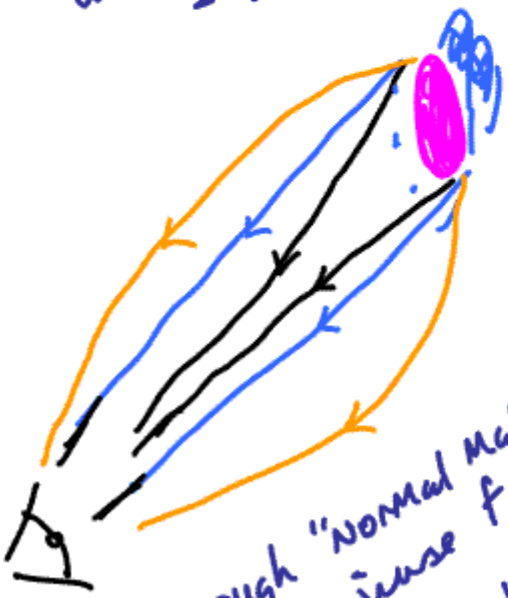
We have ideas ... but we don't know for sure the nature of the force / energy



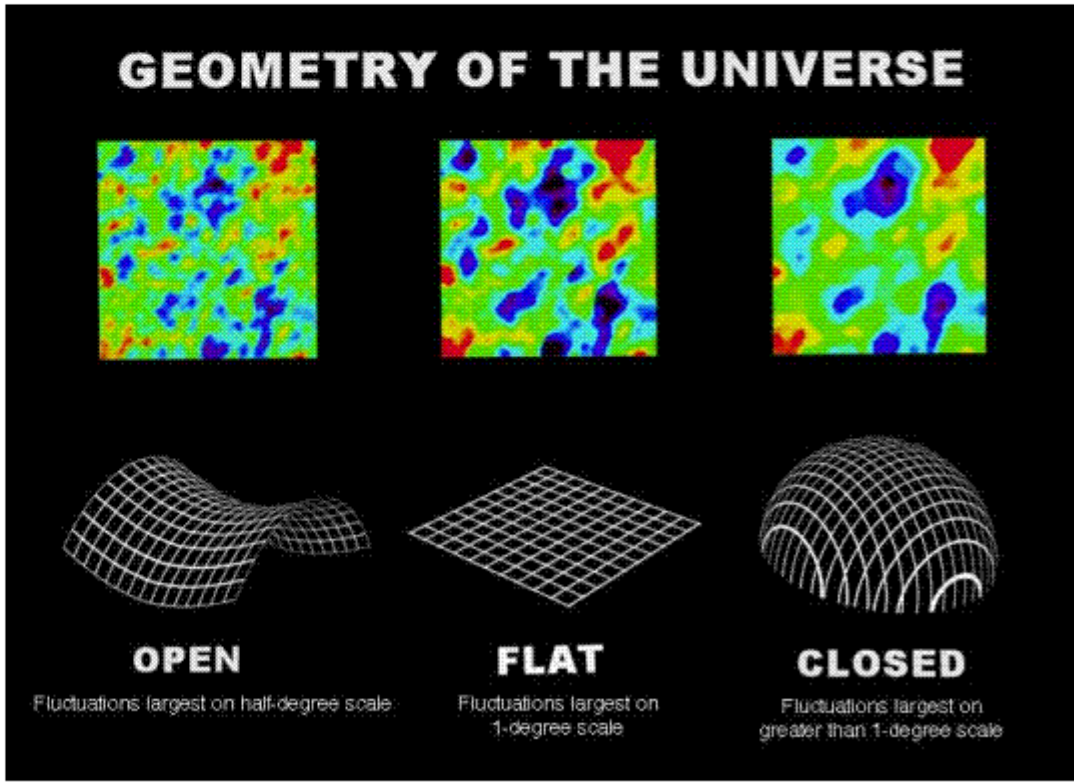
Sizes of
Temp fluctuations in CMB
Sensitive to geometry
of Space-time

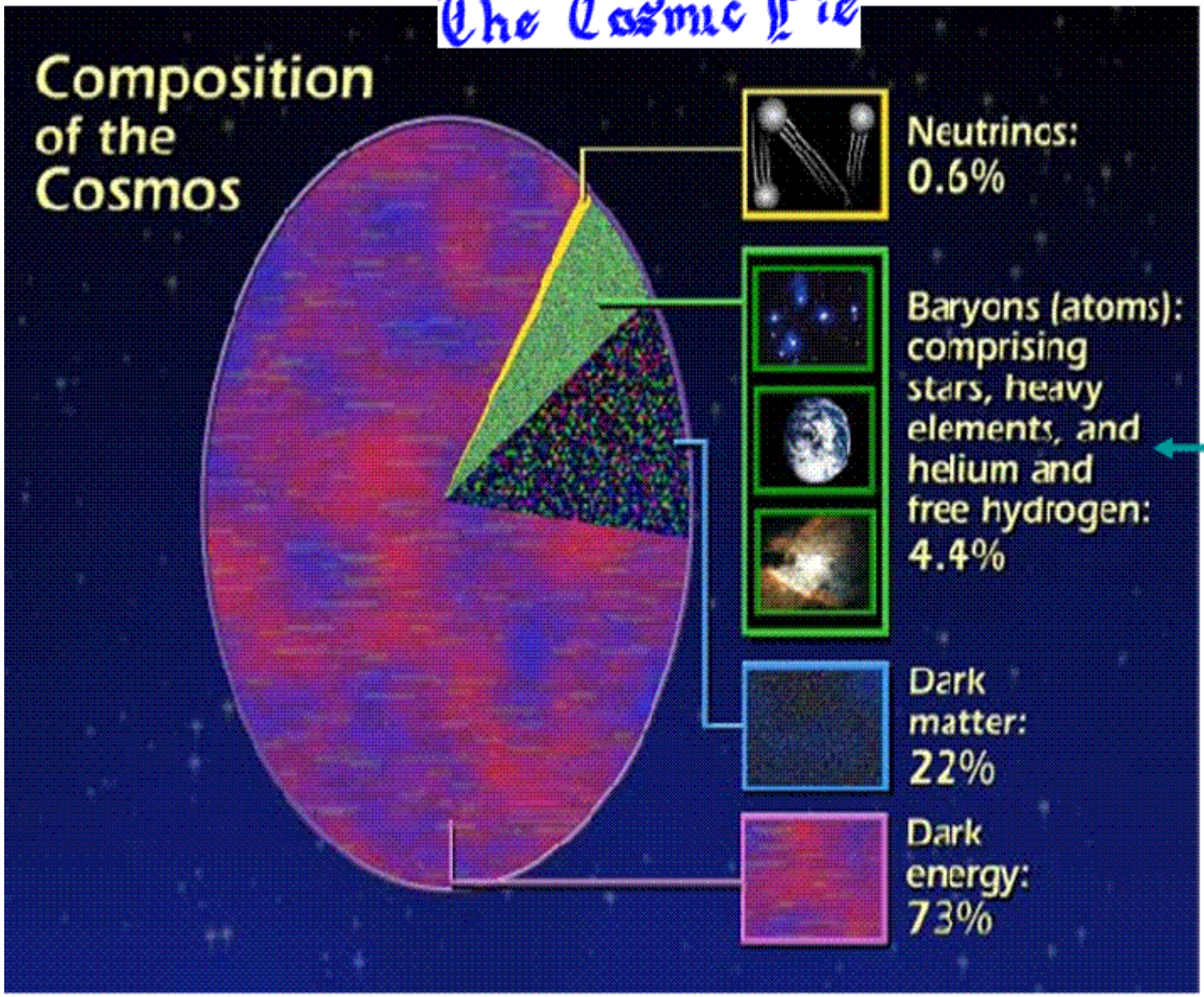
Amount of Dark Matter
Dark energy

universe is flat



NOT enough "normal matter"
to make universe flat
⇒ Dark matter



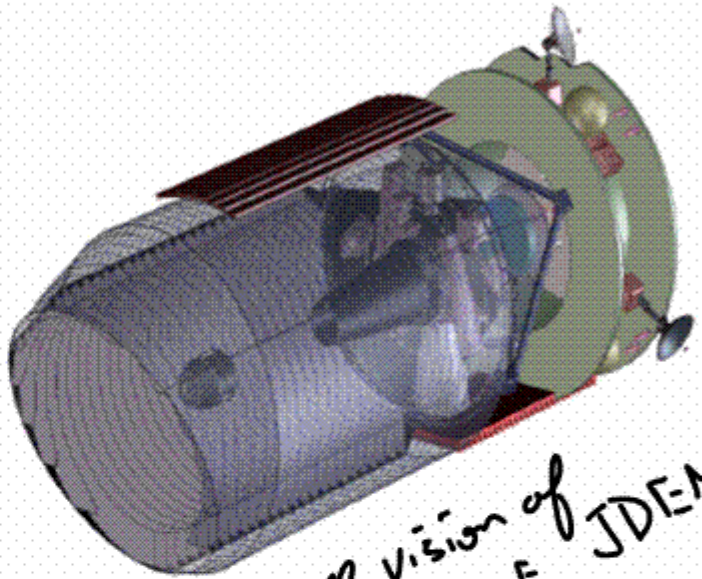


95% of the universe is unknown!

figure from E. Linder LBL

Where do we go from here?

SNAP SuperNova Acceleration Probe



one vision of NASA DOE JDEM Joint Dark Energy Mission

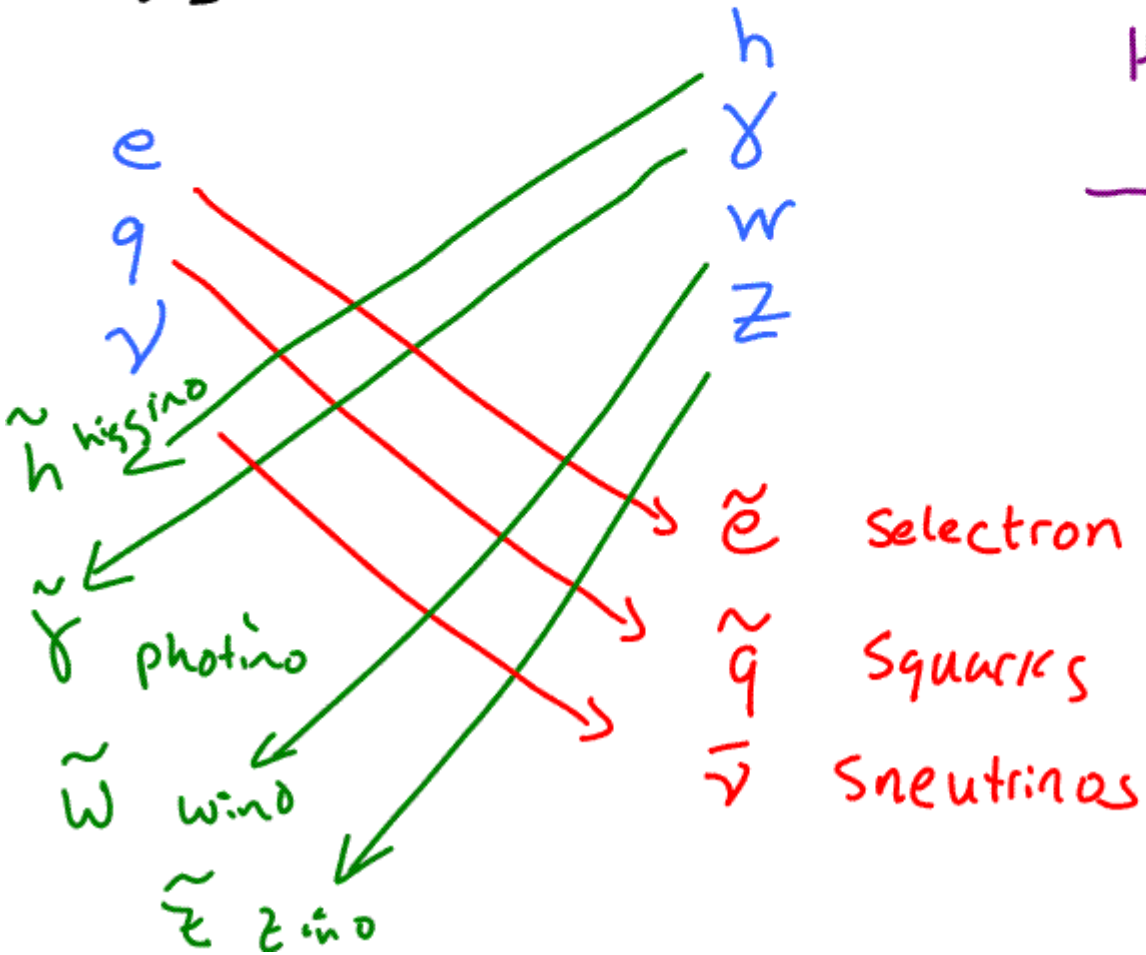
Large Hadron Collider (LHC)

Supersymmetry

Intro to particle spect
R parity
LSP
Gauge heirarchy
Coupling Unification
Dark energy?

fermion $\longleftrightarrow$ boson

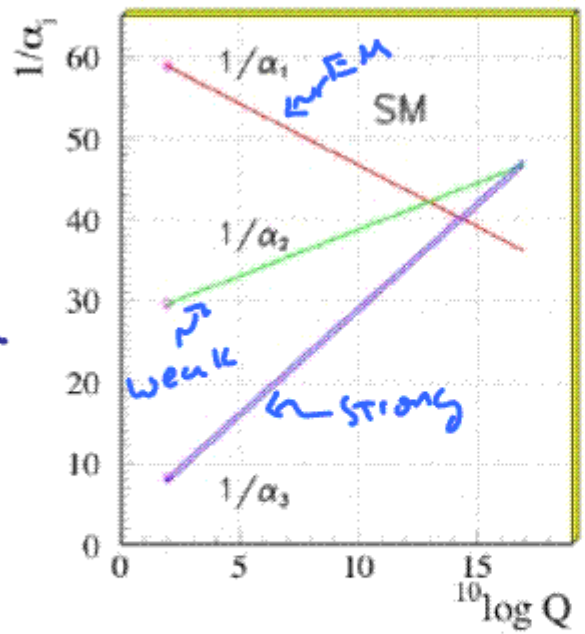
$\frac{1}{2}, \frac{3}{2}, \ldots$ $\quad$ $0, 1, \ldots$



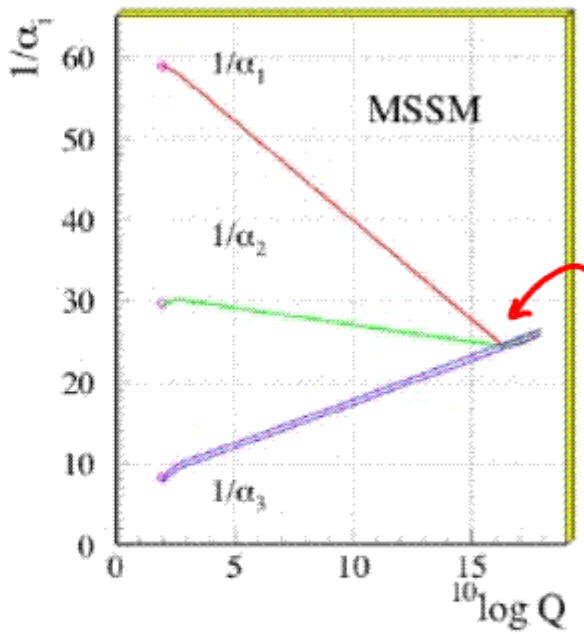
STANDard Model

Minimal Supersymmetric Model

Strength of Interaction



~Interaction Energy (Temperature)



~Interaction Energy (Temperature)