In the Beginning

December 2, 2002

1) The Early Universe
2) SETI

Final Exam will be held in Ruby Diamond Auditorium

NOTE THIS!!!

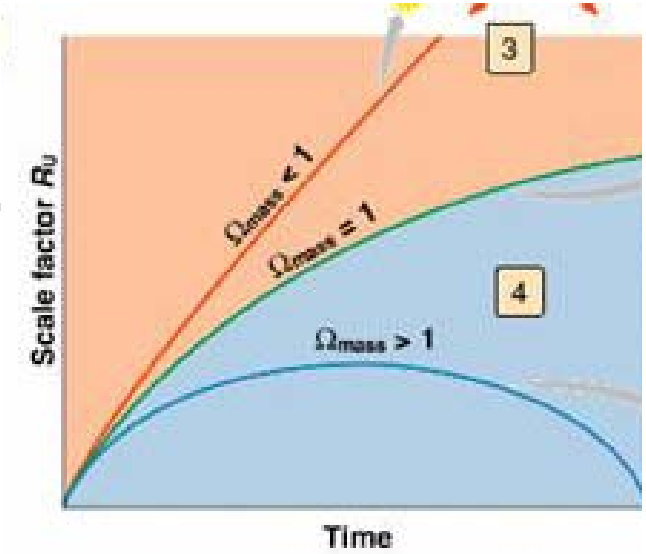
not UPL

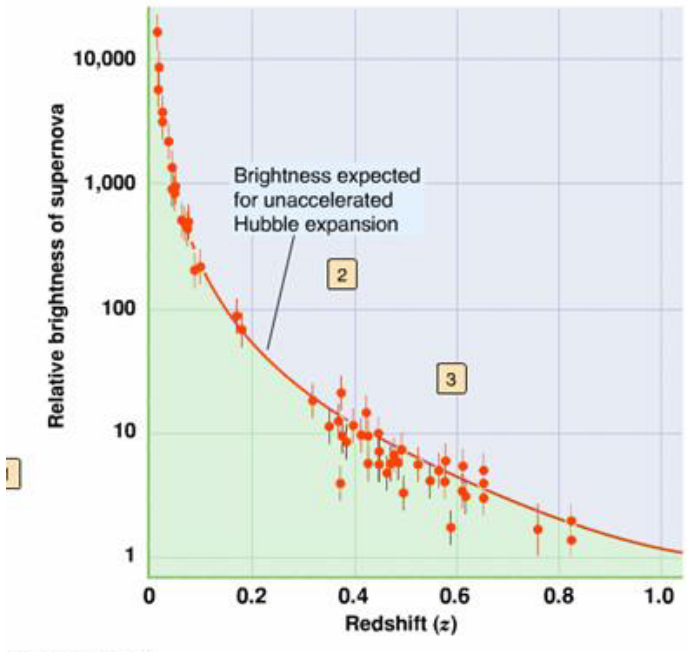
Dec. 11, 2002 10am-noon

Bring your ID, calculator and pencil

Review

- Fate of the Universe
  - expansion speeding up
- Shape of the Universe
  - $\Omega_{MASS} + \Omega_{\Delta} \sim 1$
  - $\Omega_{MASS} \sim 0.3$
  - $\Omega_{\Delta} \sim 0.7$
- Large scale structure
  - dark/normal matter

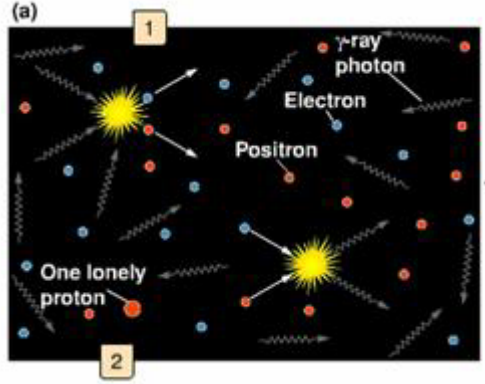




Elementary Forces

- Four primary forces
  - Electromagnetism
  - Strong nuclear force – nuclear fusion
  - Weak force – nuclear decays
  - Gravity
- At high energies/temperatures, these forces are really the same
  - only possible at the time of the early Universe

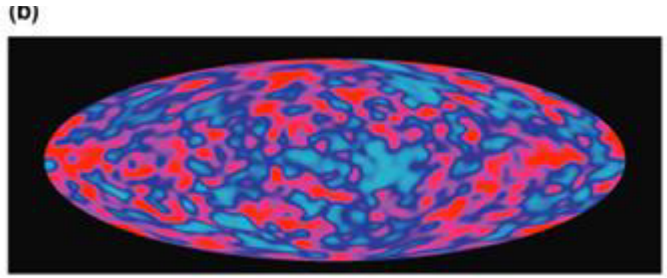
At the Beginning



- Originally all the energy of the Universe was condensed into an incredibly small region
  - MUCH smaller than the size of a proton
- Energy, matter, space and time were all very different than today
  - need a new "theory of everything" to understand
    - not yet possible
    - 11-dimensional space???
- During early expansion, space-time and gravity became separate from energy and mass
  - particles and antiparticles were being created from energy and annihilating into energy all the time

Inflation

- At a very early point, the Universe went through a period of rapid expansion
  - time = 10^{-35} to 10^{-33} seconds
  - size went from 10^{-12} the size of a nucleus to 3 meters
  - VERY rapid expansion



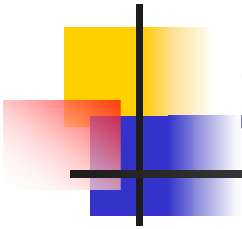
- Expansion explains:
  - apparent flatness of the Universe
  - smoothness of the cosmic microwave background

Expansion and Forces

- From inflation to recombination
  - Universe expanded and cooled
  - first became less dense that a neutron star and then less dense than a white dwarf
- Elementary forces separated and started behaving like they do now
- Matter-antimatter creation halted
  - temperature less than 10^9 K
- Matter-antimatter annihilation continued
  - why is there only matter left?

Nucleosynthesis and Recombination

- When cool enough, nuclei formed and fused together
  - Big Bang nucleosynthesis
  - formed hydrogen, helium, lithium, beryllium, and boron
- Eventually, the Universe cooled enough to form atoms
  - recombination
  - the Universe became tranparent
  - the CMB was created

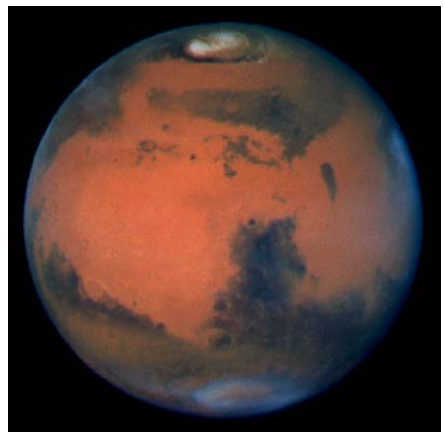


Success and Questions

- Big Bang theory explains a lot
  - flatness of Universe
  - structure of Universe
  - cosmic microwave background
  - expansion of Universe
  - composition of Universe
- Leaves a lot of questions
  - why did the Universe begin expanding?
  - what happened during the very early Universe?
  - why only matter, no antimatter?
  - exactly why is the expansion accelerating?

Life Out There

- What evidence do we have of life beyond Earth?
  - Actually, we have no direct evidence of life beyond Earth
- What possibilities are there?
  - Mars
  - Europa
  - Comets/asteroids
  - Terrestrial planets/moons in other systems



The Search for Life

- We search for intelligent life using radio waves
  - radio waves travel far distances
  - not produced by most stars
  - seems fairly easy to develop technology
  - possible to communicate information
- Numerous large radio telescope arrays around the world

SETI

- Search for ExtraTerrestrial Intelligence (SETI)
- There are numerous programs
- First search, Project Ozma, was in 1960
  - 200 hours of observing two nearby stars
- Project Phoenix
    - privately financed US project
  - search 2 billion channels for each of 1000 nearby stars
    - stars similar to the Sun and at least 3 billion years old
  - about half done – nothing yet

SETI Still Going

- SERENDIP Project
  - search for signals using regular radio telescope observations from the Arecibo telescope in Puerto Rico
  - you can participate by downloading a screen saver which analyzes data while your computer is idle
    - www.setiathome.ssl.berkeley.edu
- Allen Telescope Array
  - series of 1000s of small satellite dishes
  - funded by Paul Allen (of Microsoft)

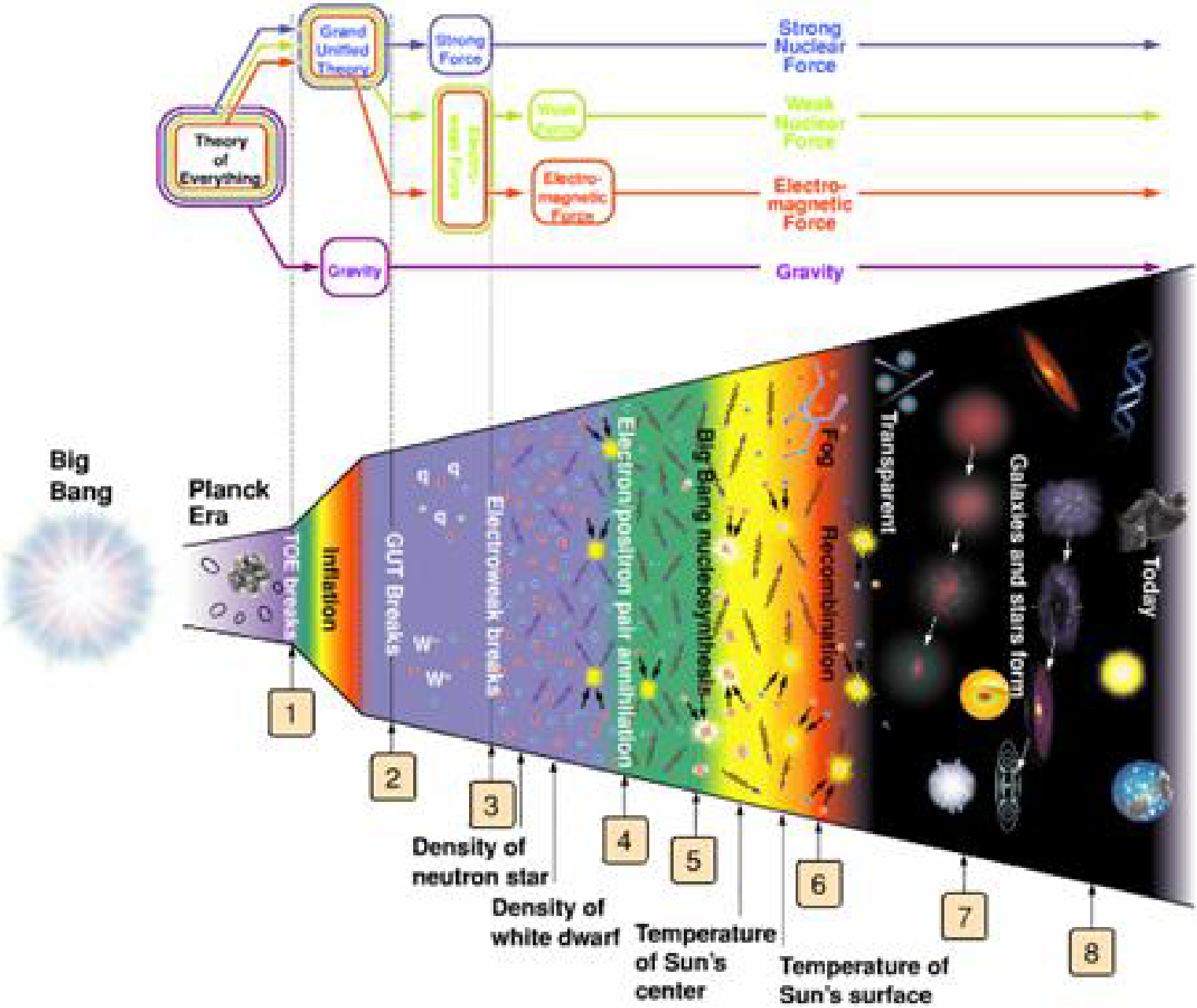
Drake Equation

- What are the factors to determine the chance there is advanced intelligent life out there?
  - number of stars (T)
  - number of planets/moons (n_{pm})
  - number of planets/moons where life does actually start (f_l)
  - number of times life becomes intelligent (f_c)
  - length of intelligent civilization (L)

$$N = T \times n_{pm} \times f_l \times f_c \times L$$

Messages from Earth

- We have tried to communicate with other life
- Probes
  - Pioneer and Voyager carry plaques and recordings
- Radio signals
  - been emitting radio signals since the 1970s
  - sent several messages
    - Arecibo broadcast – 1974
    - Encounter 2001


Theory of Everything
Grand Unified Theory
Strong Force
Strong Nuclear Force
Weak Force
Weak Nuclear Force
Electro-magnetic Force
Electro-magnetic Force
Gravity
Gravity
Big Bang
Planck Era
TOE breaks
Inflation
GUT Breaks
Electroweak breaks
Electron/positron pair annihilation
Big Bang nucleosynthesis
Fog
Recombination
Transparent
Galaxies and stars form
Today
1
2
3
4
5
6
7
8
Density of neutron star
Density of white dwarf
Temperature of Sun's center
Temperature of Sun's surface

Semester Review

- Science
- Solar System
- Stars
- Galaxies
- Large Structure
- Cosmology
- Answered lots of questions (hopefully)
- Raised lots of questions (hopefully)