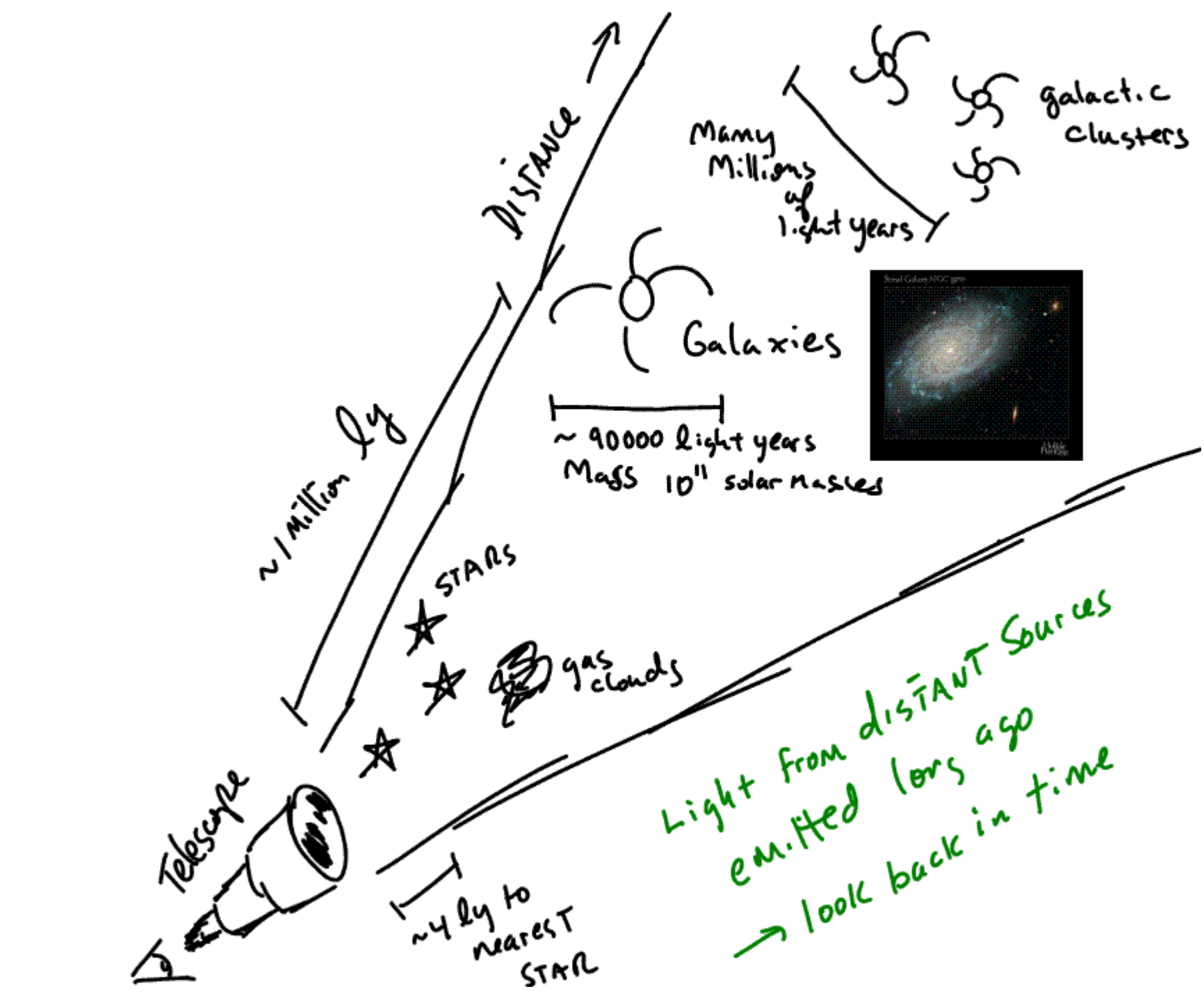
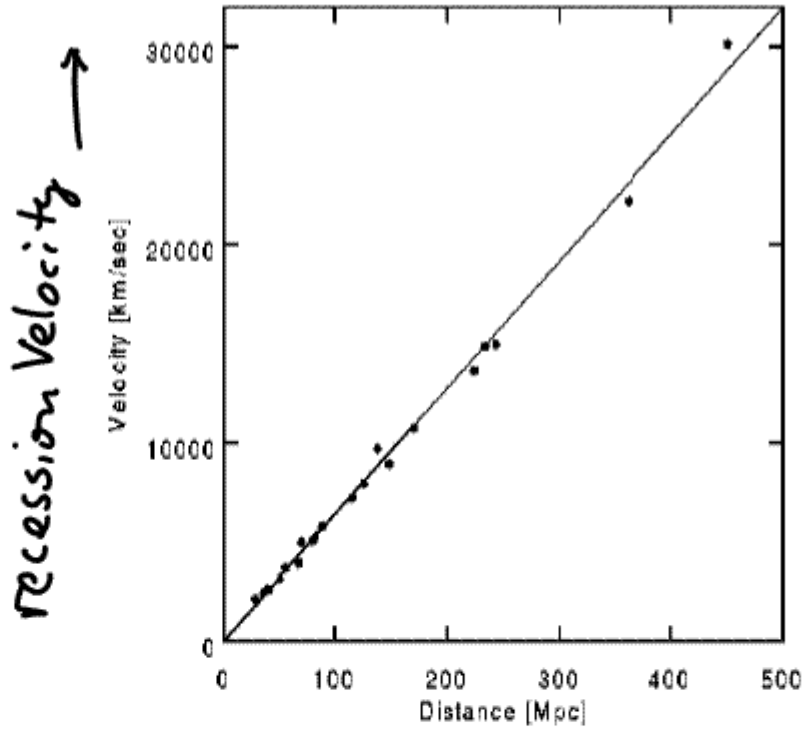
Physics 100 - April 9, 2007

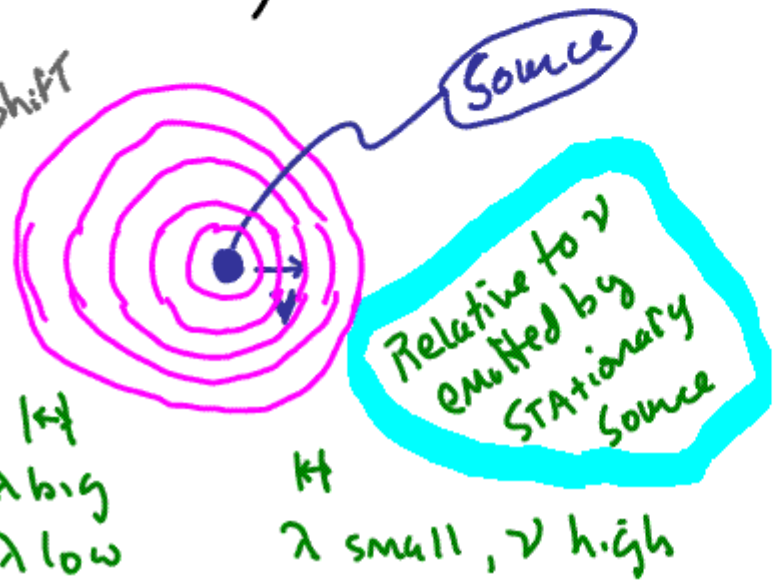
- Exam 2 is Wednesday
- Will try to get "formula sheet" up on web soon
- Exam 2 Q+A session
  Tuesday 5-6:35pm
  Meliora 203


DISTANCE
Many Millions of light years
galactic clusters
Galaxies
~ 90000 light years
Mass 10^11 solar masses
~1 Million ly
STARS
gas clouds
Telescope
~4 ly to nearest STAR
Light from distant sources emitted long ago
→ look back in time

Edwin Hubble
(1929)



Doppler Shift



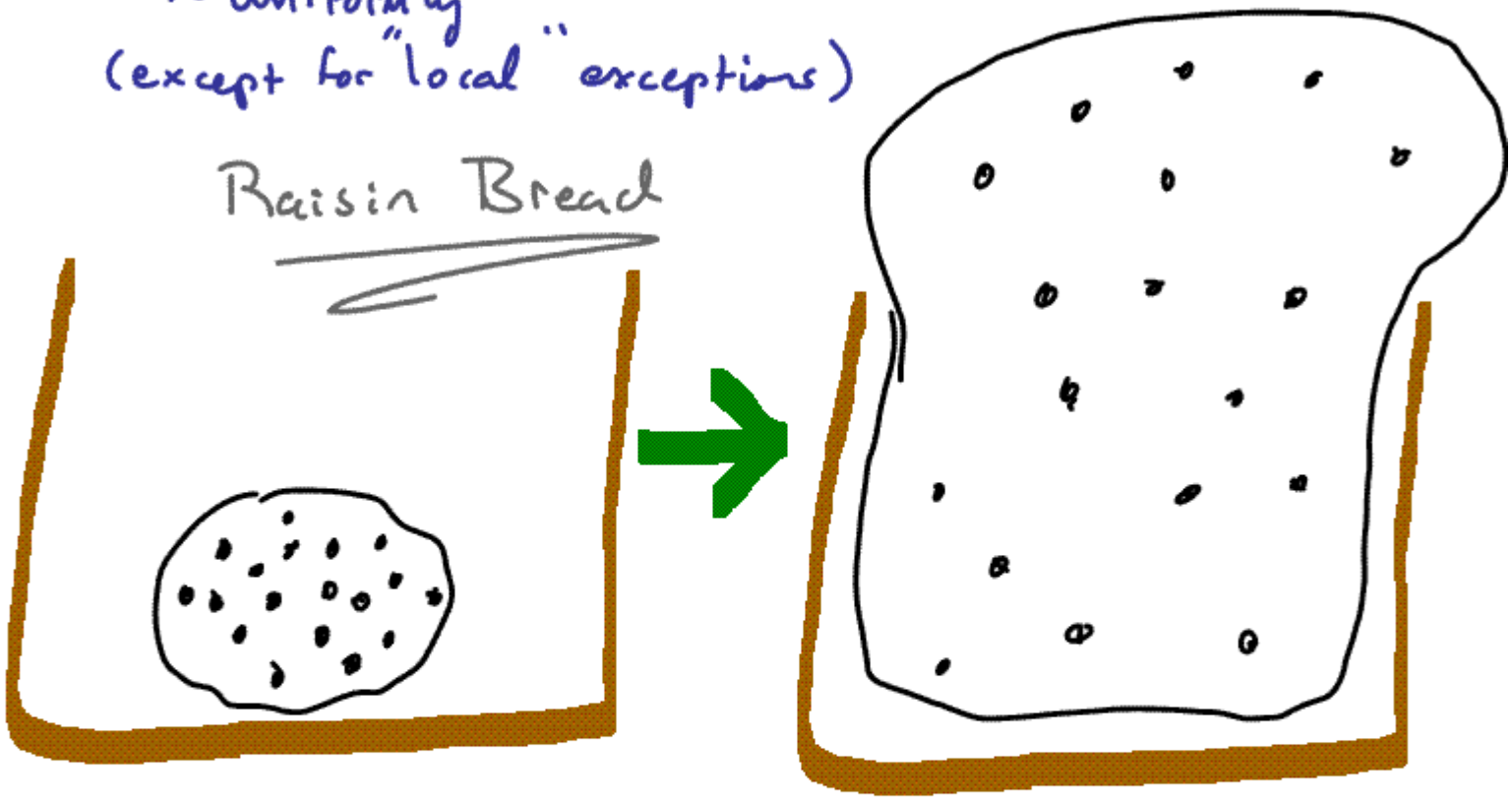
DISTANCE to galaxy →

observer

relative Motion of Source or observer

See applet on class web

Galaxies Receding in all directions
~ uniformly
(except for "local" exceptions)



No need to think our galaxy is at center of universe.

Expansion of space makes effect same to all observers throughout universe.

Cosmology

Not quite the same thing

Scientific Study of the large scale structure of the universe — Attempt to understand to origin, evolution and fate of the universe

http://wmap.gsfc.nasa.gov/m_uni.html good online reference for this class

Cosmetology

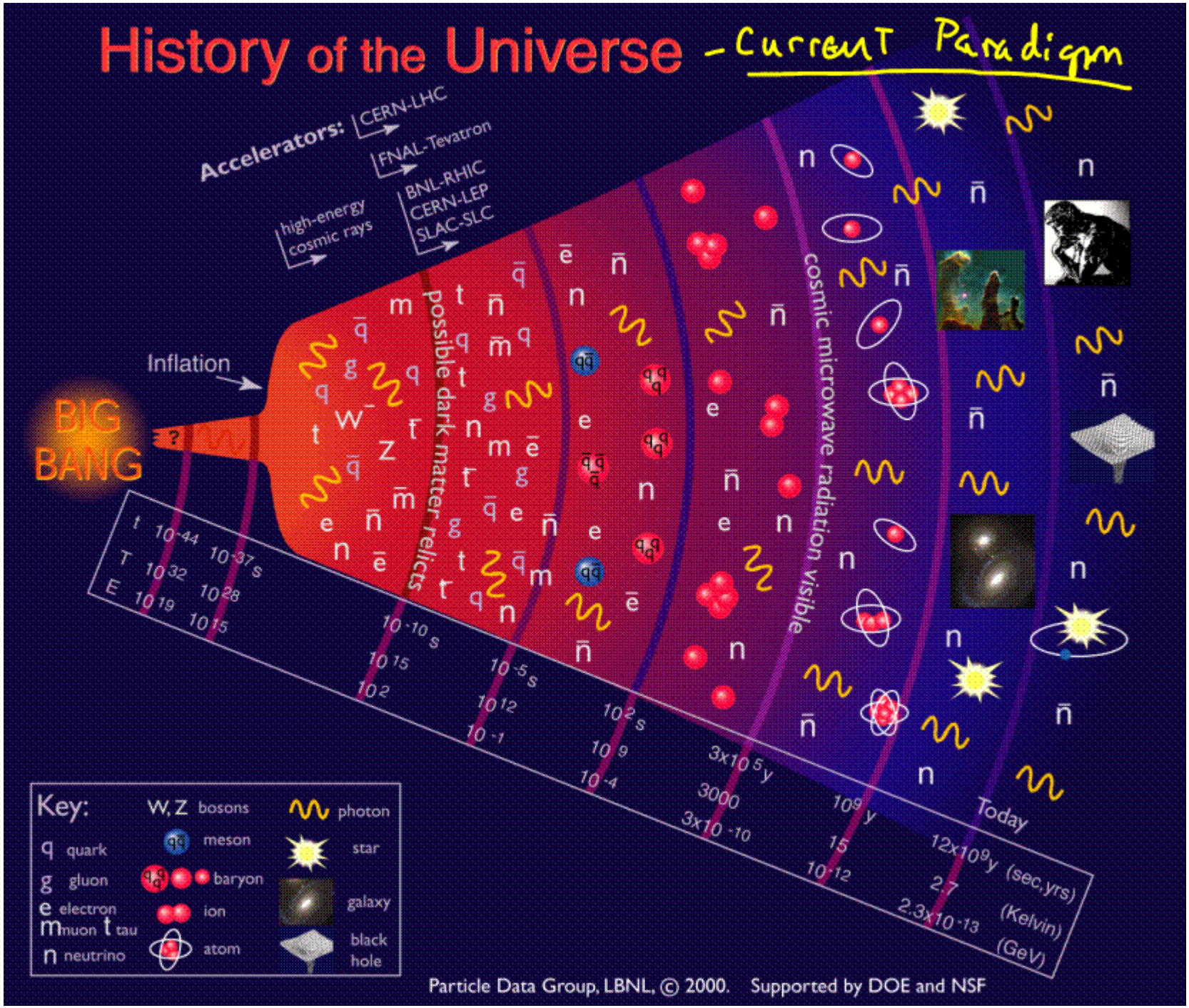
The business of being a beautician — The treatment of skin, hair and nails

http://careerplanning.about.com/cs/occupations/p/cosmetology.htm

while weie at it ...

Astronomy

Astrology


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

Inflation

Universe starts very small —
quantum fluctuation
quantum effect causes massive
and extraordinarily fast expansion called ↑

quantum space + time

10^{-24} cm 100 billion x smaller Than proton

quantum fluctuations

Higgs field

↳ "metastable state"

false vacuum → repulsive grav. field

10^{-37}

expands ~ 10^{25} times → 1 mm

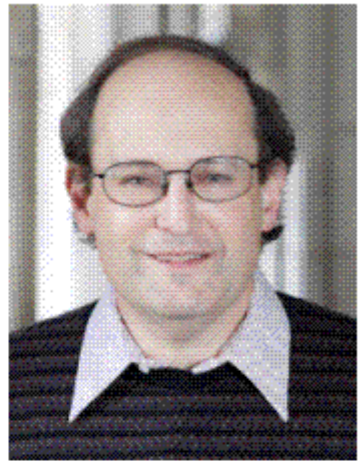
Energy in matter inc ~> 10^{75}

Guth "If inflation is right, the universe can be properly called the ultimate free lunch."

Cosmic Inflation

~1979

Andrei Linde (Stanford)



Paul Steinhardt (Princeton)

Andy Albrecht (UC Davis)

Strange but important development

Solves "Flatness Problem" & "horizon problem"

Alan Guth (MIT)

Paper by Guth discussing inflation

http://web.mit.edu/physics/alumniandfriends/physicsjournal_fall_02_cosmology.pdf

Preprint of a Discovery article describing a cyclic universe based on string theory ideas (Steinhardt, Turok)

http://wwwphy.princeton.edu/~steinh/Discover0204.pdf

Era of heavy particles

10^{-36} s $\rightarrow$ 10^{-10} s Temp $10^{28} \rightarrow 10^{12}$ deg

Primordial soup of particles

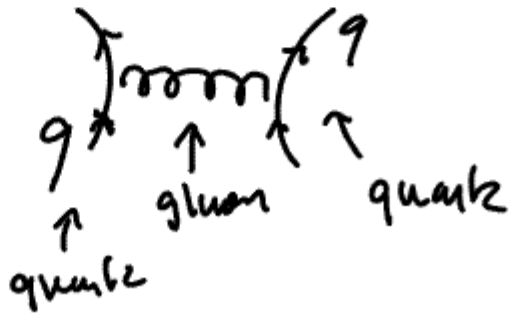
$W, Z, g, \gamma, \bar{q}$ e, μ, τ

Mass Z, W irrelevant

Electroweak force

Strong interaction at high energies is Weak

Quark-gluon plasma



So quarks NOT Bound into Baryons and Mesons (like protons)

10^{-10}

Energy density dropped enough

Mass W, Z becomes relevant

Weak force "freezes out"

10^{-6}

10^{12} = Temp

Strong force becomes very strong

quark gluon plasma $\longrightarrow$ colorless states condenses

(qqq) $(\bar{q}\bar{q}\bar{q})$ Protons neutrons

γ, e^-

quarks + gluons condense into Baryons + Mesons

at $t = 100\ s$ Temp $= 10^9$ degrees

light nuclei form (nucleosynthesis)

e^-, p, n, light nuclei

H, He, Li

deuterium (pn)

universe opaque to light

photons are there ... but absorbed quickly

at $t = 100{,}000$ years $T \rightarrow 3000$

neutral ATOMS form

$\gamma \longrightarrow$ free streaming

"First light"

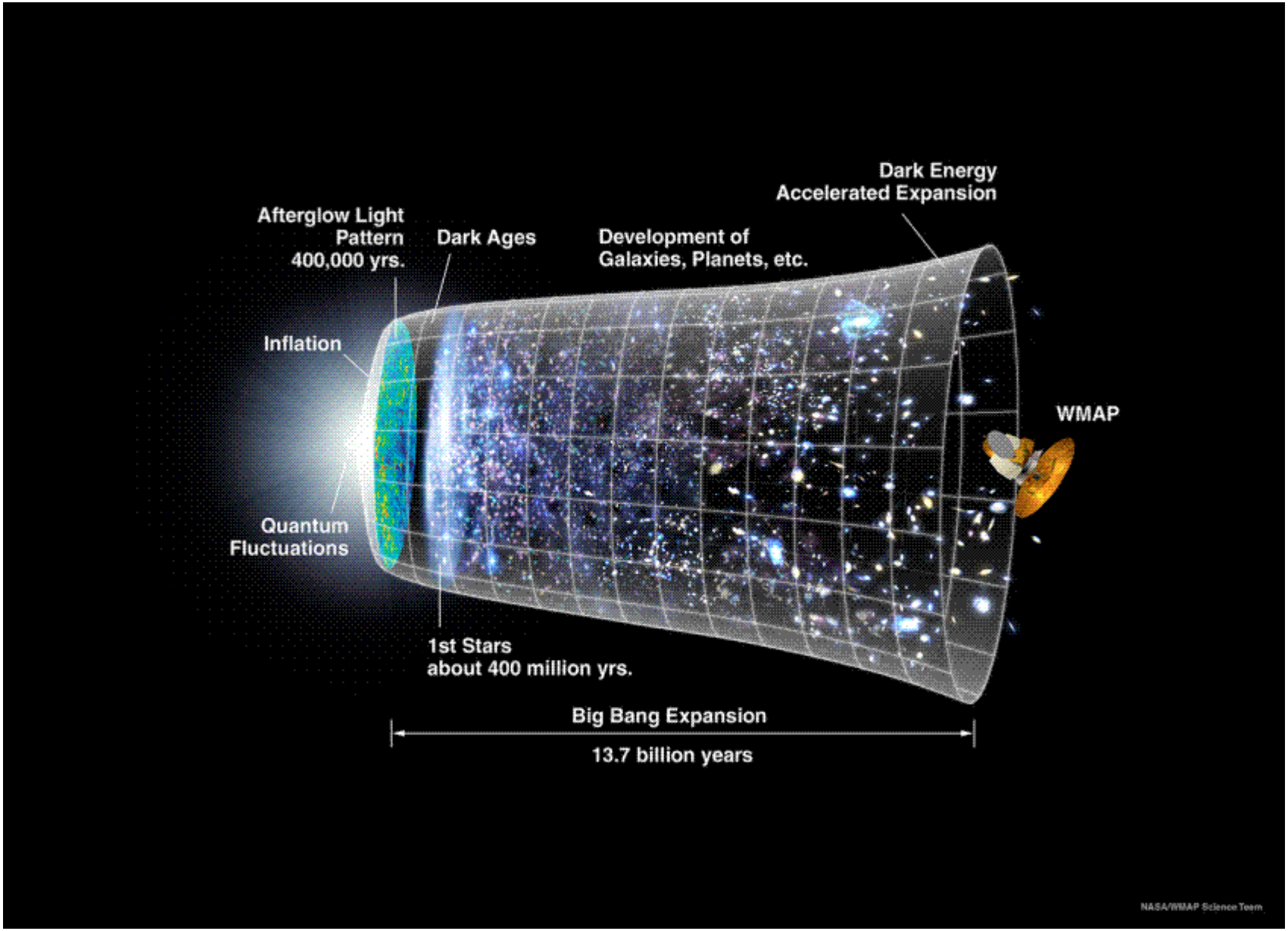
Seen $\longrightarrow$ Cosmic Microwave Background

Stars form $t = 30$ million yrs

galaxies form few hundred million yrs

gravity Amplifies lumpiness from quantum fluctuations → pre-inflation

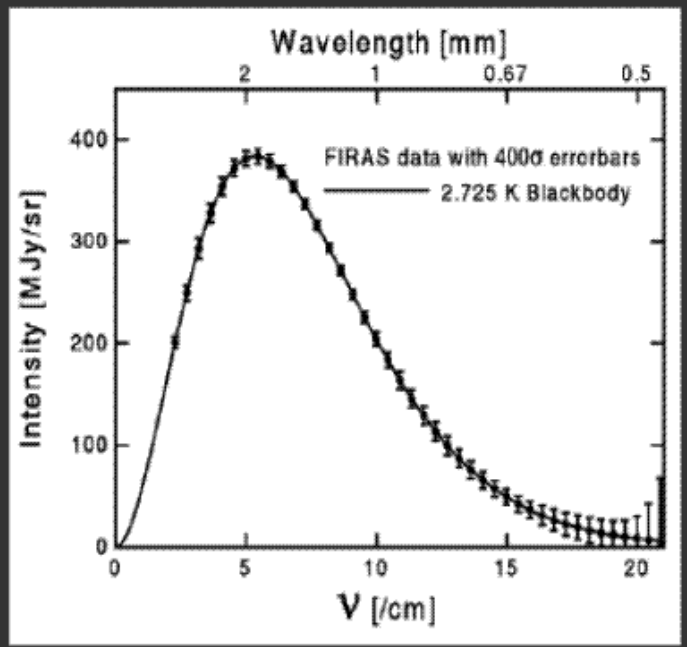
"... galaxies are nothing but quantum Mechanics writ large across the sky"


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

Evidence for Big BANG

Cosmic Microwave Background

Penzias and Wilson - 1964



Uniform and isotropic

– in as far as they could measure

1978 Nobel Prize