Today – Exam#3 Review

- Exam #3 is Thursday December 8th in this room, BPS 1410
- The exam is 40 multiple choice questions. There are three or four questions where you will have to use a formula. There are several “number” questions, like what was the initial temperature of the Big Bang (10^{35} Kelvin)
- Bring your student ID
- You will have the full 80 minutes for the exam.
- You can bring one 8.5x11 inch sheet of notes (front and back)

Final Exam

- The final exam is Tuesday Dec. 13th from 10am till noon.
- The final will be 40 multiple choice questions like the midterms.
- There will be no makeup credit like on the midterms.
- Questions for the exam will be taken (and slightly modified) from the midterm exams.
- You can bring 3 8.5x11 double sided sheets of notes.
- Note: The final counts the same as a midterm. Your lowest exam score will be dropped.

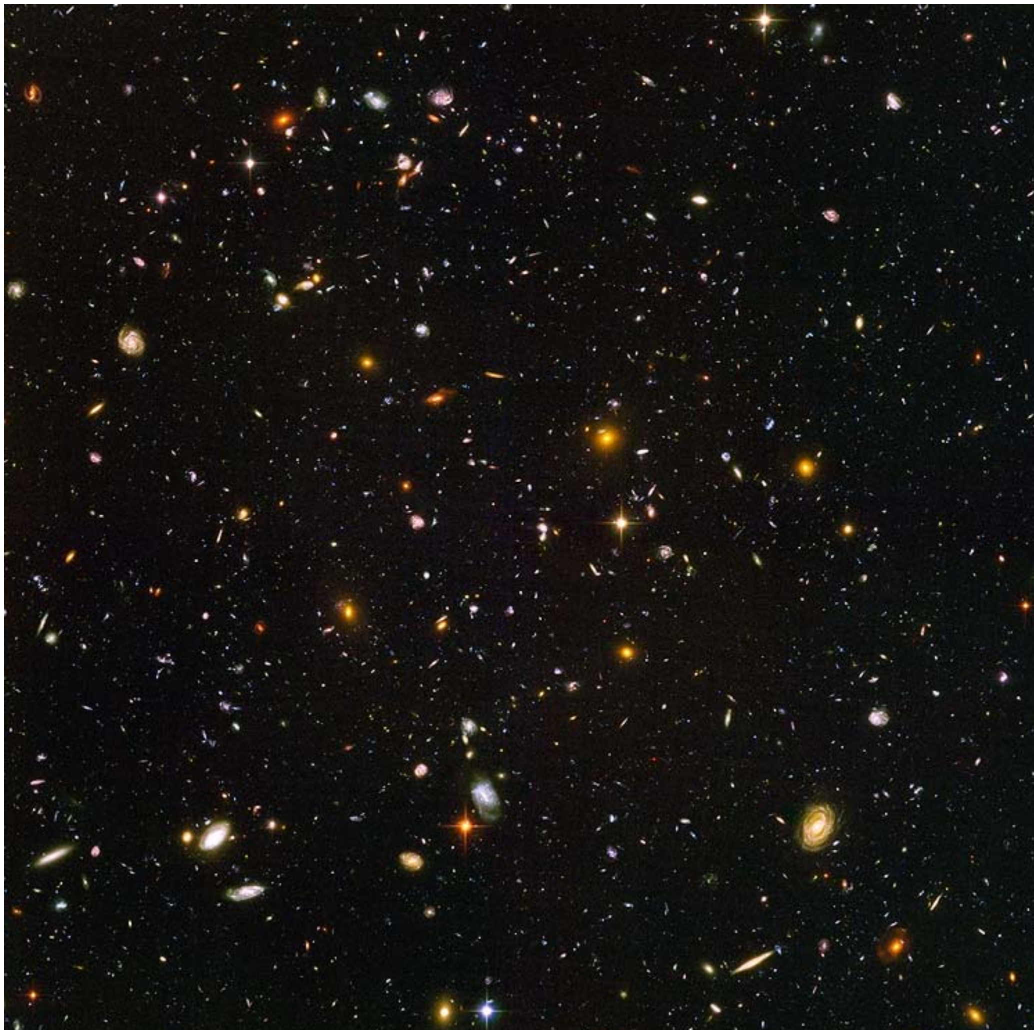
HW#11 is Due

- Please note that homework #11 is due tomorrow at 8:00am.
- The bead problem will not be on the exam.
- One last extra credit assignment is still open.

How did the Universe Begin?

- Evidence points to the Universe beginning in a hot fireball 13.7 billion years ago. We call this the Big Bang
- Evidence for the Big Bang
  - Expansion of the Universe
  - The Big Bang model correctly predicts the formation of the light elements observed to be present in the early universe (mostly hydrogen and helium).
  - The cosmic microwave background radiation

What do we know about the Universe?

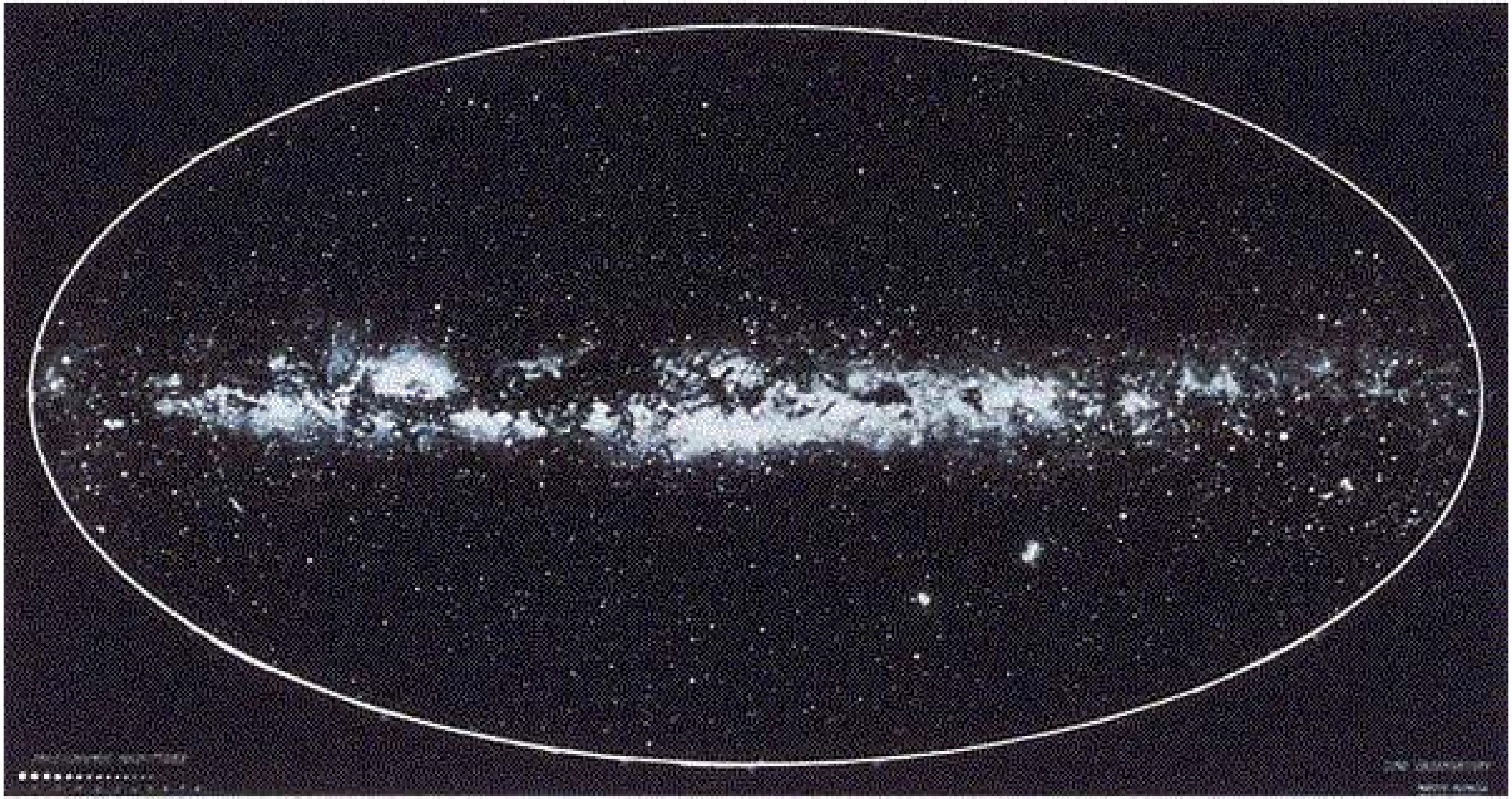


Picture of distant galaxies taken by the Hubble Space Telescope

There are approximately 200 billion galaxies

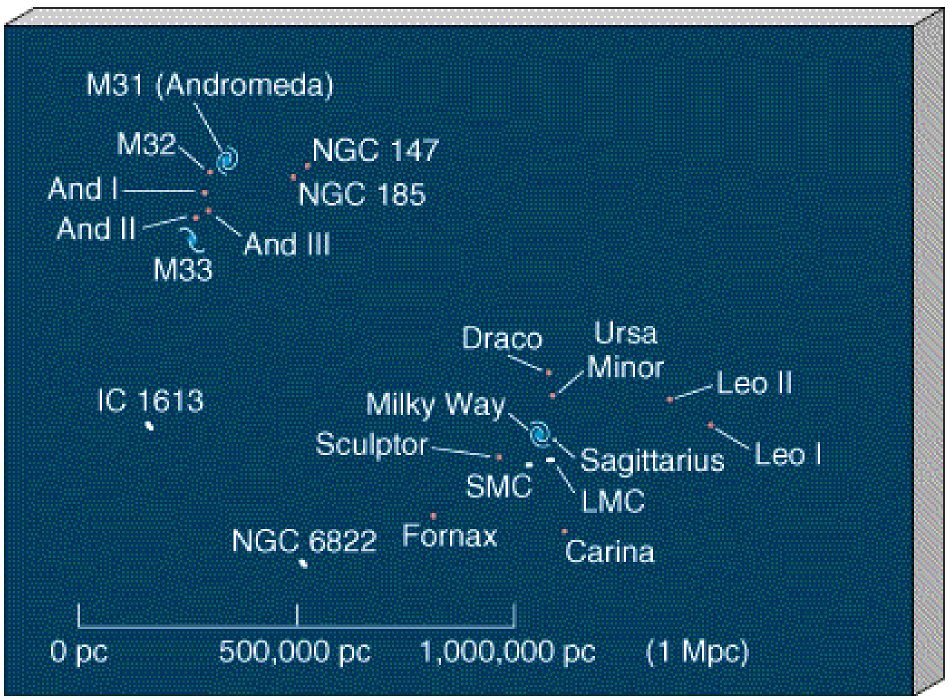
Looking at distant galaxies is like looking back in time.

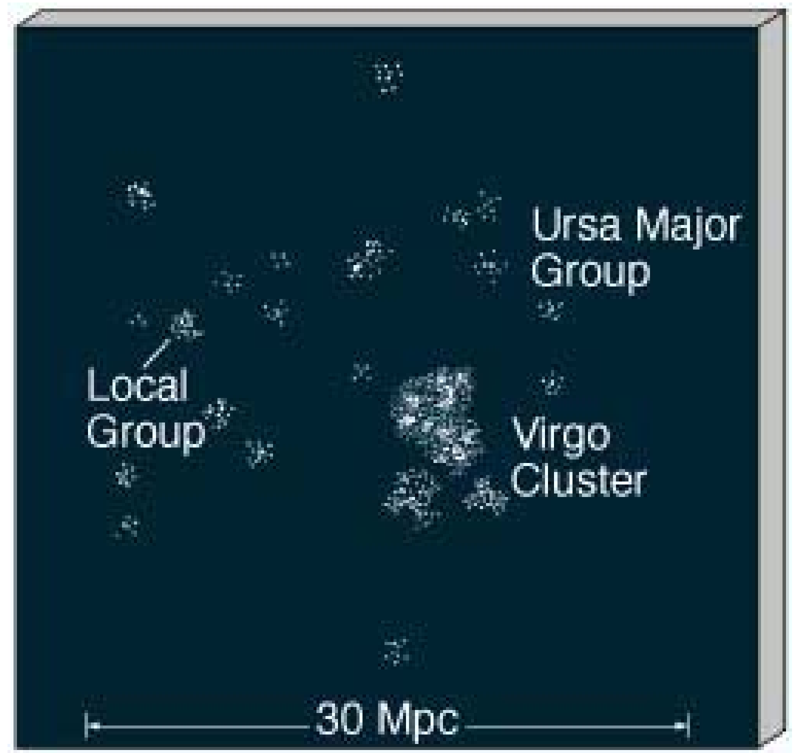
Map of the night time sky



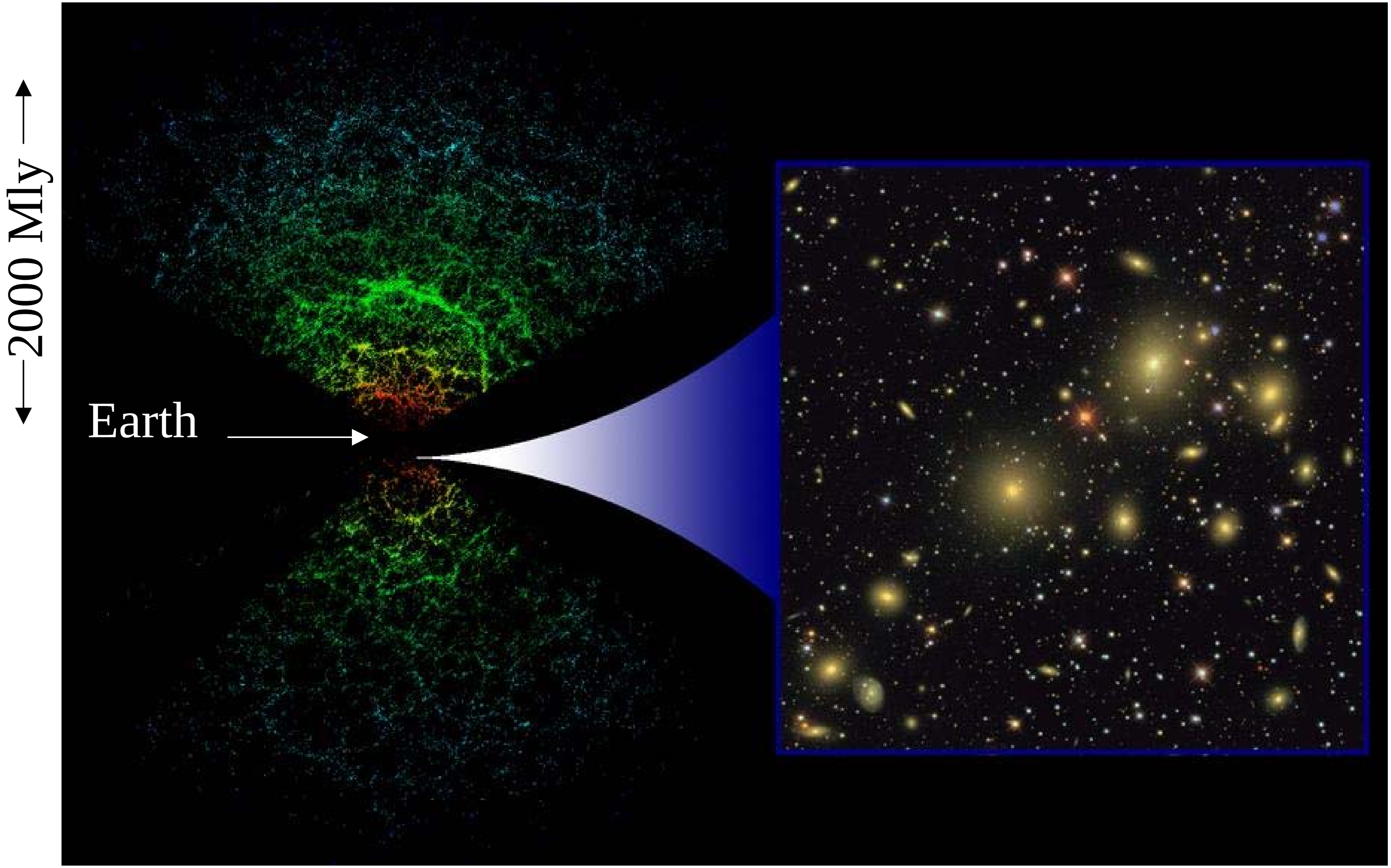
The Great Galaxy in Andromeda – M31

The structure of our local set of galaxies

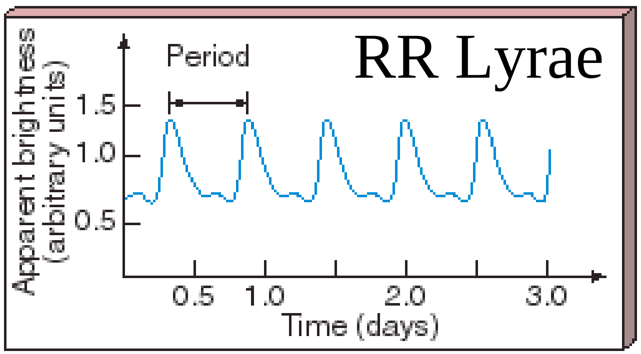


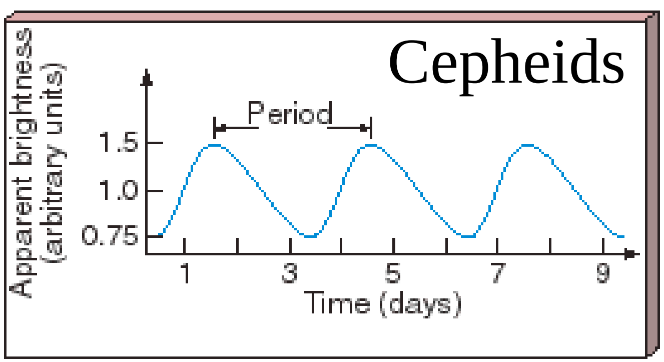


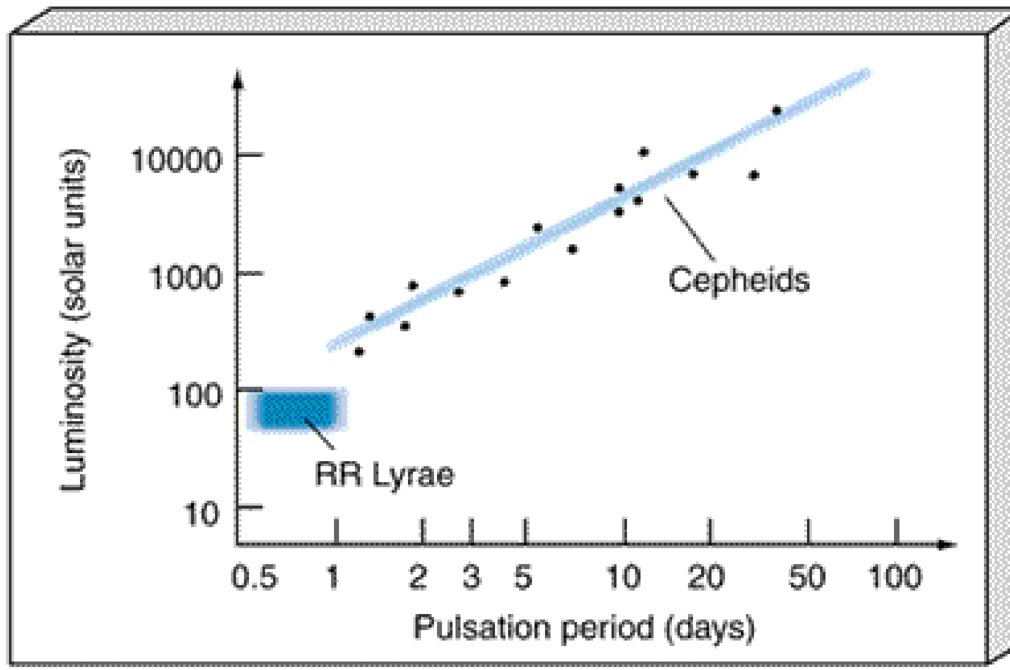
Sloan Digital Sky Survey of Galaxies



Variable Stars – standard candles







Once you find a variable star, you know how luminous it is.

A Sample Problem

- Suppose star A and star B have the same luminosity.
- If star A is 5 times brighter than star B, what can we say about their relative distances?
- Star B is farther away

$$brightness = \frac{\text{luminosity}}{4\pi(\text{distance})^2}$$

$$\frac{b_a}{b_b} = \frac{L_a / 4\pi d_a^2}{L_b / 4\pi d_b^2} = \frac{d_b^2}{d_a^2} = 5 \Rightarrow d_b = \sqrt{5} \cdot d_a$$

Hubble Expansion

- Hubble observed that on average all galaxies seem to be moving away from us.
- The speed is related to distance. Galaxies farther away are moving faster
- Hubble Law:

$$\text{velocity} = \text{H}_0 \cdot \text{distance}; \text{H}_0 = 20\frac{km/s}{Mly}$$

- If a galaxy is observed to be moving away at 2000 km/s, we expect the galaxy is v/H_0=100 Mly away

How do we determine distances?

- Radar – nearby things like the Sun
- Parallax – 1 arcsec motion 1 pc = 3.24 ly
- Spectroscopic parallax – use location on the Hertzsrpung Russell diagram
- Variable stars – to nearby galaxies
- Supernova – to nearby clusters of galaxies
- Hubble Law – to farther galaxies and quasars
- Brightness of bright galaxies (Tully-Fischer Relation) to the farthest galaxy clusters.

Clicker Question

- What would be the best way to measure the distance to galaxies more than 10 billion light years away? Choose the best answer.

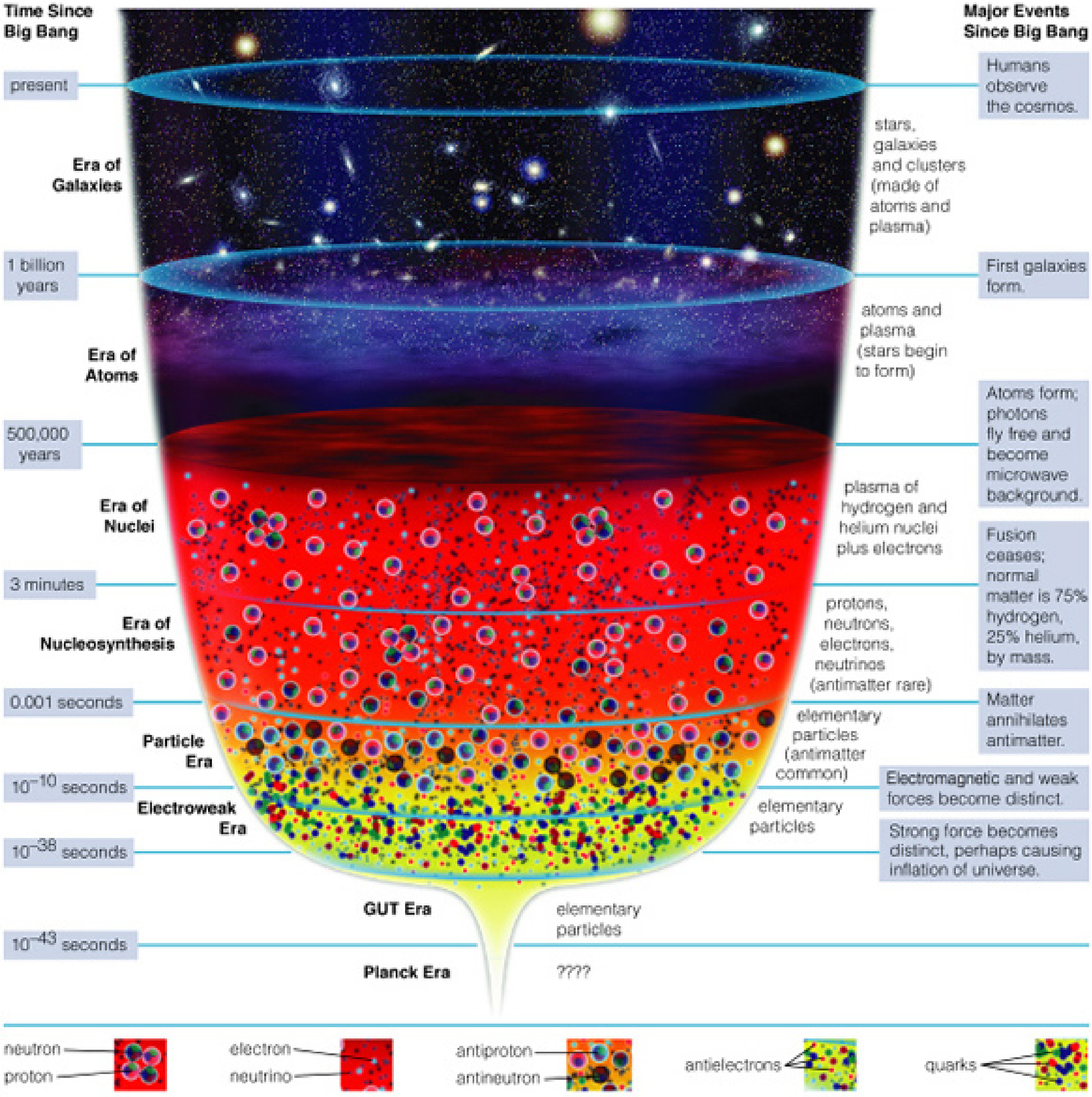
A. the recession velocity of nearby stars

B. Cepheid variable stars

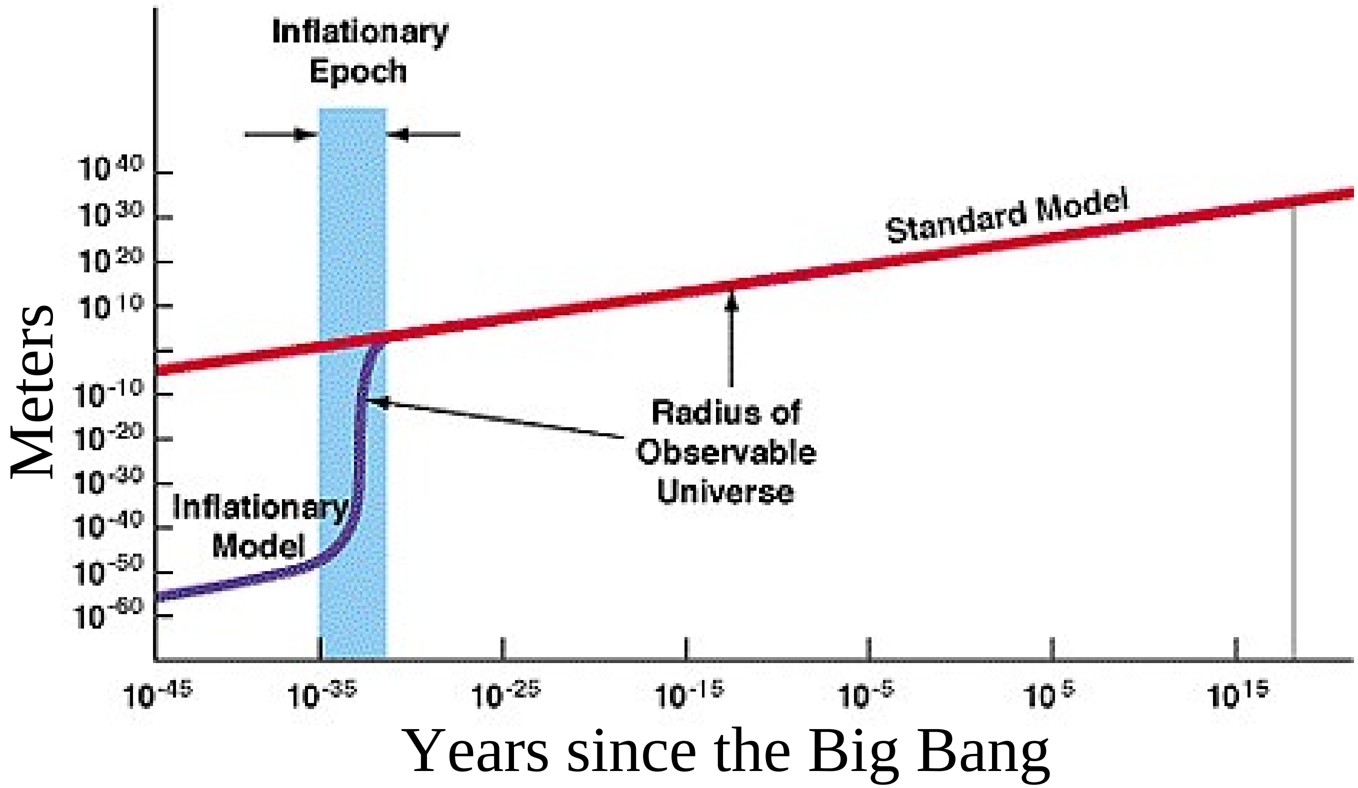
C. parallax

D. radar

E. the recession velocity of quasars

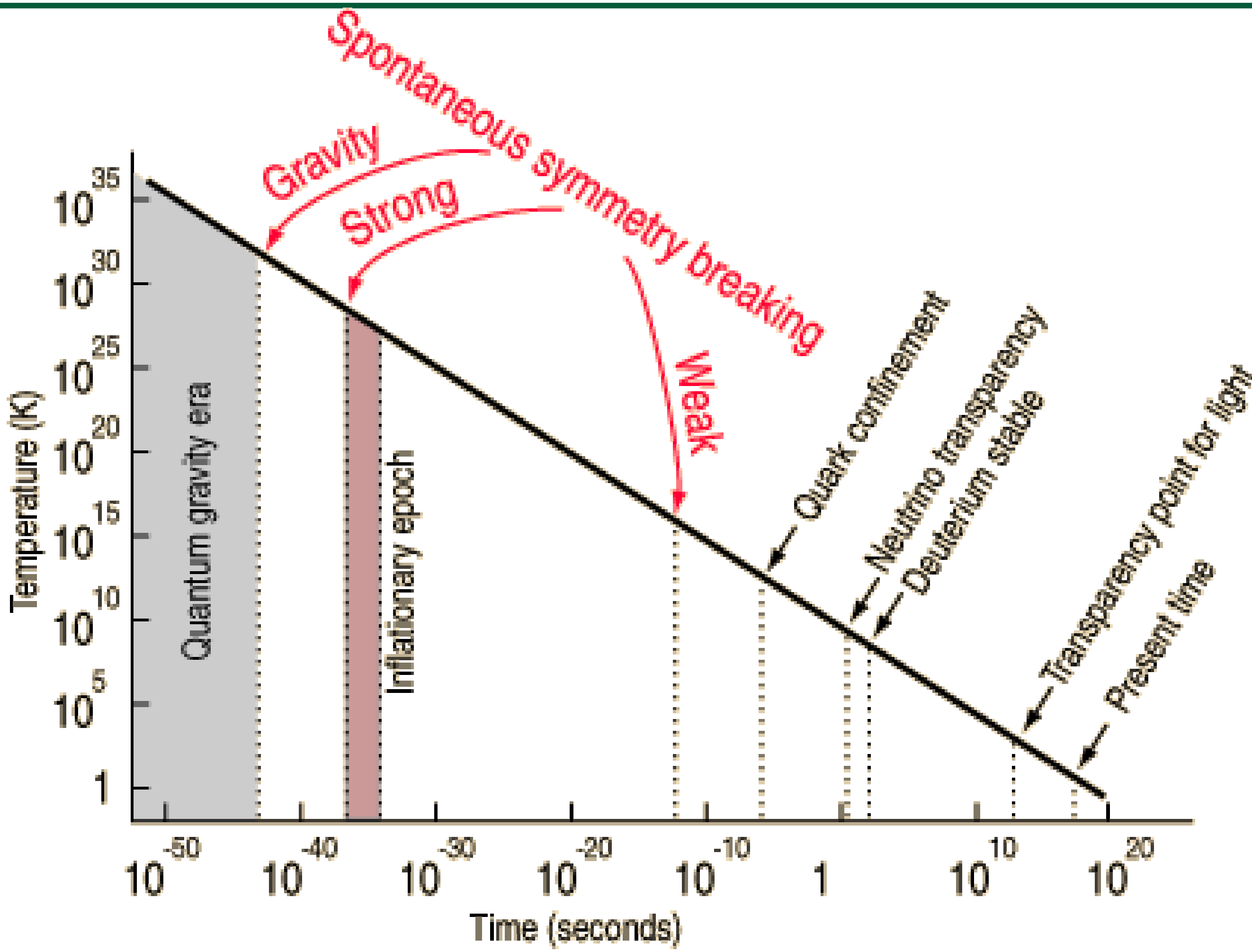

Time Since Big Bang
Major Events Since Big Bang
present
Humans observe the cosmos.
Era of Galaxies
stars, galaxies and clusters (made of atoms and plasma)
1 billion years
First galaxies form.
Era of Atoms
atoms and plasma (stars begin to form)
500,000 years
Atoms form; photons fly free and become microwave background.
Era of Nuclei
plasma of hydrogen and helium nuclei plus electrons
3 minutes
Fusion ceases; normal matter is 75% hydrogen, 25% helium, by mass.
Era of Nucleosynthesis
protons, neutrons, electrons, neutrinos (antimatter rare)
0.001 seconds
Matter annihilates antimatter.
Particle Era
elementary particles (antimatter common)
10^{-10} seconds
Electromagnetic and weak forces become distinct.
Electroweak Era
elementary particles
10^{-38} seconds
Strong force becomes distinct, perhaps causing inflation of universe.
GUT Era
elementary particles
10^{-43} seconds
Planck Era
????
neutron
proton
electron
neutrino
antiproton
antineutron
antielectrons
quarks

Inflation



The existence of an unknown scalar field caused the rapid inflation of the Universe

Big Bang Timeline (the early moments)



Clicker Question

- Which of the following events occurred earliest in the Big Bang? Choose the best answer.

A. hydrogen and helium were made
B. the era of inflation
C. electrons combined with nuclei
D. galaxies formed
E. stars formed

What is the Ultimate Fate

- 10^{100} years – all the stars will have used their fuel
- 10^{100} to 10^{150} years "dark ages"
- 10^{150} years all black holes will have evaporated
- 10^{1000} years the Universe will reach its lowest energy state
- The current age of the Universe is 13.7 billion years 10^{10} years

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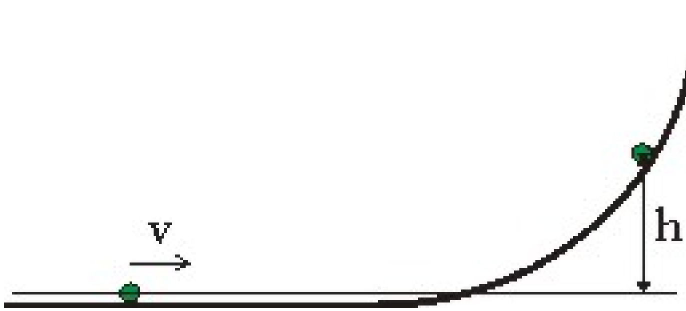
Conservation of Energy

Example: Ball on a hill

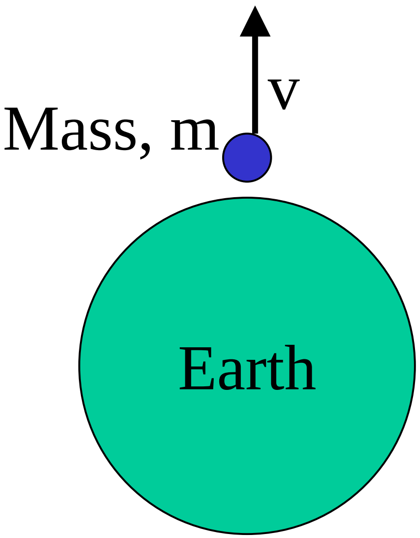


A 1.00 kg ball is rolled toward a hill with an initial speed of 5.00 m/s. If the ball roles without friction, how high, h, will the ball go?

$$KE = \frac{1}{2}mv^2 \quad PE = mgh\,;\, g = 9.80\frac{m}{s^2}$$

$$\frac{1}{2}mv^2 = mgh \rightarrow h = \frac{v^2}{2g} = \frac{(5\,m/s)^2}{2\cdot 9.80\frac{m}{s^2}} = 1.28\,m$$

Escape Velocity



The velocity to completely escape the gravity of a planet is:

$$KE(leaving) = PE(far\ away)$$

$$\frac{1}{2}mv^2 = \frac{GmM_{planet}}{R_{planet}}$$

$$v = \sqrt{\frac{2GM_{planet}}{R_{planet}}}$$

The escape velocity for the Earth is about 11 km/s. See the homework problems for examples.

Clicker Question

- What would happen to the escape velocity of a planet if the mass of the planet were 4 times larger?

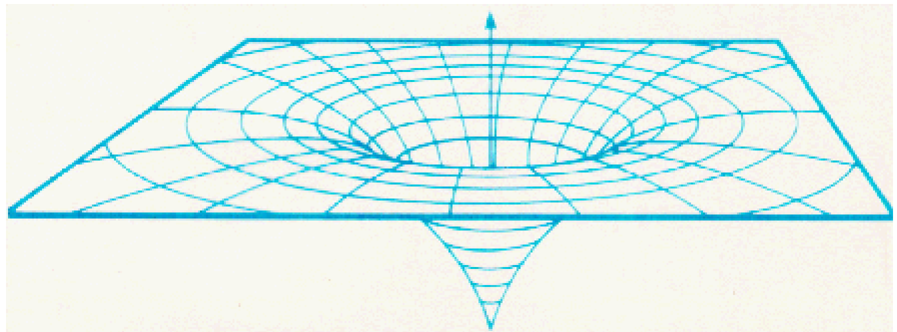
A. It would be 2 times larger

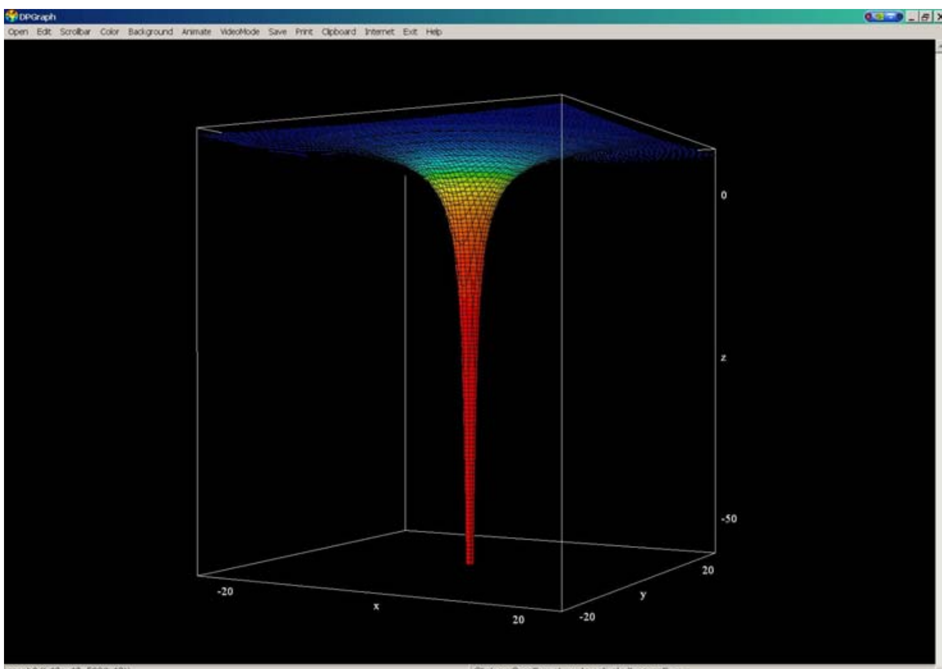
B. It would be 2 times smaller

C. It would be 4 times larger

D. It would be 4 times smaller

Black Holes





The “hole” in space is so deep that light can not escape.

Black Holes

- Black holes act as a lens. They don't necessarily look "black".
- They range from 3 solar masses to more than a billion solar masses.
  - Small ones are formed by the collapse of a large star
  - Larger ones form at the center of galaxies
- We can tell they exist because of thing orbiting nothing, and the radiation given off as things fall into them.
- If the Sun were a black hole the Earth would still orbit it.
- The distance from the black hole where gravity is so strong that even light cannot escape is called the event horizon or the Schwarzschild radius.

The Second Law of Thermodynamics

- Statement: The entropy of an isolated system never decreases.
- Statement: No device can transform a given amount of heat completely into work.
- Statement: Natural process tend to move toward a state of greater disorder.
- Consequence: Time appears to have a direction.

Entropy

- Entropy is a measure of the number of states possible in a system. We usually use the symbol S.
- The unit is J/K   (*joules/Kelvin*)
- Formula: S = k ln(W), where k=1.38E-23 J/K and W is the number of possible states of a system.
- Alternative formula: S = heat/temperature

Two examples

What is the entropy of a deck of cards that has one pair?
Data: there are 1,098,240 to order such a deck.

S = 1.38E-23 J/K ln(1,098,240)= 1.92E-22 J/K

How much is the entropy of a glass of water increased if 1.0 J of heat is added when the water is at 295 K. Assume the temperature rise of the water is small.

S = 1.0 J / 295 K = 3.39E-3 J/K

Coin Tosses

- Suppose we have 20 coins: HHHHHHHHHH
  $S = k \ln(1) = 0$

Heads	Number of ways	Entropy (J/K) $*10^{-23}$
9	10	3.18
8	45	5.25
7	120	6.61
6	210	7.38
5	252	7.63
4	210	7.38
3	120	6.61
2	45	5.25
1	10	3.18

Why does time always move in one direction?

- Inflation during the Big Bang resulted in a universe that had a very low entropy. Much too low for its size. It is like the Universe started with all heads.
- Hence, everything in the Universe moves toward reaching the correct amount of entropy.
- Time has a direction because going back in time would imply the entropy could be decreased. That is very improbable.
- The Universe tends toward increasing entropy.
- What is time?

What is the Ultimate Fate

- 10^{100} years – all the stars will have used their fuel
- 10^{100} to 10^{150} years “dark ages”
- 10^{150} years all black holes will have evaporated
- 10^{1000} years the Universe will reach its lowest energy state
- The current age of the Universe is 13.7 billion years 10^{10} years

What We Made Of?

- We are made out of atoms. The size of atoms is 10^{-9} m = nm
- Atoms are made of nuclei and electrons (+ energy; $E=mc^2$)
- Nuclei are made of neutrons and protons (plus the stuff that binds them, mesons)
- Neutrons, Protons and Mesons are made of quarks (10^{-16} m). We can measure down to 10^{-18} m
- What are quarks made of? The answer may be strings, but the size is 10^{-35} m too small for us to explore (at the moment).
- What are strings made of?

Department of Physics and Astronomy

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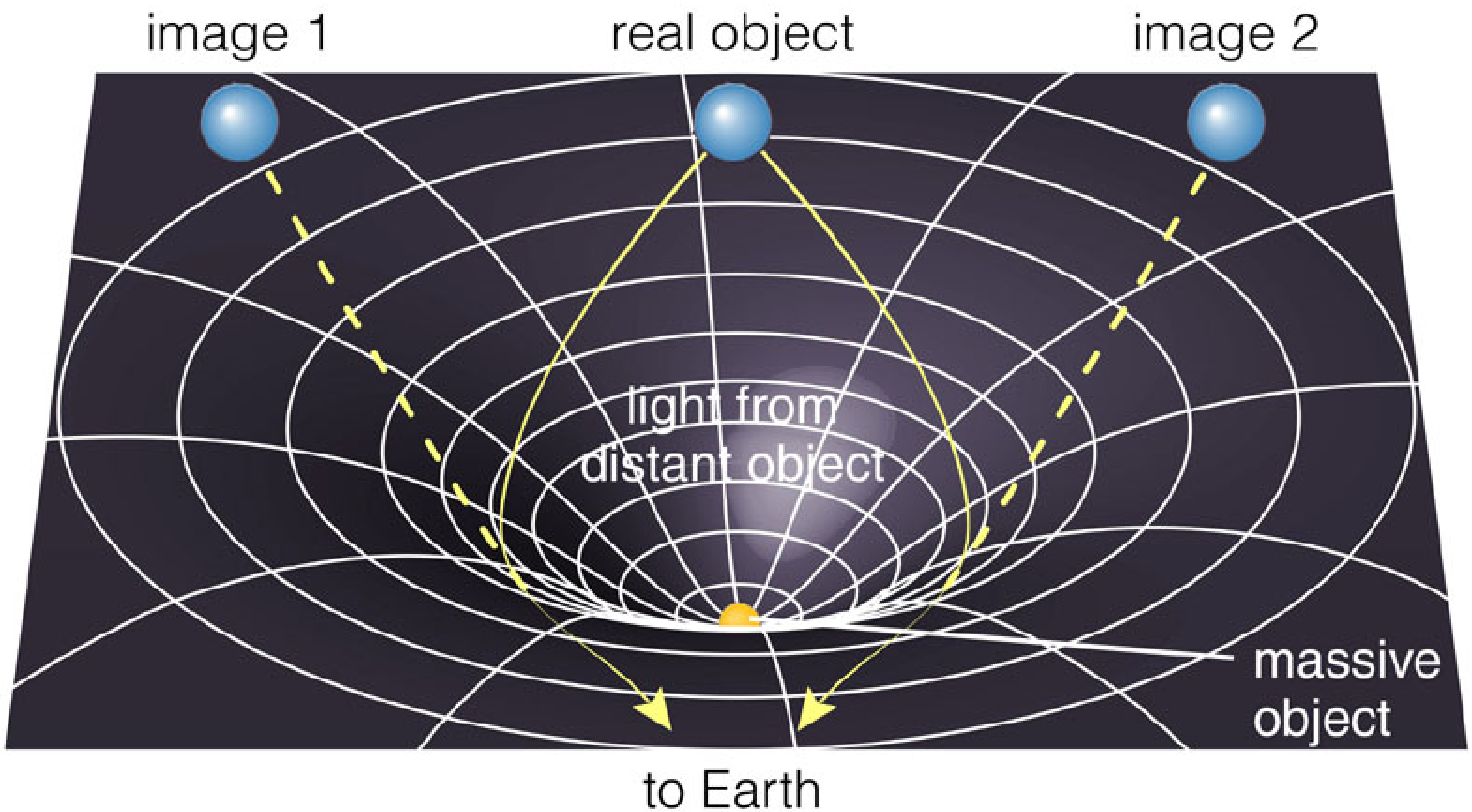
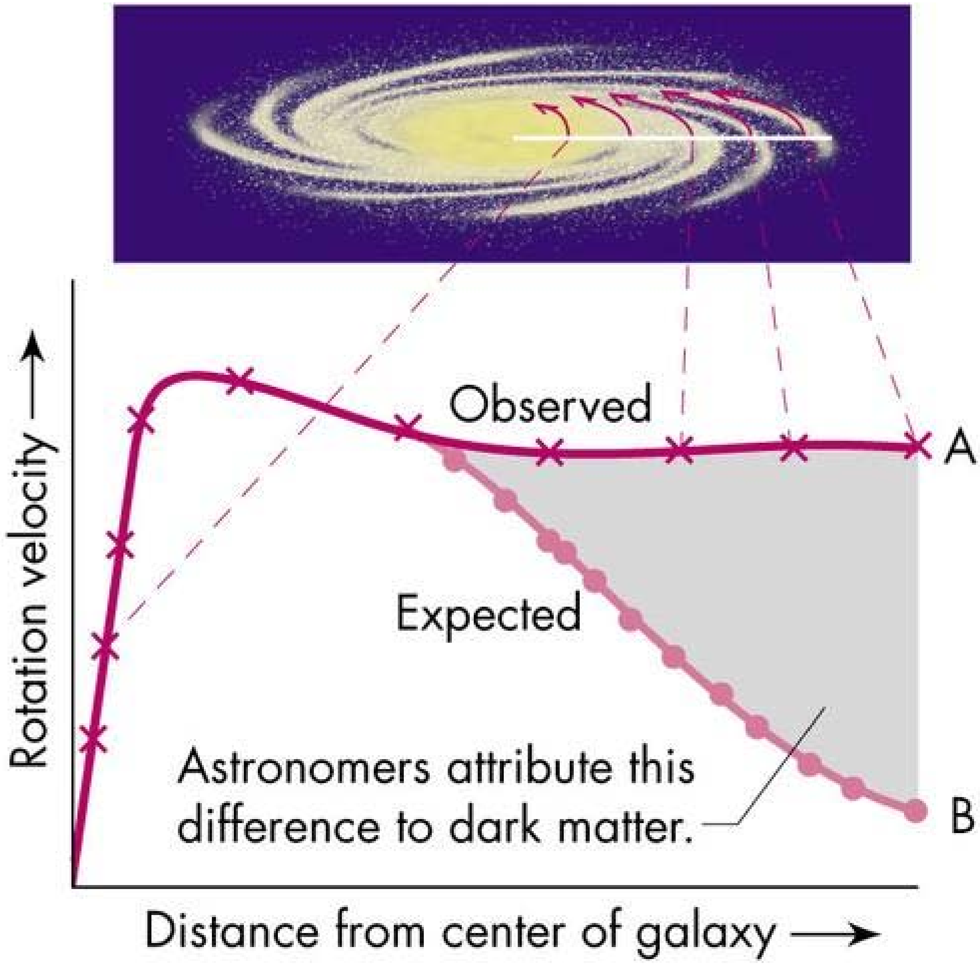
Most of the Universe is Dark Matter

- There are three main pieces of evidence that there is much more mass in the universe than that from luminous matter.
  - Gravitational lensing
  - Rotation curves of galaxies
  - Fluctuations in the cosmic microwave background radiation
- It turns out that only 4% of the Universe is made of the same stuff as us.

Gravitational Lensing results from General Relativity



Rotation Curves

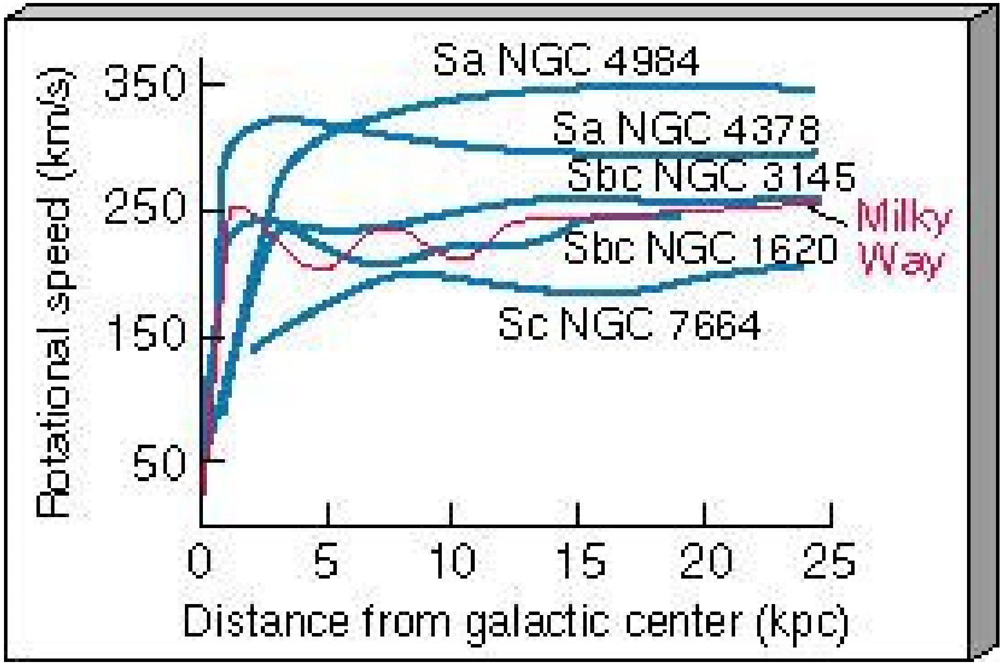


Rotation implies acceleration

The force that supplies the acceleration is gravity. More gravity implies a faster rotation.

There is more rotation and hence more gravity than expected at large radii.

Most galaxies show this behavior



Conclusions: Galaxies contain a fairly uniform distribution of dark matter. We don't know what this stuff is.
The local density is 5.38E-28 kg/cm^3

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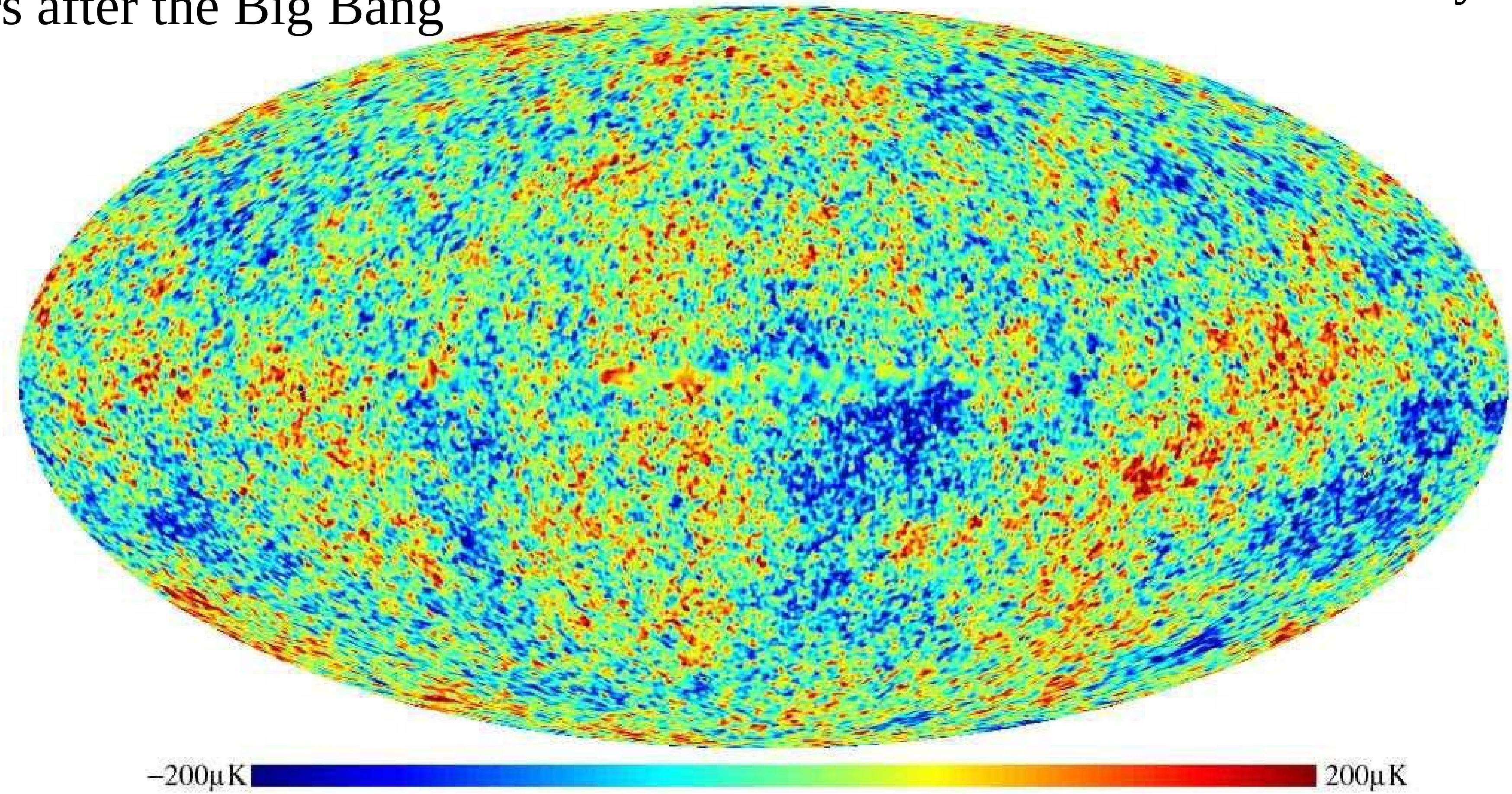
Fluctuations in the Cosmic Background

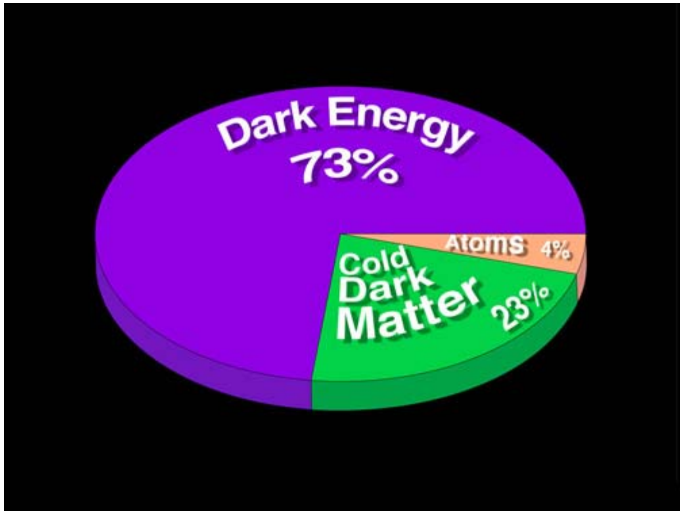
Image of the universe at about 300,000 years after the Big Bang

WMAP observatory



What we have learned from WMAP

- Within a 1% accuracy the Universe is 13.7 billion years old.
- We don't know what 96% of the Universe is made of.
- The first stars formed about 200 million years after the Big Bang.
- The picture of the background microwave radiation is from 379,000 years after the Big Bang.
- At the present it appears the Universe will expand forever, but since we don't know what dark energy is, this conclusion could change.



What are Dark Matter and Dark Energy?

- We don’t know.
- Dark energy actually acts like anti-gravity and is pushing the universe apart. We can tell this because distance supernova are moving away faster than they should.
- Dark matter is probably some type of undiscovered particle.
  - These Particles may interact by the weak force (they do interact by gravity)
  - People are looking for WIMPs (Weakly interacting massive particles)