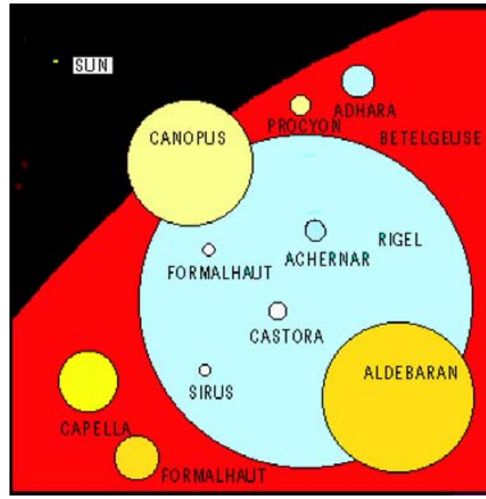
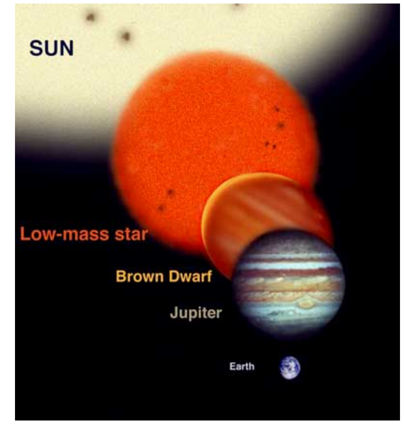
Today – Exam#3 Review

- Exam #3 is Thursday April 24th in this room, BPS 1410; Extra credit is due 8:00 am Tuesday April 29
- Final Exam is 3:00pm Monday April 28 in BPS 1410
- The exam is 40 multiple choice questions. There are two or three 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)

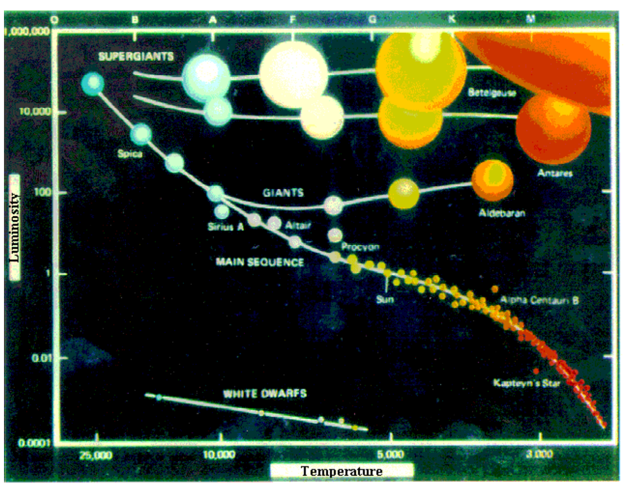
Relative Sizes of Stars



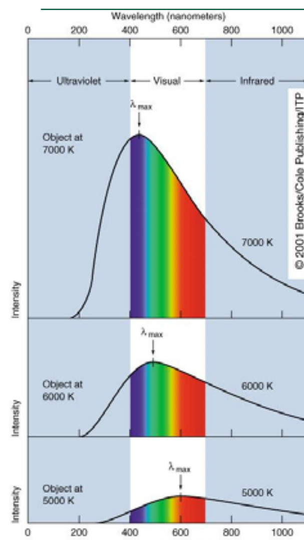


Blue – hot Red - cooler

Hertzsprung-Russell Diagram



Blackbody Radiation



All objects emit a spectrum of photons. A perfect black body has the spectrum shown at the left.

The emission spectrum depends on temperature, T. The amount depends on surface area, A and temperature T.

$$L = \sigma A T^4 \; ; \sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$$

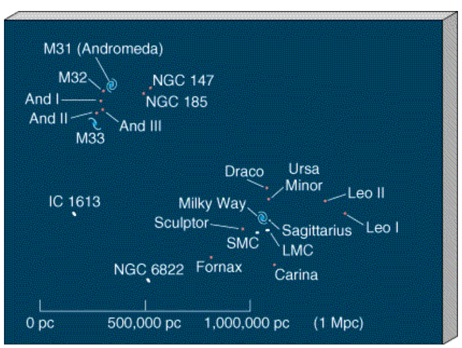
How do stars do it?

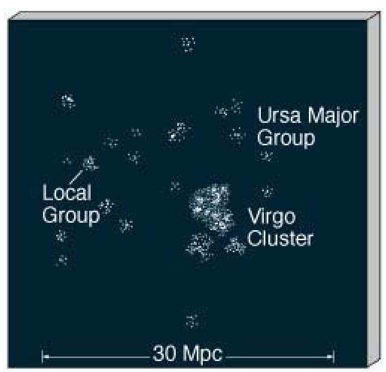
- The color of a star depends on its Temperature (blue, more hot – red, more cool)
- In 5 billion years, the Sun will become a red giant and then, later, a white dwarf
- Stars generate energy by fusing lighter elements into heavier elements. This is where most atoms in our bodies were made.

How did the Universe Begin?

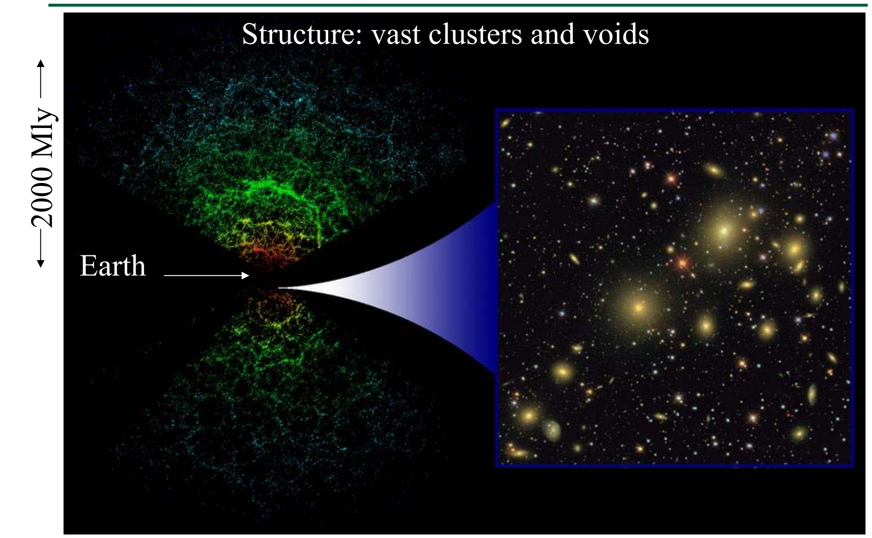
- Evidence points to the Universe beginning in a hot fireball 13.7 billion years ago. We call this the Big Bang
- Evidence for the Big Bang
  - Expansion of the Universe
  - The Big Bang model correctly predicts the formation of the light elements observed to be present in the early universe (mostly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

The structure of our local set of galaxies

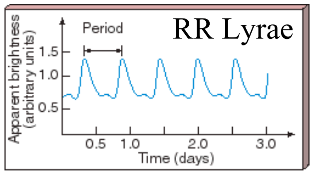


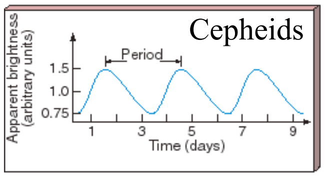


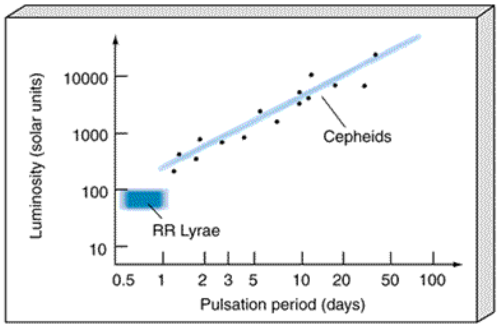
Sloan Digital Sky Survey of Galaxies



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

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

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

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:

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

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

The Universe as we know it now

Us → Nearest Star 3 ly
Sun 1.6E-8 ly

Expand by 1,000,000

Us → Virgo Cluster 30 Mly
Local Group 3 Mly

Expand by 50,000

Us → Edge of Universe 80 Bly
Edge of visible universe 13.6 Bly
Farthest Quasars and Galaxies 13 Bly

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

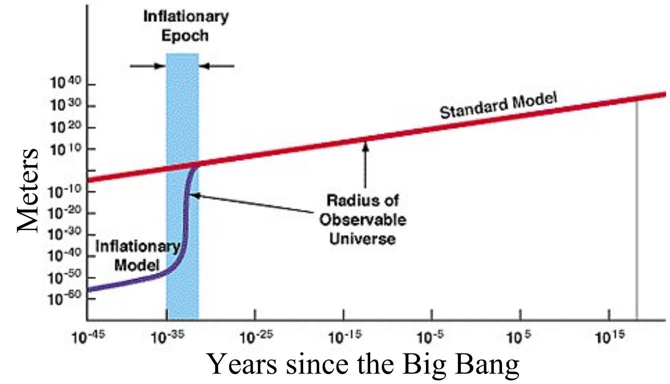
B.Cepheid variable stars

C.parallax

D.radar

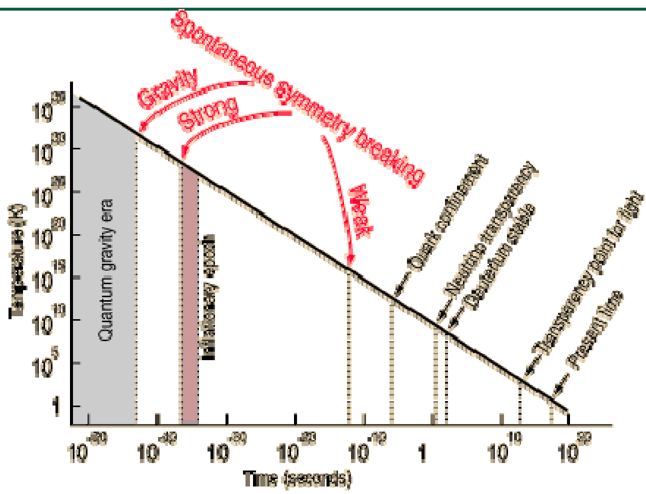
E.the recession velocity of quasars

Inflation



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

Big Bang Timeline (the early moments)



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?

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 where universe grew by 10^{50} times

C. electrons combined with nuclei

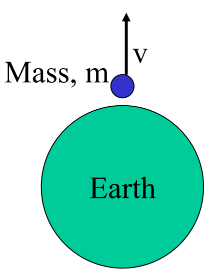
D. galaxies formed

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
- Note: The current age of the Universe is 13.7 billion years 10^{10} years

Escape Velocity



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

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

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 radius of the planet were 2 times larger and the mass was the same?

A. It would be √2 times larger

B. It would be √2 times smaller

C. It would be 2 times larger

D. It would be 2 times smaller

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

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Clicker Question

What would happen to the escape velocity of a planet if the mass of the planet were 4 times larger and the radius was the same?

A.It would be √2 times larger

B.It would be √2 times smaller

C.It would be 2 times larger

D.It would be 2 times smaller

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

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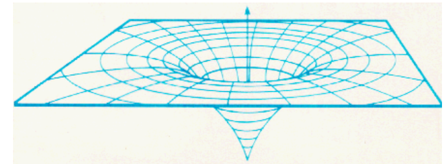
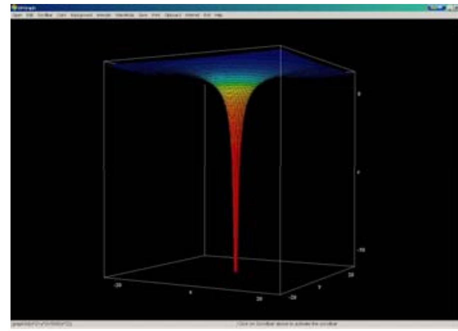
Black Holes





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

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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
  - Typical event horizon for a black hole with the mass of our Sun is 15 km
- 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.

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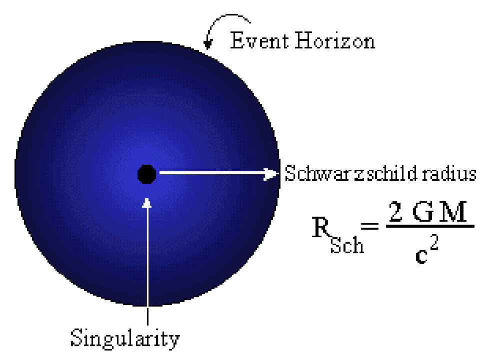
Parts of a black hole



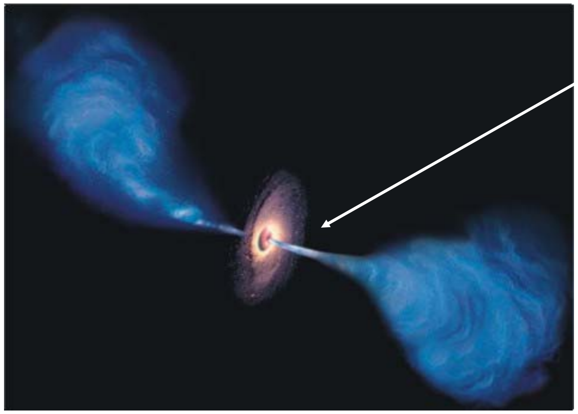
$$R_{Sch} = \frac{2GM}{c^2}$$

Clicker Question

What would happen to the event horizon of a black hole if the mass were doubled?

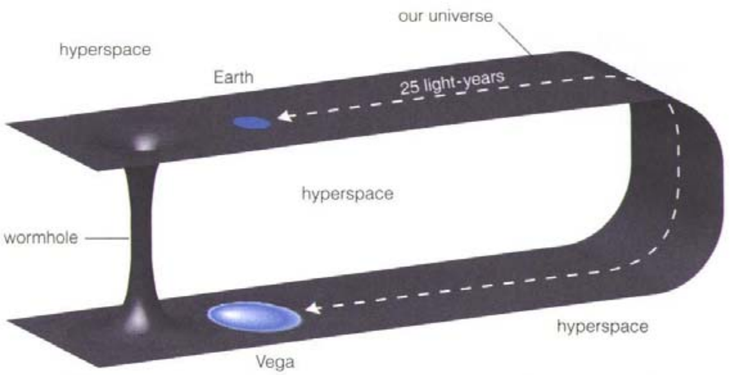
a) it would be 4 times larger
b) it would be half as large
c) it would be one-fourth as large
d) it would double
e) it would stay the same

Model for Quasars, Radio Galaxies, Active Galaxies



Supermassive black hole $10^9\ M_{sun}$

Wormholes



Wormholes

- Wormholes are a possible solution to Einstein's equations.
- If there are wormholes, there must be white holes. No white hole has ever been observed.
- We think a white hole is not stable since material would collect near the opening and collapse the white hole to a black hole.
- Some type of exotic material (that acts as antigravity) is necessary to keep the white hole end open.

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What We Made Of?

- We are made out of atoms. The size of atoms is 10^{-9} m
- Atoms are made of nuclei and electrons (+ energy; $E=mc^2$)
- Nuclei are made of neutrons and protons (plus the energy that binds them)
- 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?

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String Theory and the Standard Model

- "Standard Model" is a collection of the currently known particles and the forces between them. It does not answer "Why".
- The LHC at CERN is searching for the Higgs particle to explain where mass comes from and for dark matter.
- Know that science is trying to find one theory that describes everything. Part of this quest is to understand how all the forces are related.
- Know that String Theory tries to describe everything in terms of vibrating strings. The size of the strings is 10^{-35}m.
- The minimum number of dimensions for M-theory to work is 11.
- We experience only 4 dimensions. The others are too small.
- String Theory as a whole has not yet made falsifiable predictions. Another problem with String Theory is the Landscape problem, which is that sting theory may not explain why our Universe is as it is.

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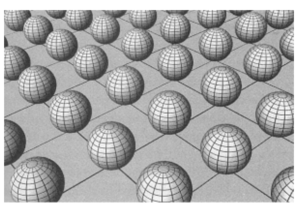
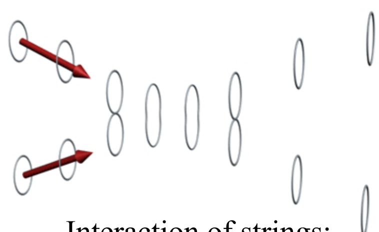
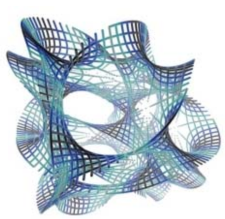
String Theory Pictures



Extra dimensions



Interaction of strings:
The finite size (10^{-35}m) overcomes many of the problems with the interaction of point particles.



What one of the dimensions might look like. Calabi-Yau space

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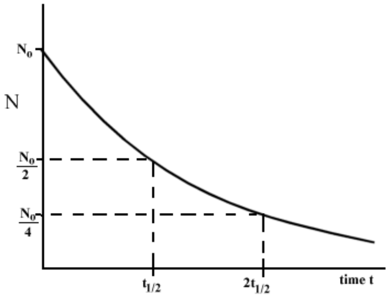
Atomic Nuclei

- Number of protons determines the atomic number and chemical nature.
- The isotope is determined by the number of neutrons.
- 14-C has 6 protons (that makes it carbon, C) and 14-6=8 neutrons.

Half life

Radioactive decay is governed by the rules of probability. If we start with N atoms, in the time of one half-life on average half will have decayed. In the next half life, half of those remaining will have decayed, and so on.



$$f = \frac{N(t)}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

$$if\ t = 2t_{1/2}$$

$$f = \frac{N(2t_{1/2})}{N_0} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

Sample Problem

The amount of 14-C in an old sample is 0.125 of the expected amount. How old is the sample? DATA: Assume the half-life of 14-C is 6000 years.

A)6000 years
B)12,000 years
C)18,000 years
D)24,000 years
E)30,000 years

$$N(t) = N_0\left(\frac{1}{2}\right)^{\text{number of half - lives}}$$

Half-life fraction table

Time (half-lives)	Fraction, f
0	1
1	.5
2	.25
3	.125
4	.0625
5	.03125

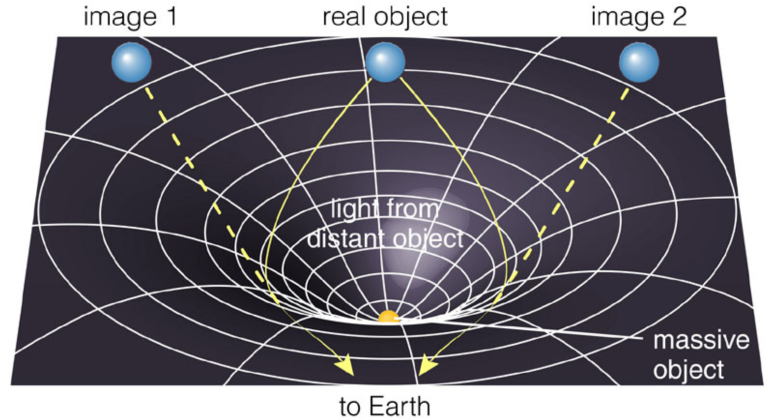
Life in the Universe

- The one ingredient for life of Earth is liquid water
- Liquid water might be found on Mars, the moons of Jupiter (e.g. Europa) and moons of Saturn
- The Drake Equation can be used to estimate the number of technological civilizations we might be able to communicate with

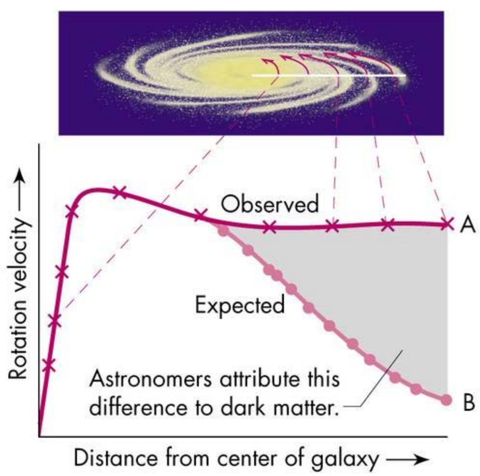
Most of the Universe is Dark Matter

- 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

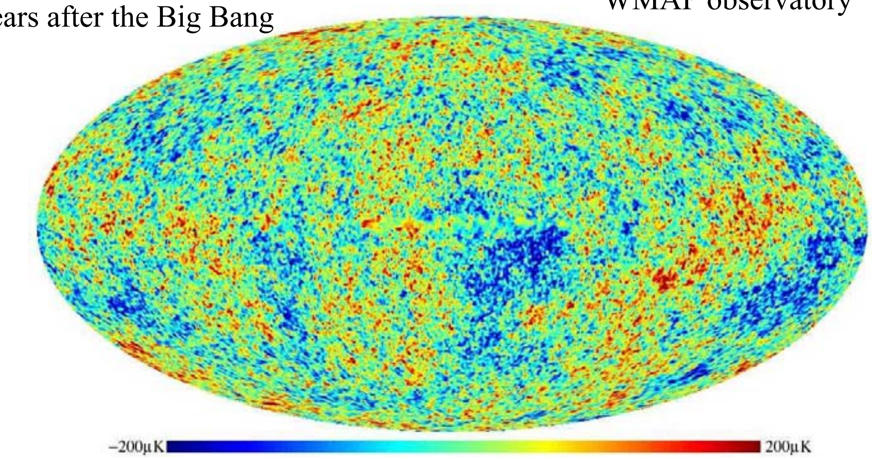
The force that supplies the acceleration is gravity. More gravity implies a faster rotation.

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

Fluctuations in the Cosmic Background

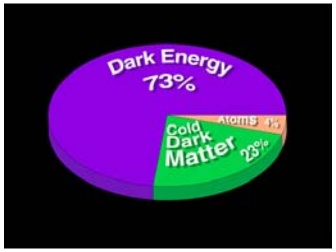
Image of the universe at about 379,000 years after the Big Bang

WMAP observatory



What we have learned from WMAP

- Within a 1% accuracy (100 million years) 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.



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)