# Today

- Announcements:
  - HW#10 is due April 11 at 8:00 am
  - HW#11 (Last one!) is due April 18 at 8:00 am. There are two short paragraphs to write.
  - Voting for the Spring Break Story is due April 18 at 8:00am.
  - Intellegent Design Extra Credit is due April 25 at 8:00 am
- The nature of the Universe

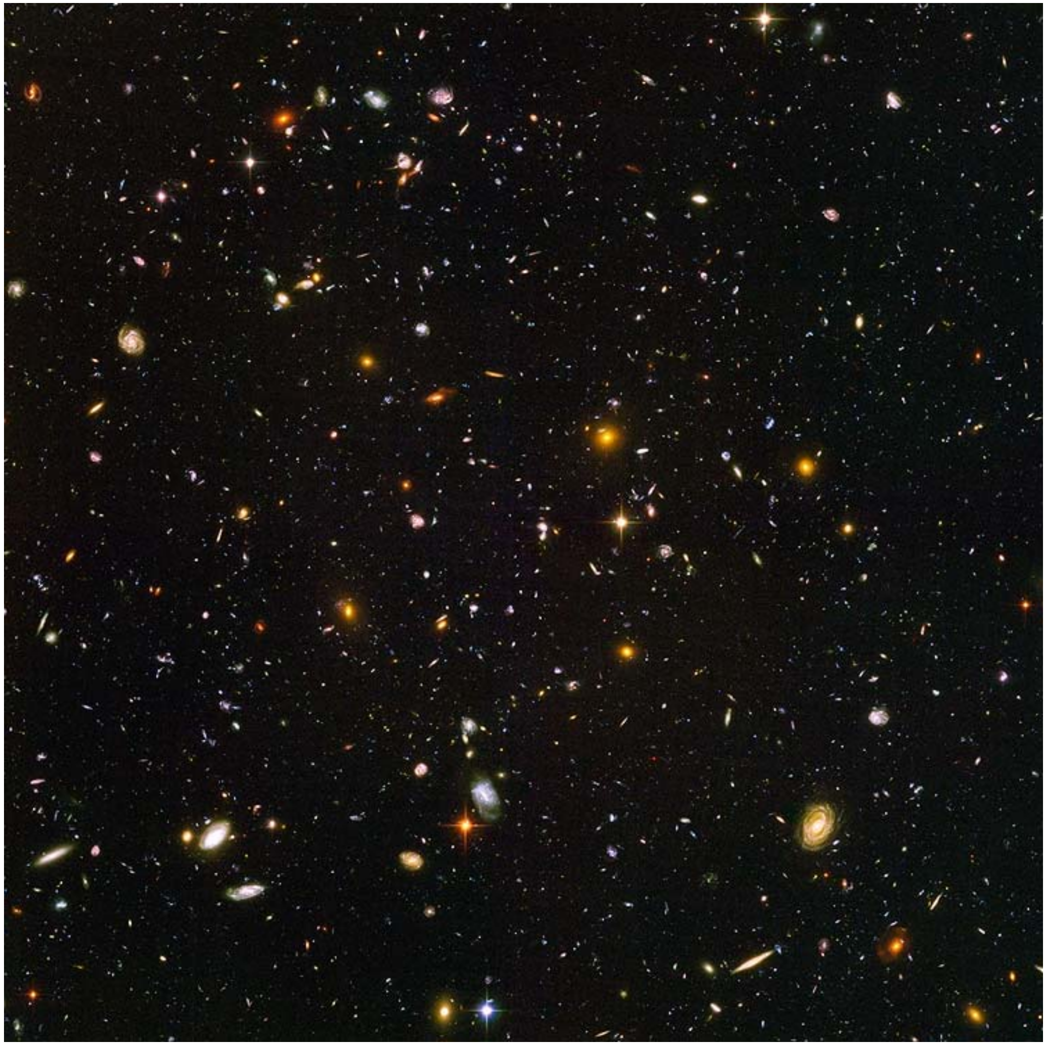
# Lecture on Thursday

- Dr. Byron Jennings will join us to talk about how science works and its relation to religion.
- Read his paper and come prepared to ask questions. LINK
- He would enjoy a lively discussion
  - What are the limits of science?
  - Are science and religion incompatible views of nature?
  - Plus whatever you want to ask…

# The goals of science

- Reach an understanding based on the fundamental building blocks of nature and their interactions.
- Human bias – simple is better; one equation should describe everything (goal of string theory)
- The standard model is our current collection of fact. It does not answer the why question.

# What do we know about the Universe?

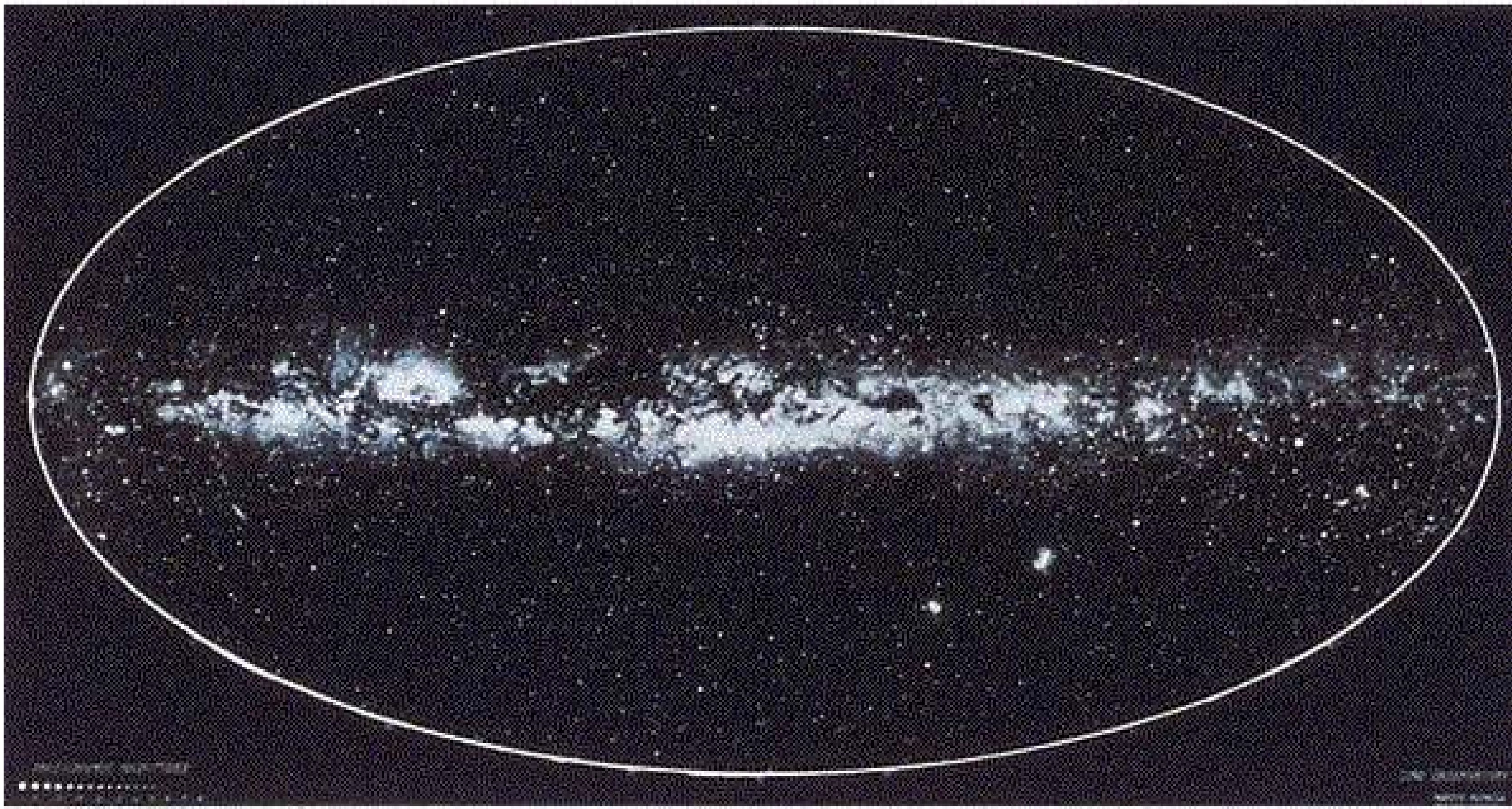


Picture of distant galaxies taken by the Hubble Space Telescope

There are approximately 200 billion galaxies

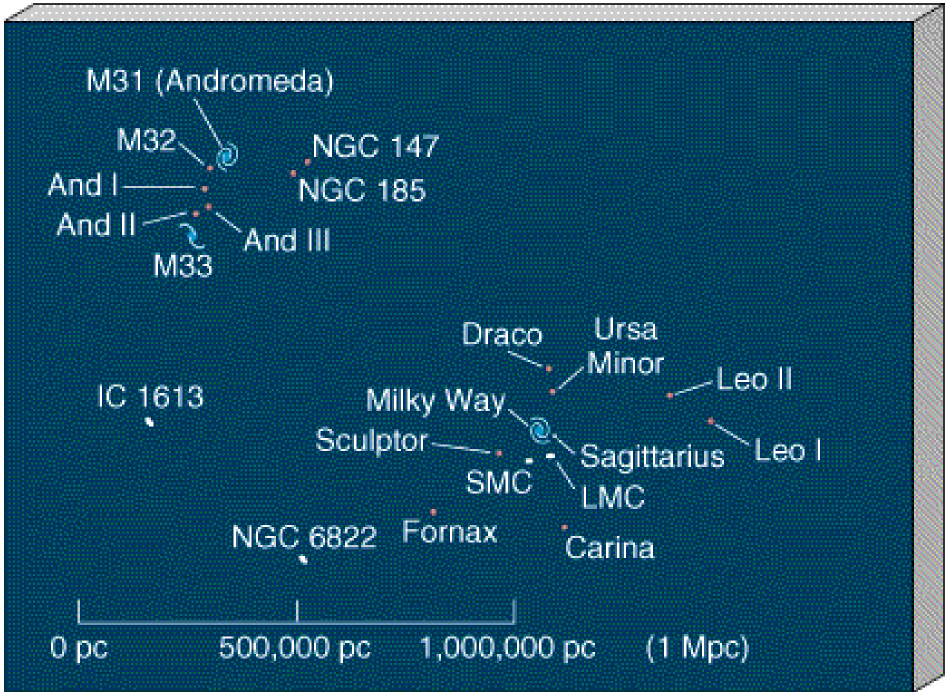
Looking at distant galaxies is like looking back in time.

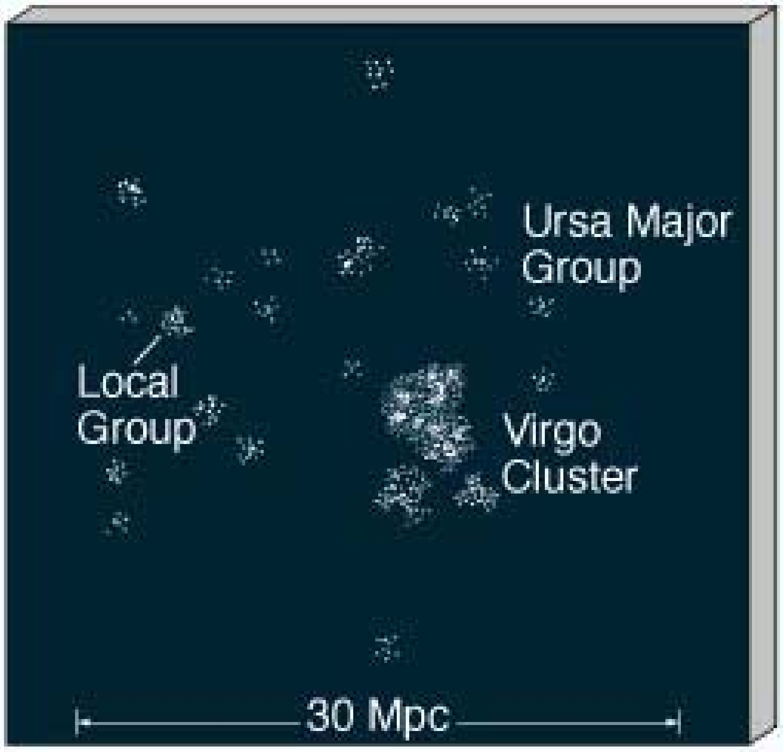
# Map of the night time sky



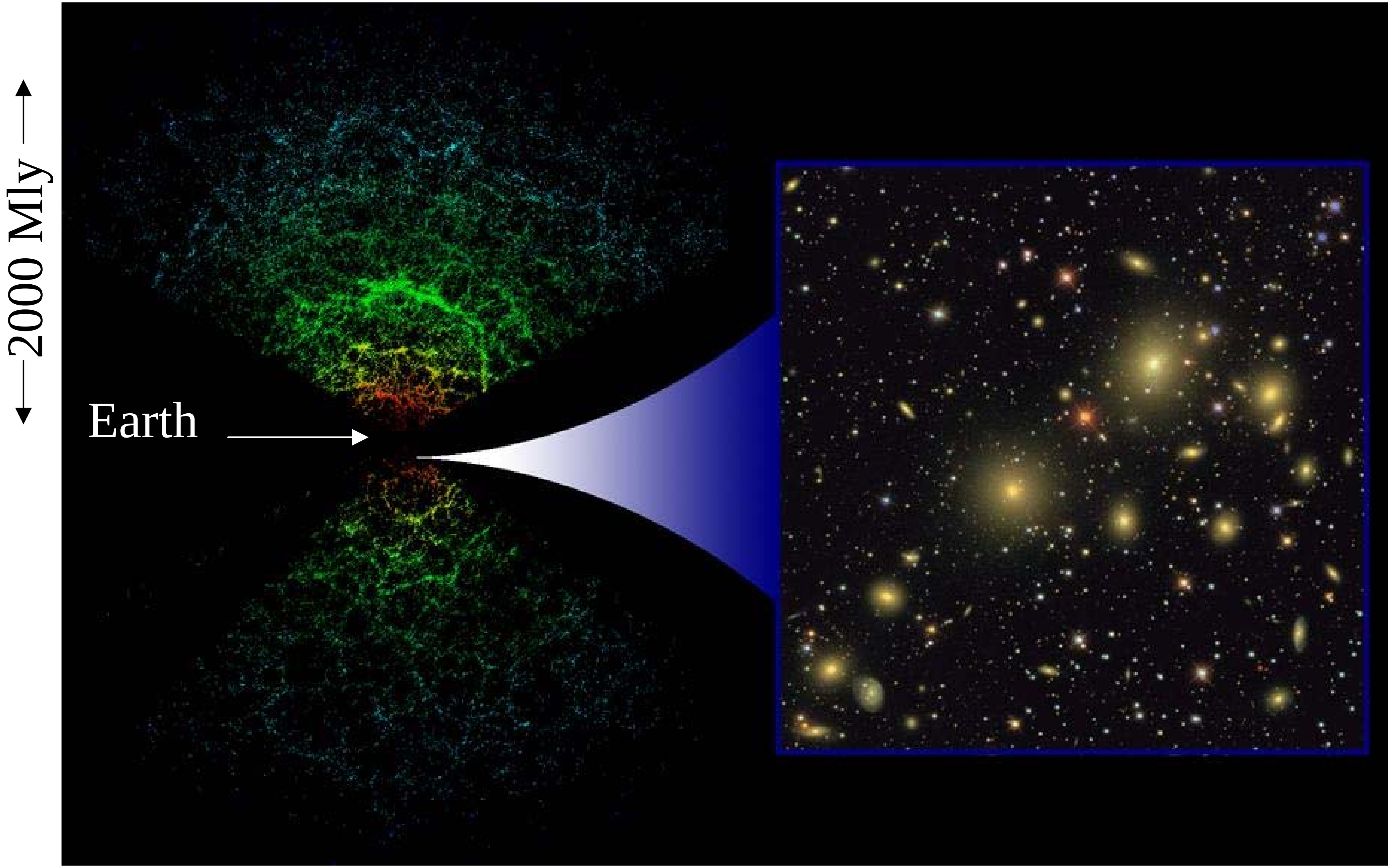
# The Great Galaxy in Andromeda – M31

# The structure of our local set of galaxies



# Sloan Digital Sky Survey of Galaxies



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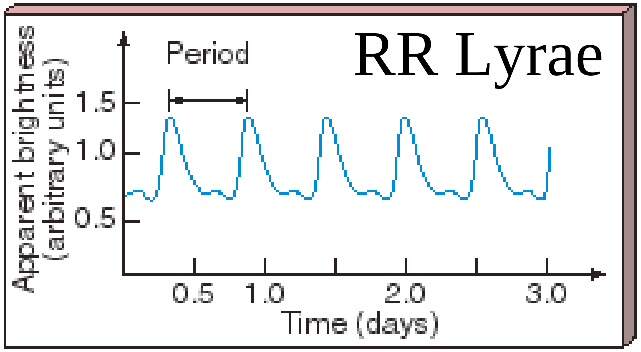
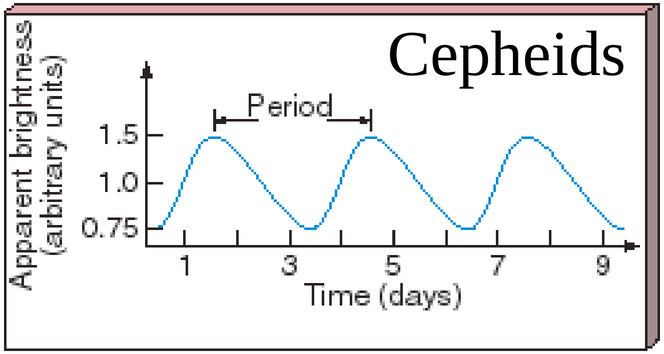
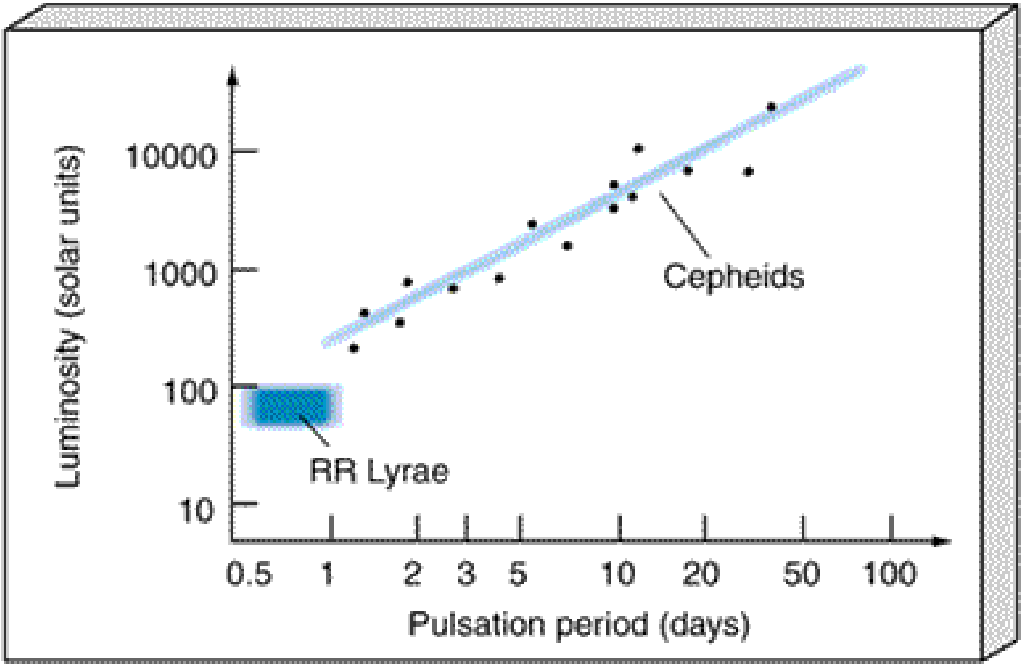
# Variable Stars – standard candles




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

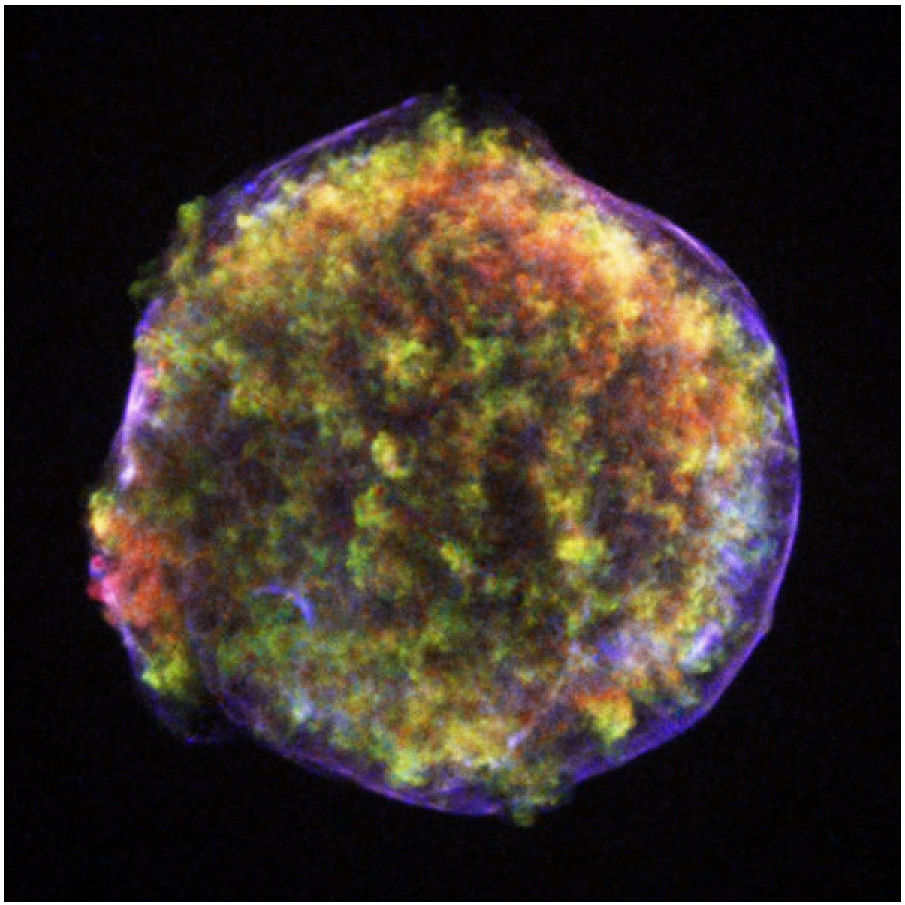
# A Sample Problem

- 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

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

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

# Supernovae can be used to measure distance



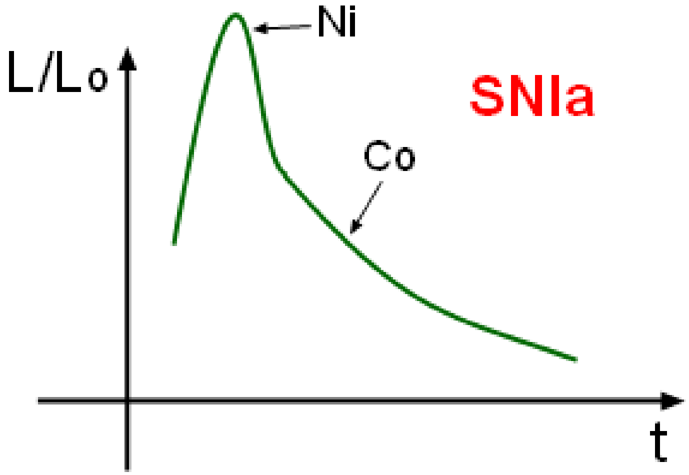
X-Ray image of Tyco's supernova (Type I from the collapse of a white dwarf)

The shock wave moves through surrounding material and causes it to give off x-rays.

Date 1572

# Type Ia Supernova Light Curves

Light curve – A light curve is just the graph of the luminosity versus time.



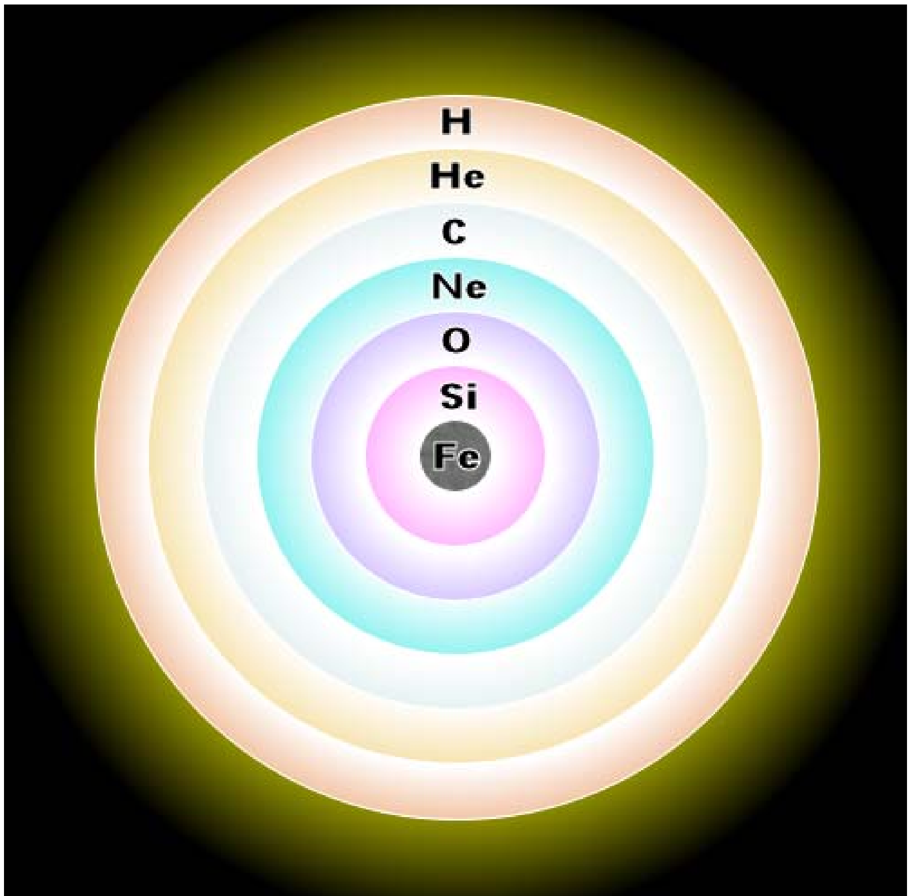

All type Ia supernova show the same light curve. Probably because the white dwarfs that collapse are all similar.

The peak is a billion times the luminosity of our Sun.

# Type Ia supernova SN1994D

NGC 4526

# Type II Supernova



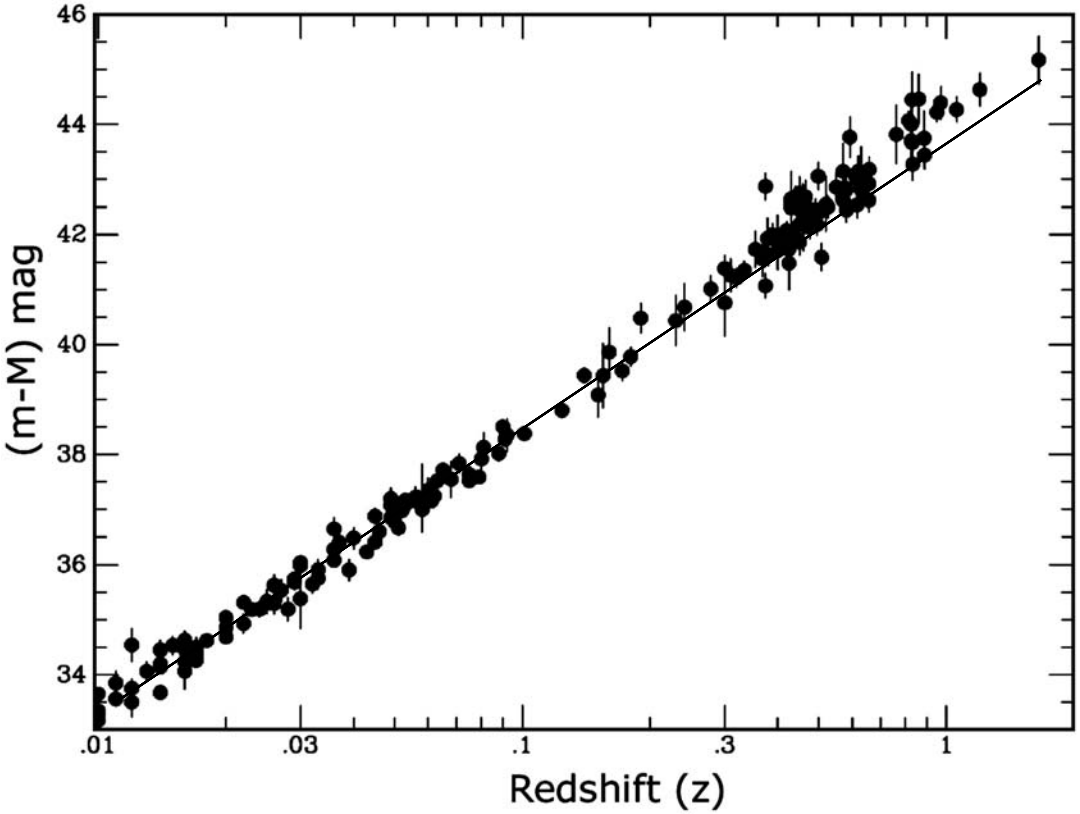

Type II supernovae result from the last stage of the evolution of a star more than 8 times the mass of our Sun.

The central core collapses and causes an explosion. The details are very complicated and not understood.

This type can be very different.

# Distance supernova show acceleration in expansion

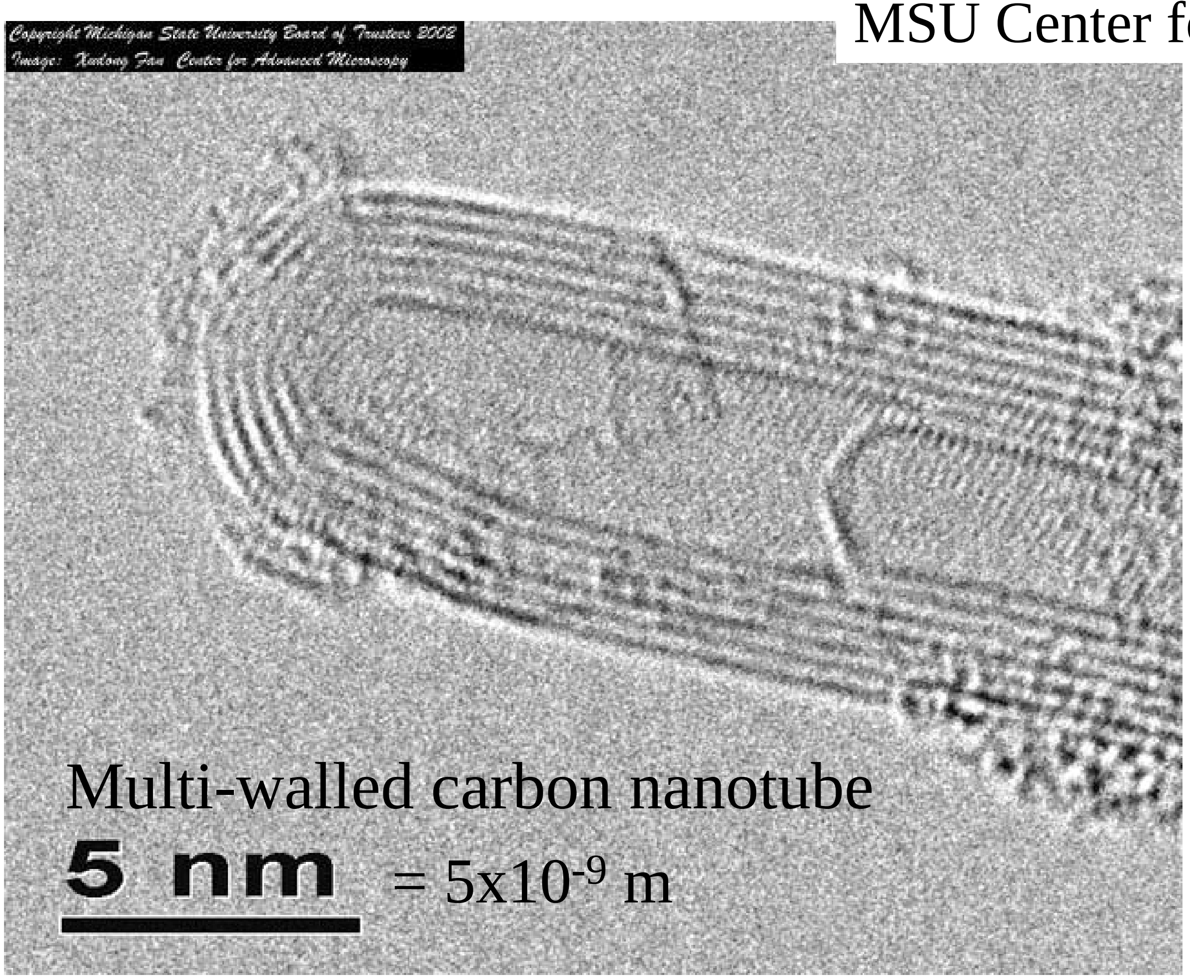
Brightness




Distance from us

# How do we know what things are made of?

MSU Center for Advanced Microscopy

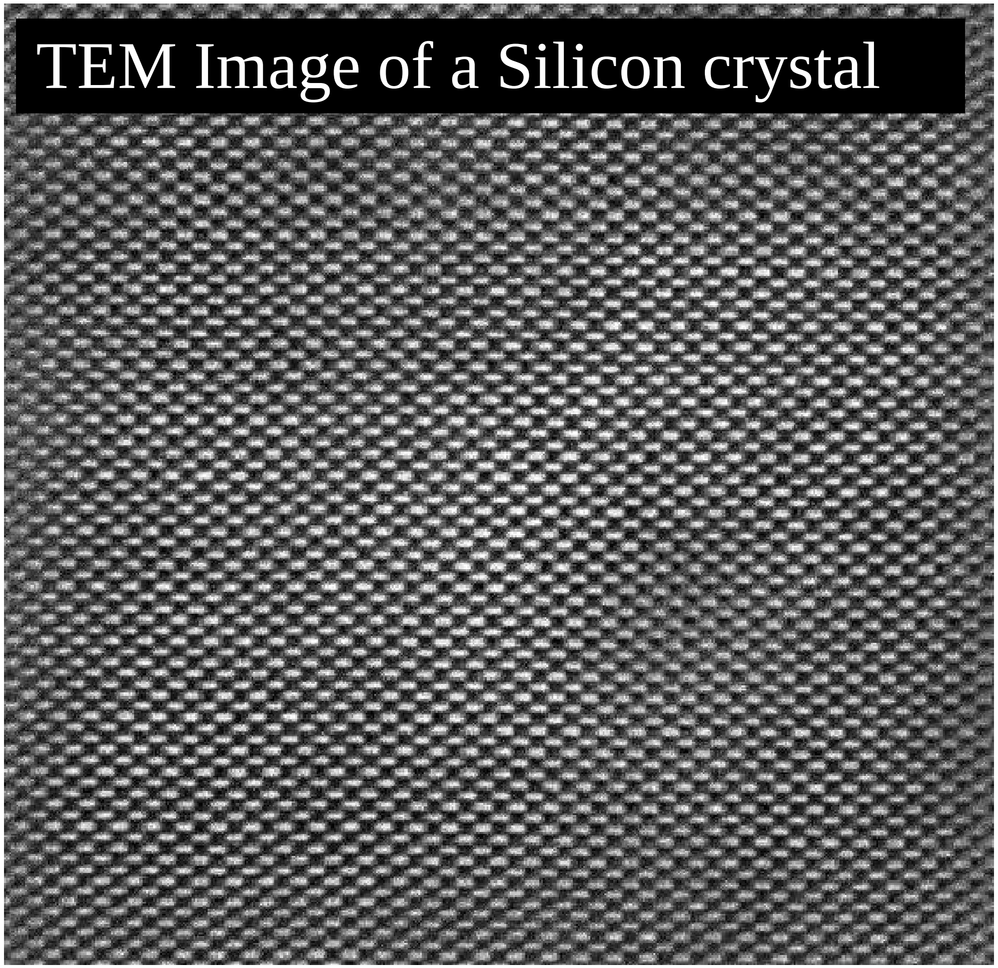



Multi-walled carbon nanotube

5 nm = $5x10^{-9}$ m

TEM Microscope

# The highest magnification possible




We can see pairs of silicon atoms.

Image of Si [110]

0.136nm separation between Si atoms

Xudong Fan, MSU

MSU Center for Advanced Microscopy http://www.ceo.msu.edu/

# 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?

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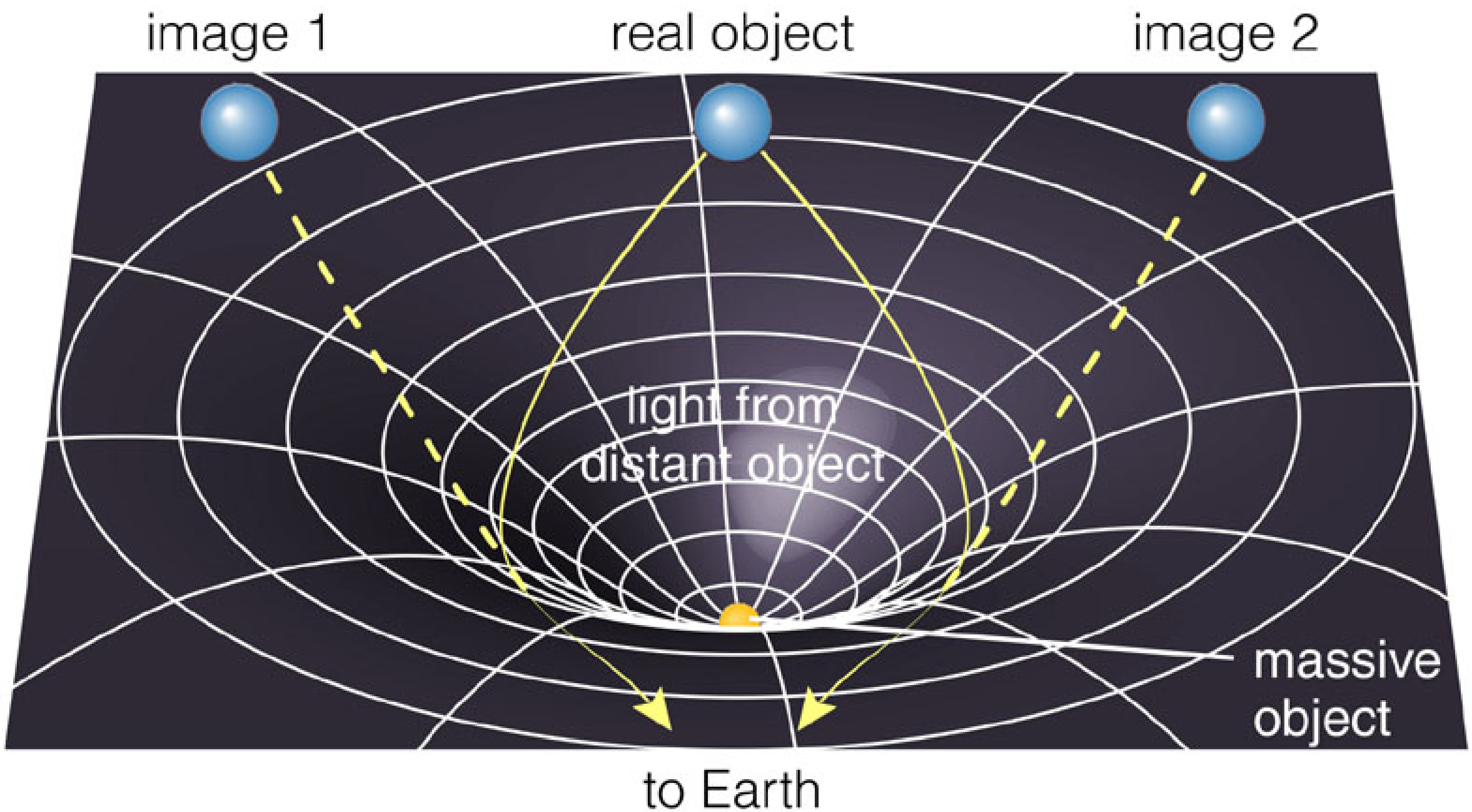
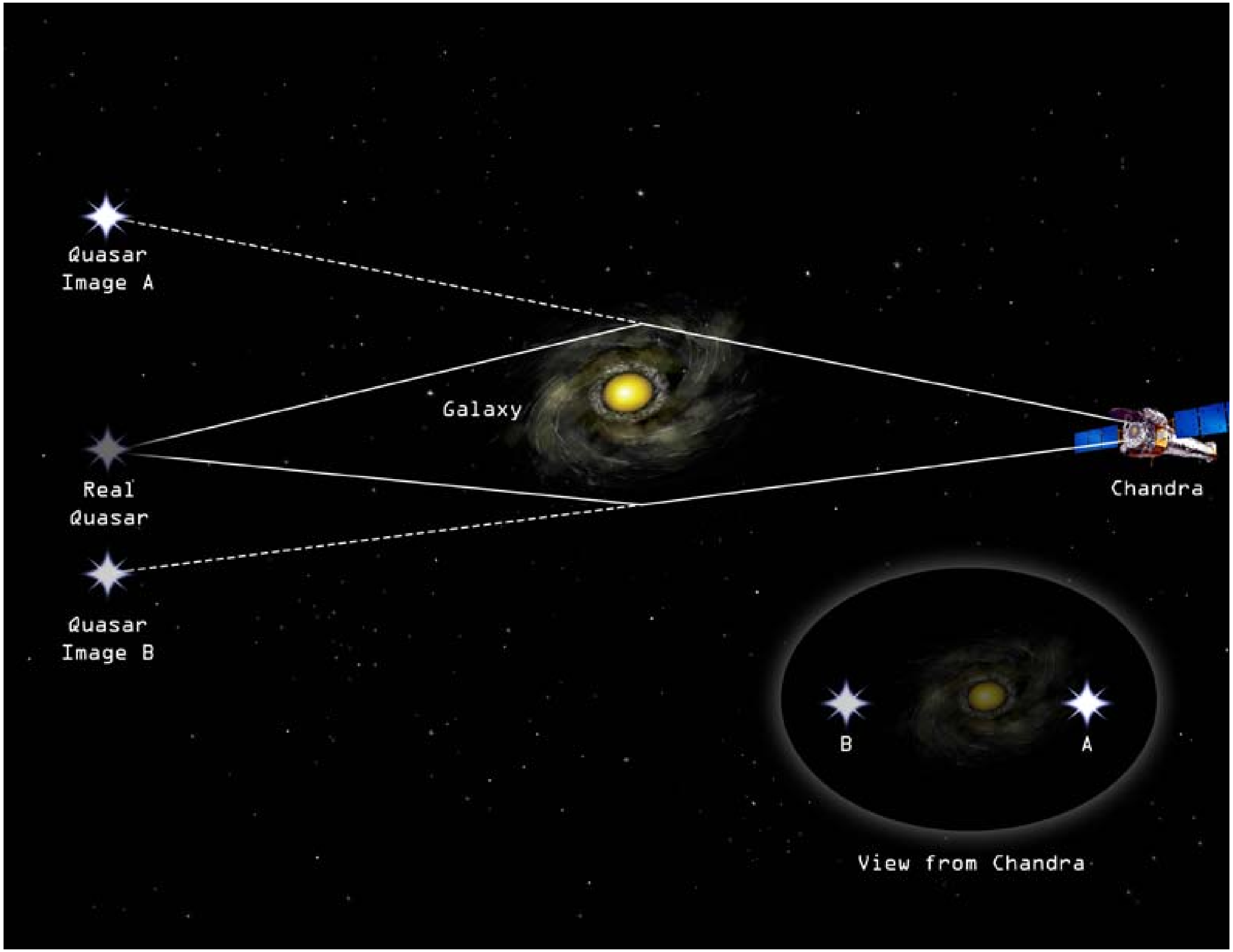
# Most of the Universe is Dark Matter

- 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.

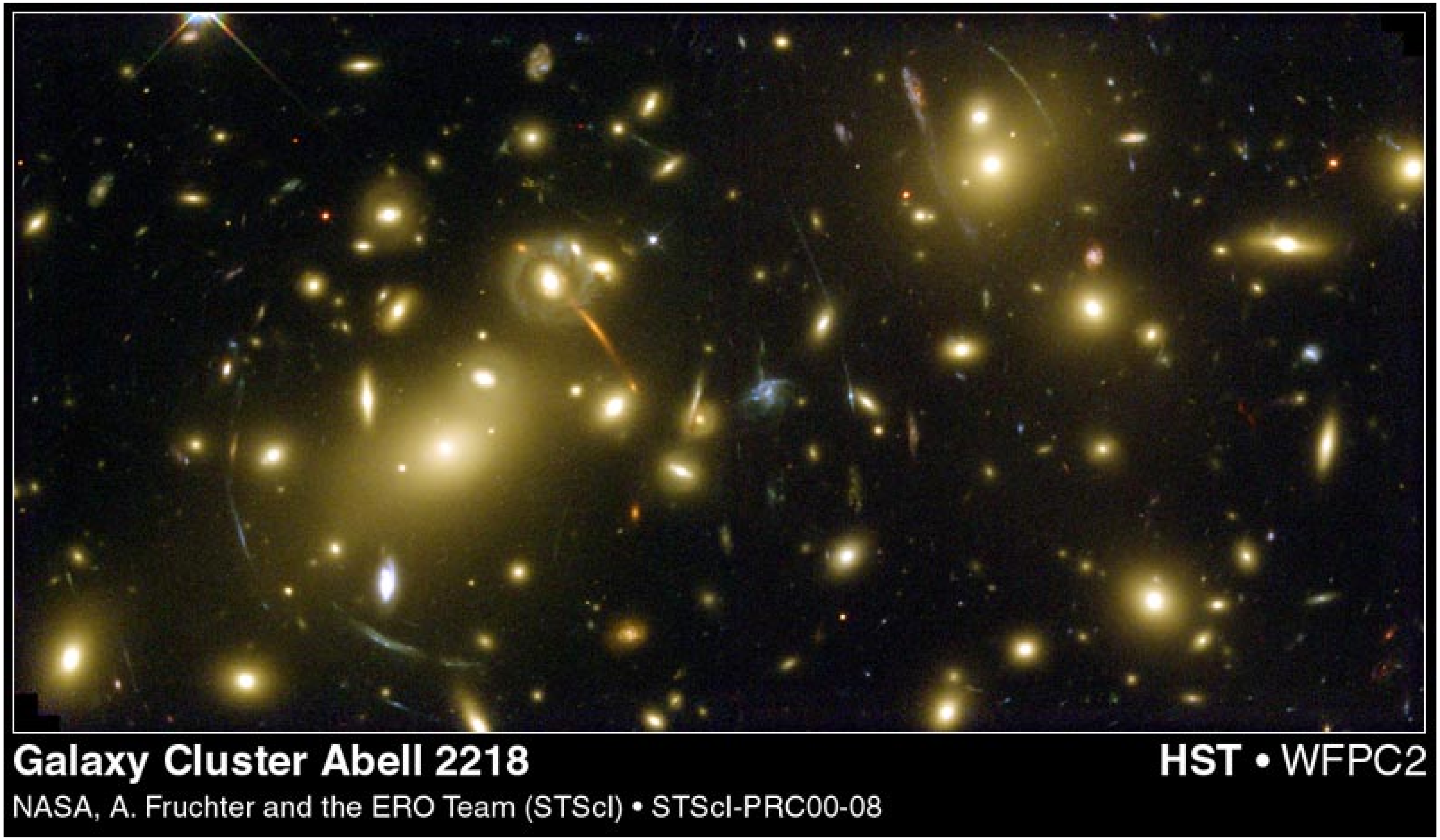
# Gravitational Lensing results from General Relativity



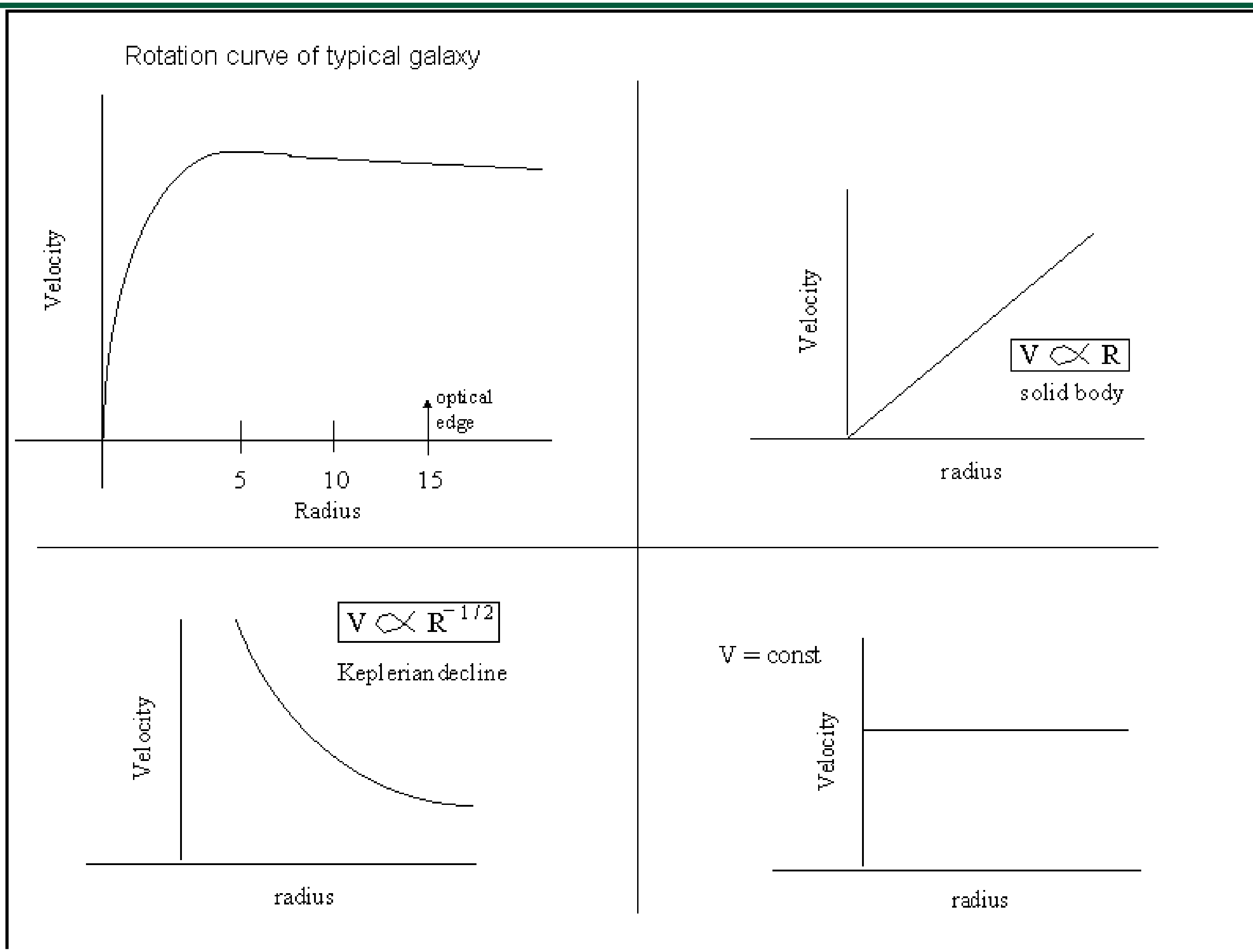
# Gravitational Lensing



# A Fantastic Picture

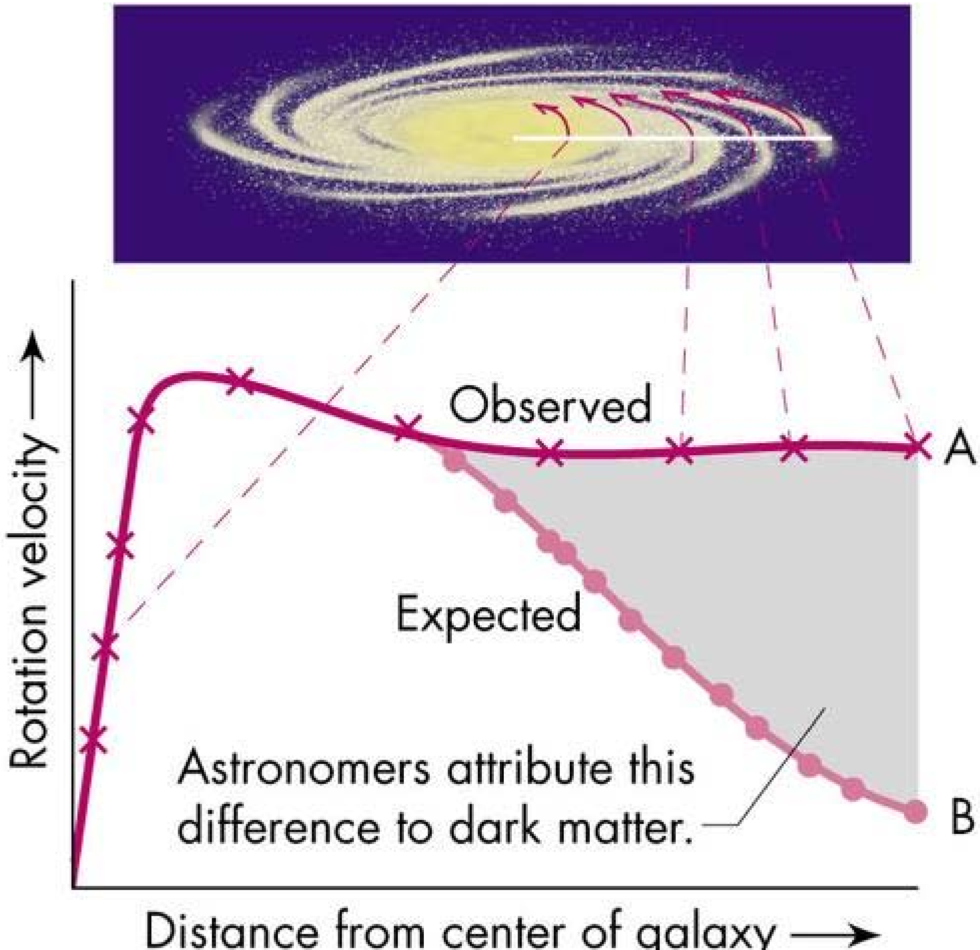


# Rotation Curves for Various Objects




http://astrosun2.astro.cornell.edu/academics/courses/astro201/rotation_curves.htm

# Rotation Curves

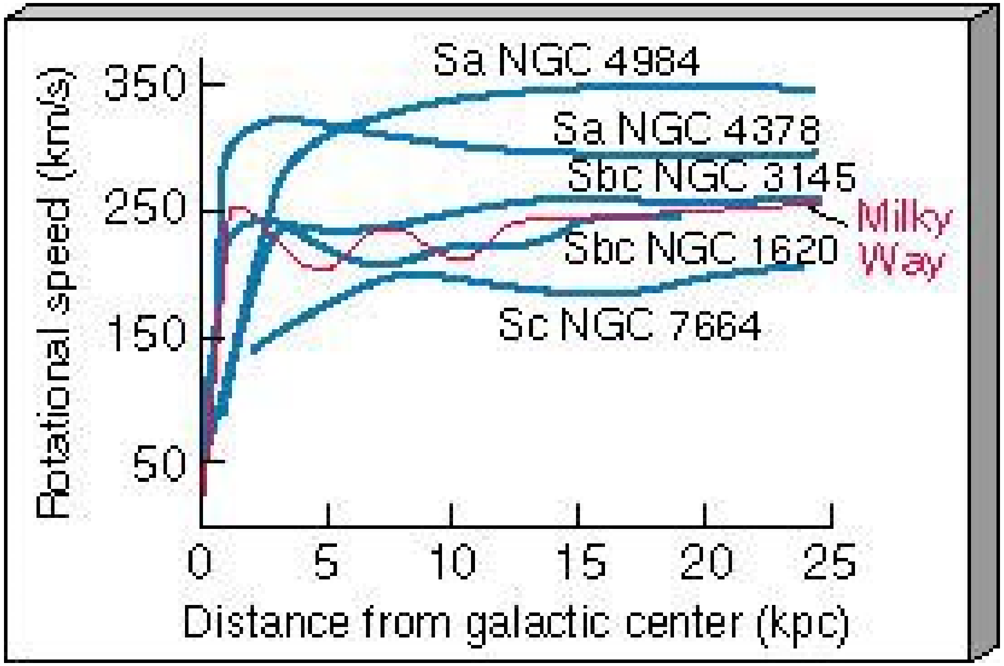



Rotation implies acceleration

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

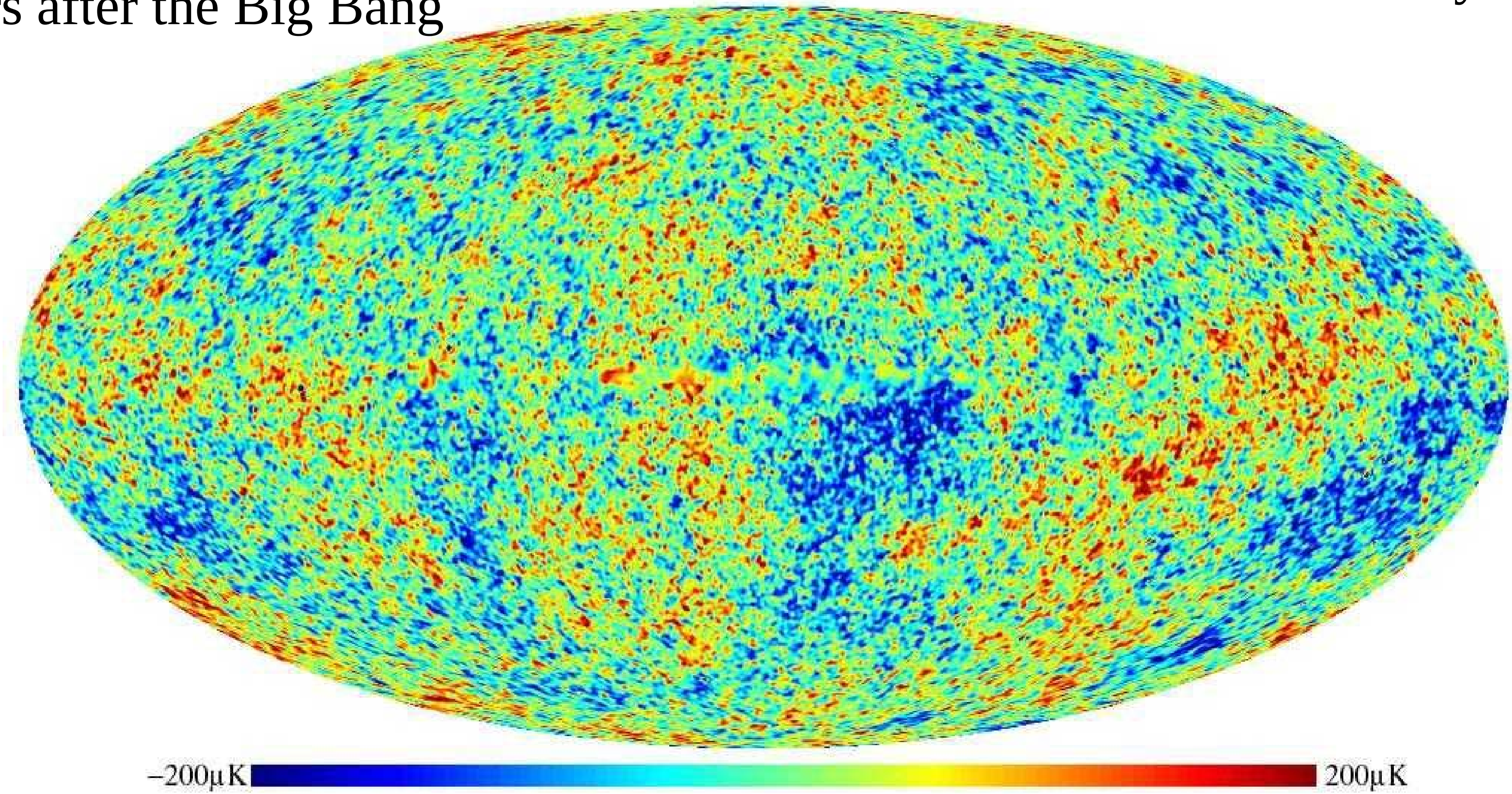



Conclusions: Galaxies contain a fairly uniform distribution of dark matter. We don’t know what this stuff is.
The local density is 5.38E-28 kg/cm$^3$

# Fluctuations in the Cosmic Background

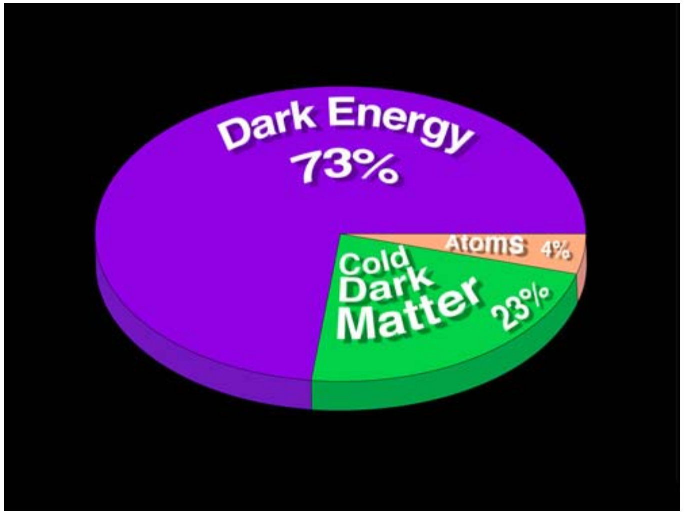
Image of the universe at about 379,000 years after the Big Bang

WMAP observatory



# What we have learned from WMAP

- Within a 1% accuracy 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). There is a chance they will be discovered at the LHC accelerator in CERN.