Lecture 25 30 April 2009

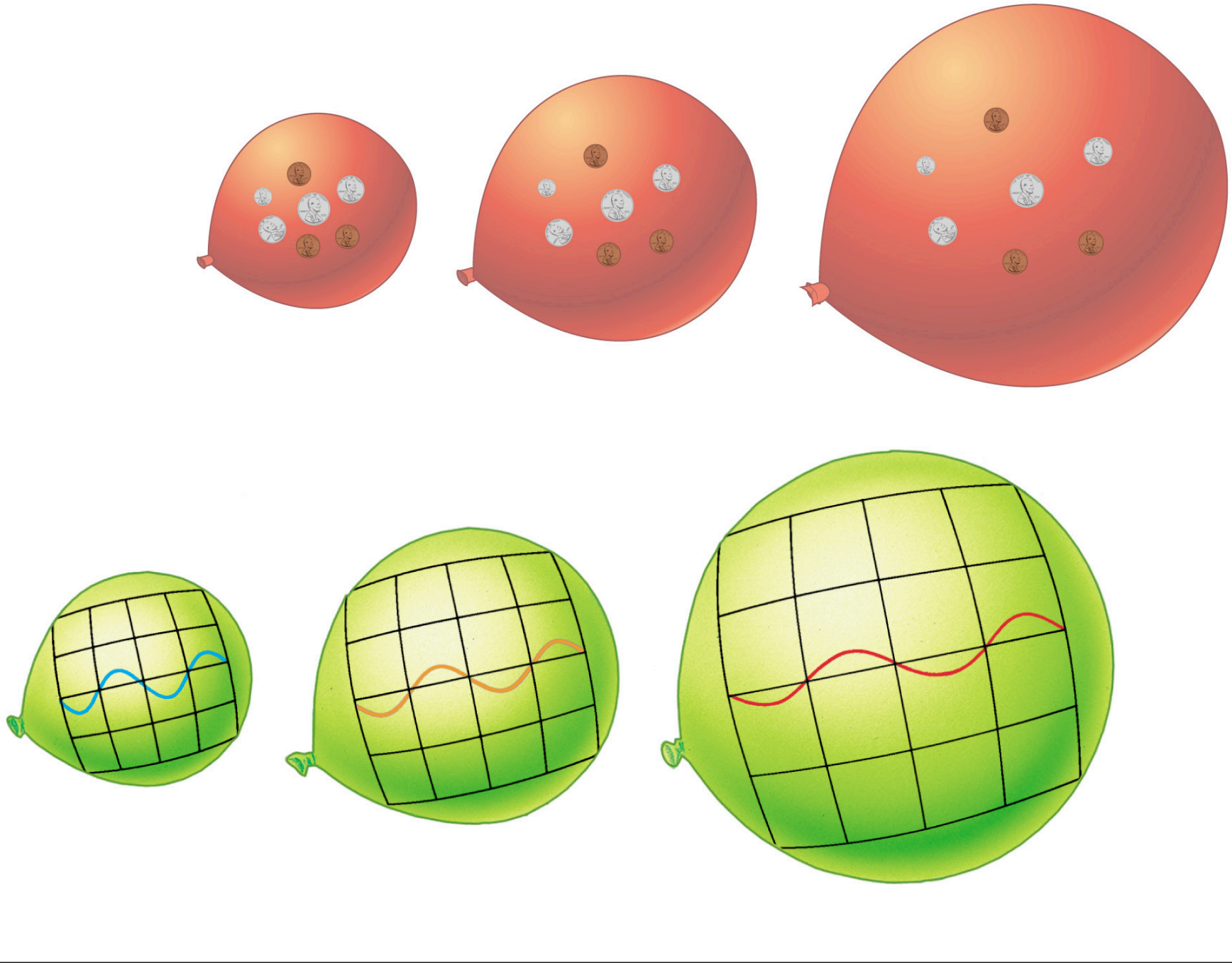
- **SCIENCE TOPICS**:
  Dark Energy and
  The Fate of the Universe
- **READING**
  Ch.17, Sections 17.2-17.7
- **PRACTICE: Ch 17**
  Review: 1, 2, 5, 6
  Self-test: 1, 2, 5, 6, 10,
  Problems: 4, 5

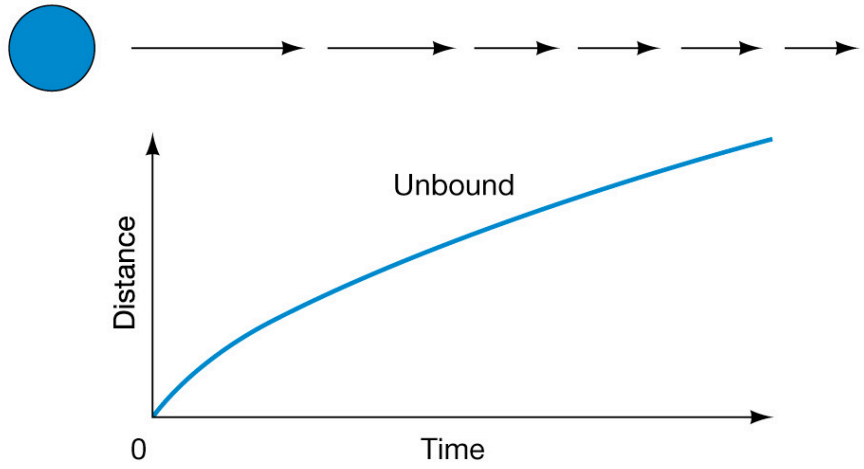
HOMEWORK 09:
Due tonight,
11:59pm
FINALS: Friday 8th
May 2009, 08:00am

The Fate of the Universe

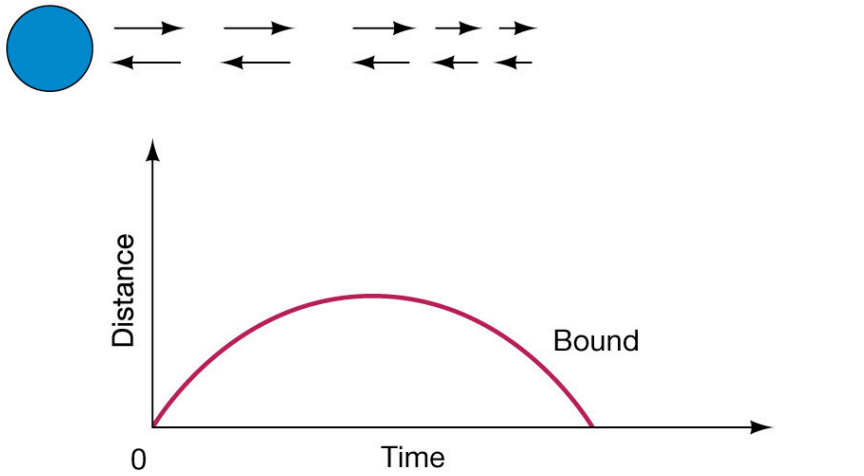
... depends on
what the Universe
is made of.

- The CMB tells the **TOTAL AMOUNT** of matter and energy in the Universe.
- Evidence from galaxies tells that most of the matter is in the form of dark matter
- *BUT even then* there isn't enough matter and energy to tally with the CMB
- Something VERY strange is going on…





(a)



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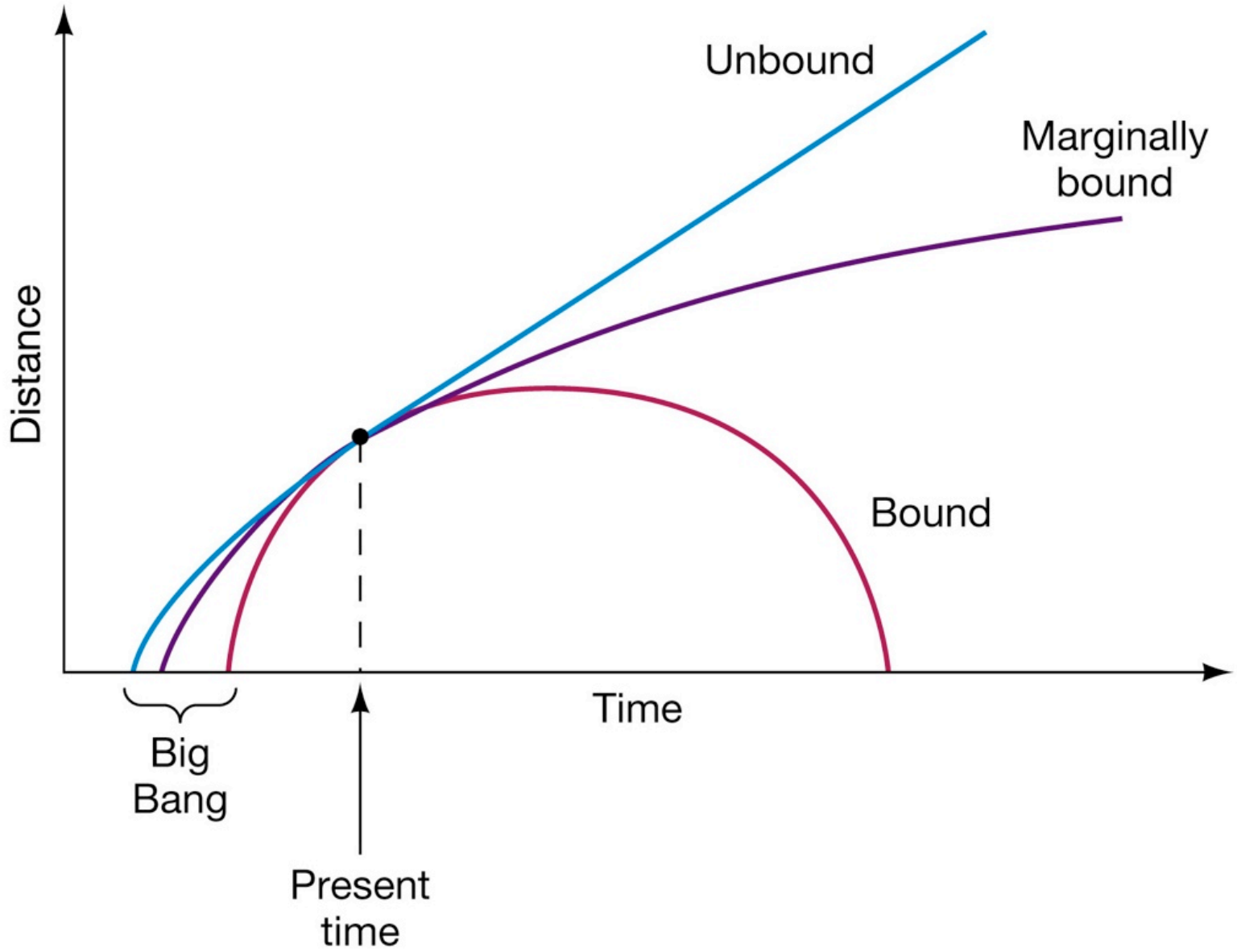
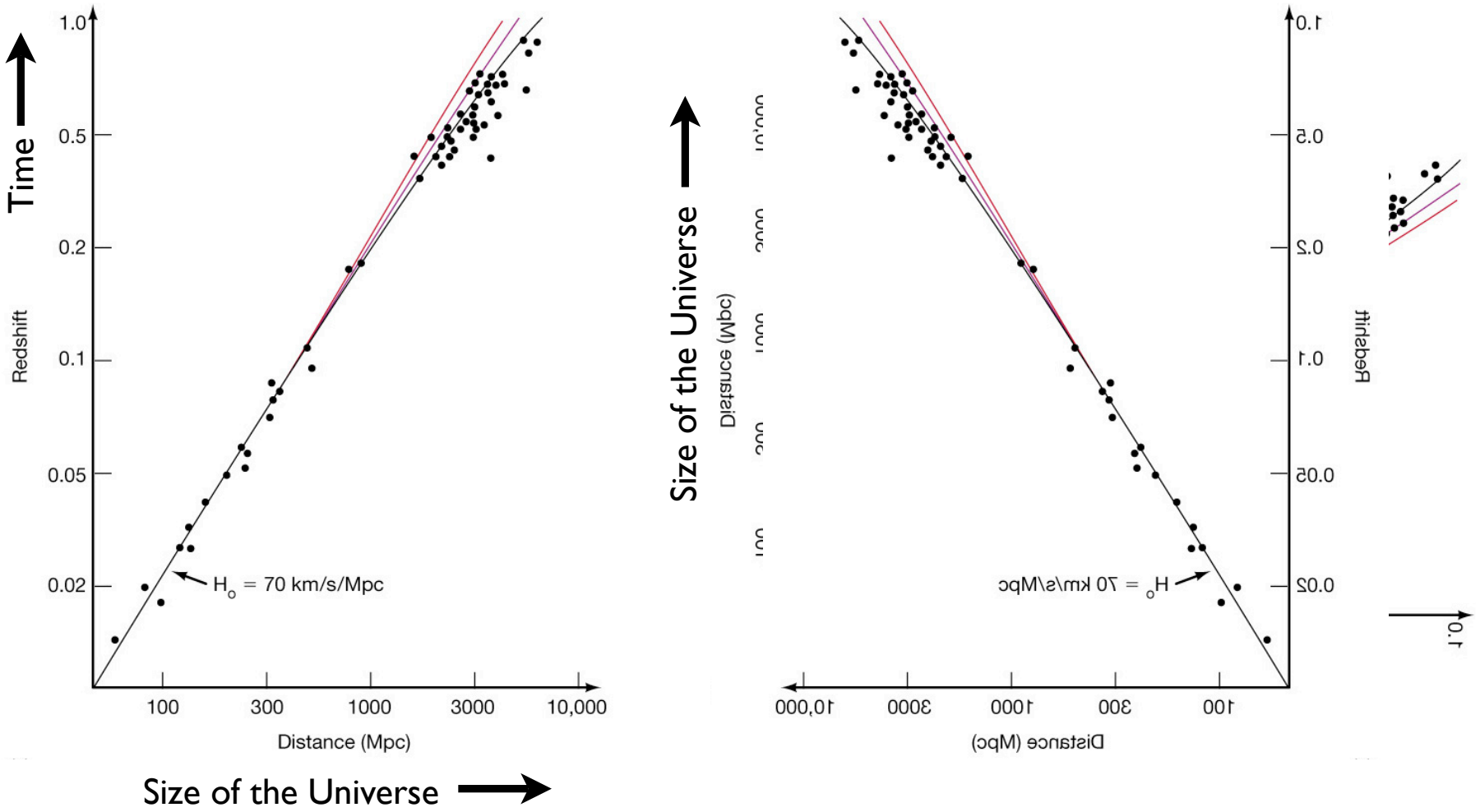
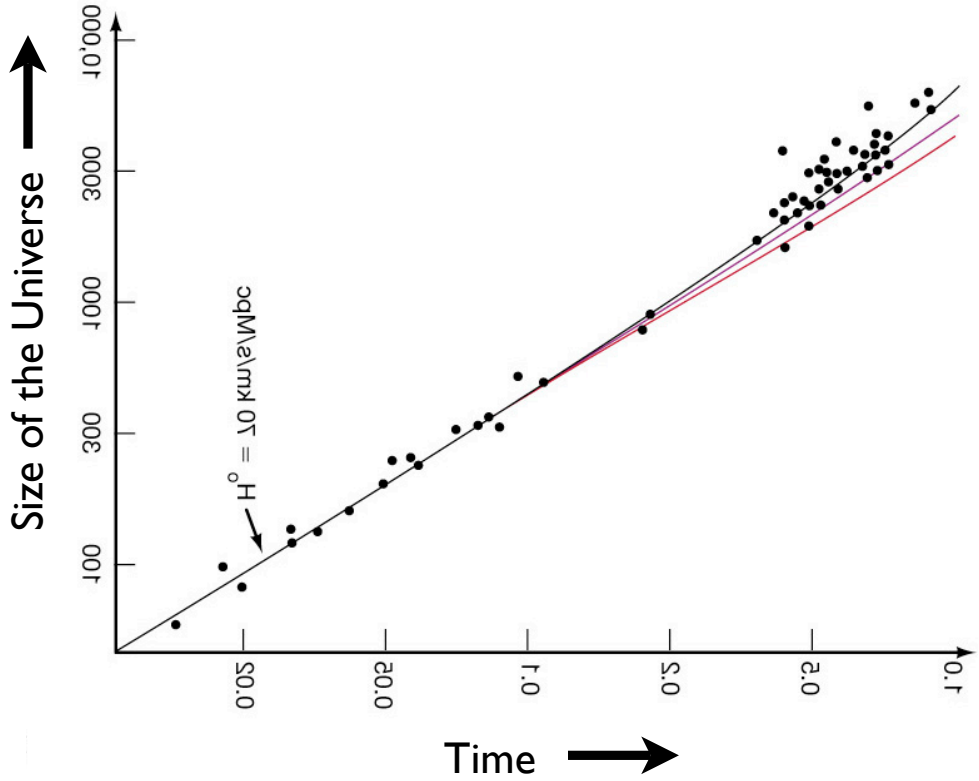
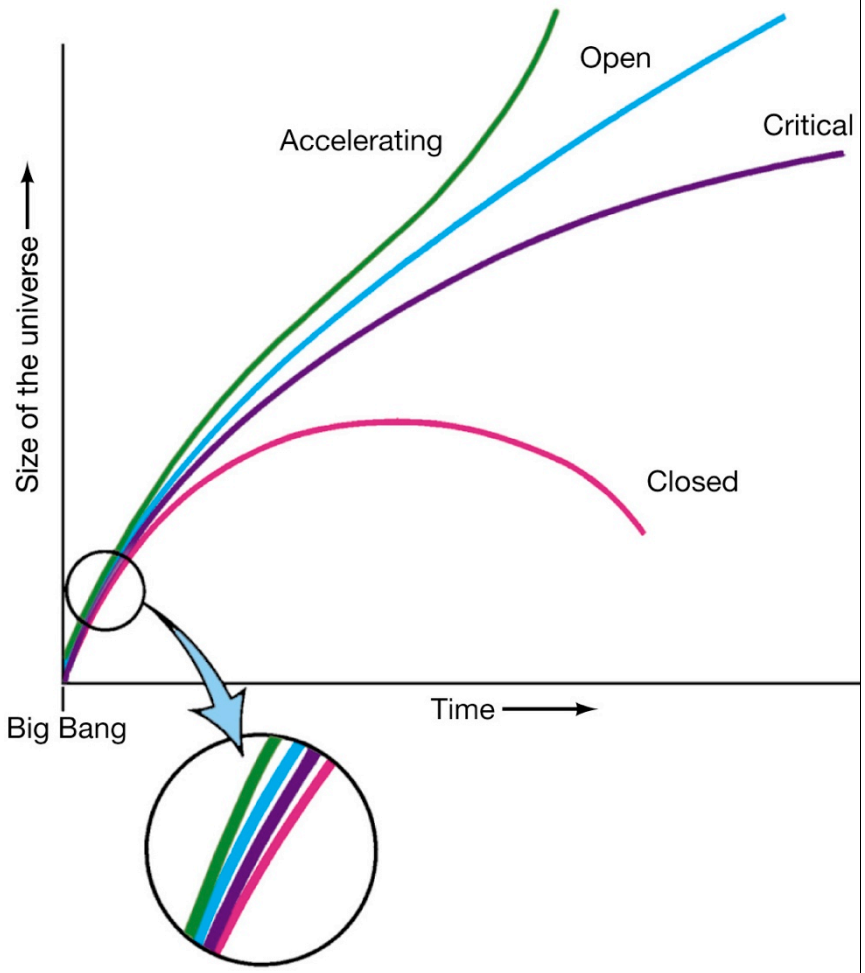
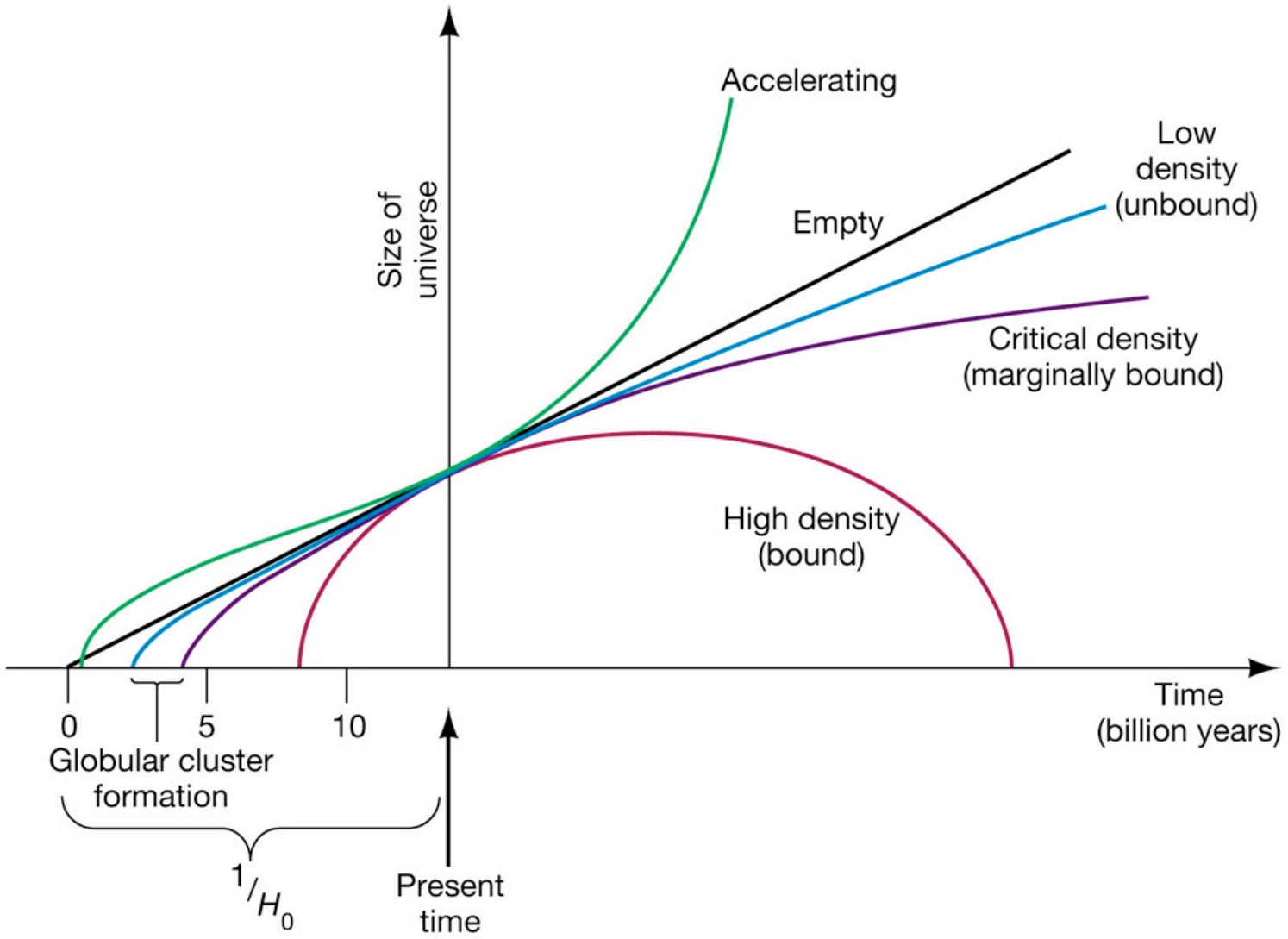

Unbound
Marginally bound
Bound
Distance
Time
Big Bang
Present time


Time
Redshift
1.0
0.5
0.2
0.1
0.05
0.02
H_o = 70 km/s/Mpc
100
300
1000
3000
10,000
Distance (Mpc)
Size of the Universe
Size of the Universe
Distance (Mpc)
Redshift


Size of the Universe
Time
H_o = 70 km/s/Mpc
100
300
1000
3000
10,000
0.05
0.02
0.1
0.5
2.0
0.1


Size of the universe
Accelerating
Open
Critical
Closed
Big Bang
Time


Accelerating
Low density (unbound)
Empty
Size of universe
Critical density (marginally bound)
High density (bound)
0
5
10
Time (billion years)
Globular cluster formation
1/H0
Present time

Einstein's Greatest ``blunder"

- Einstein's Theory of Gravity, ``General Relativity" 1916-7.
- ``The Big Bang Theory" not until 1920s...

Type Ia Supernova

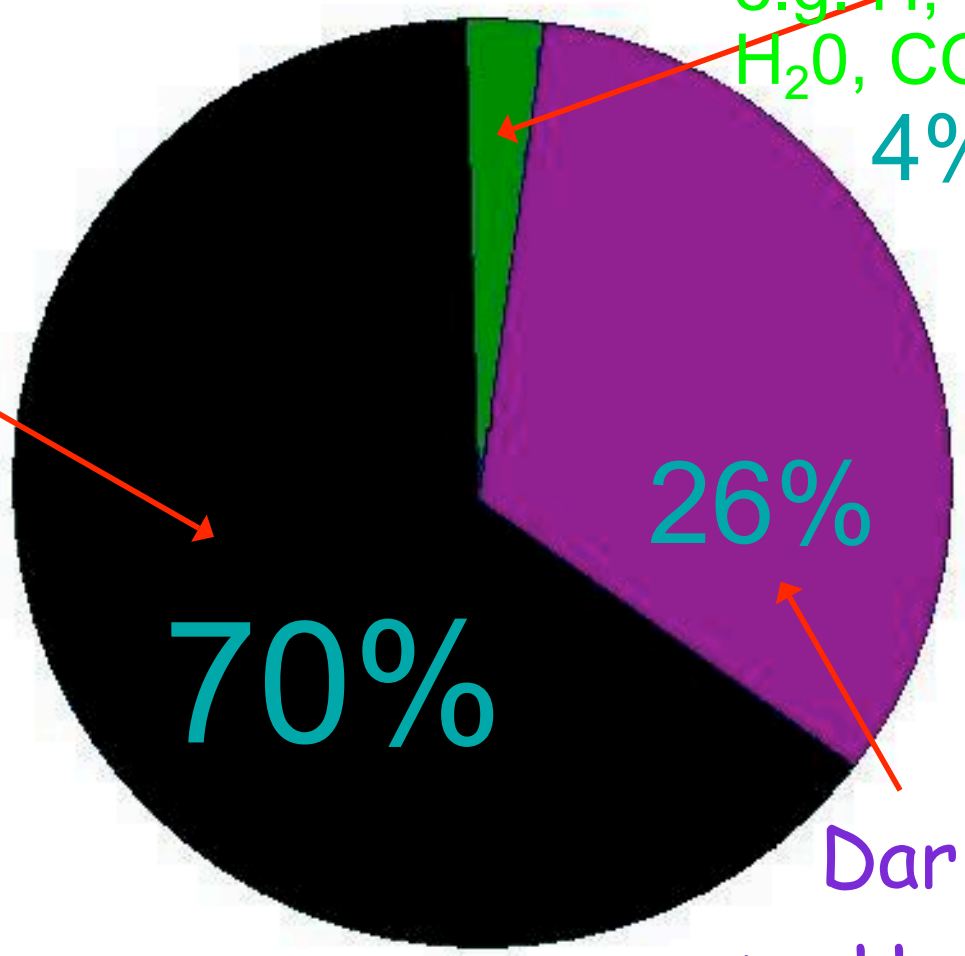
- Late 1990s...

DARK ENERGY

Dark Energy

- is weird.
- "Anti-gravity" (has -ve pressure)
- Have NO clue to what it is (just have very good evidence it is there)
- Predictions from best theories of Particle Physics suggest a "natural energy scale" of Dark Energy.
- Problem is, when you do the sums, you are out by a factor of $\boldsymbol{10^{120}}$ ***(!!!!!!!!)***
- (Arguably) The biggest challenge/problem/question in physical science at the beginning of the C.21st.

What is the Universe made of?



How will the Universe end?

We think that the Universe will go in to a BIG CHILL. This means that eventually, as the Universe continues to expand and cool, all the stars will go out and the Universe will be left with just a sea of Black Holes…

Now 5 billion 100 billion 1000 billion 10^{36} 10^{100} time (years)

The Sun becomes a red giant & then fades

Galaxies move very far apart

Stars begin to die and fade

White dwarf star and neutron star era

All that's left are black holes