Today

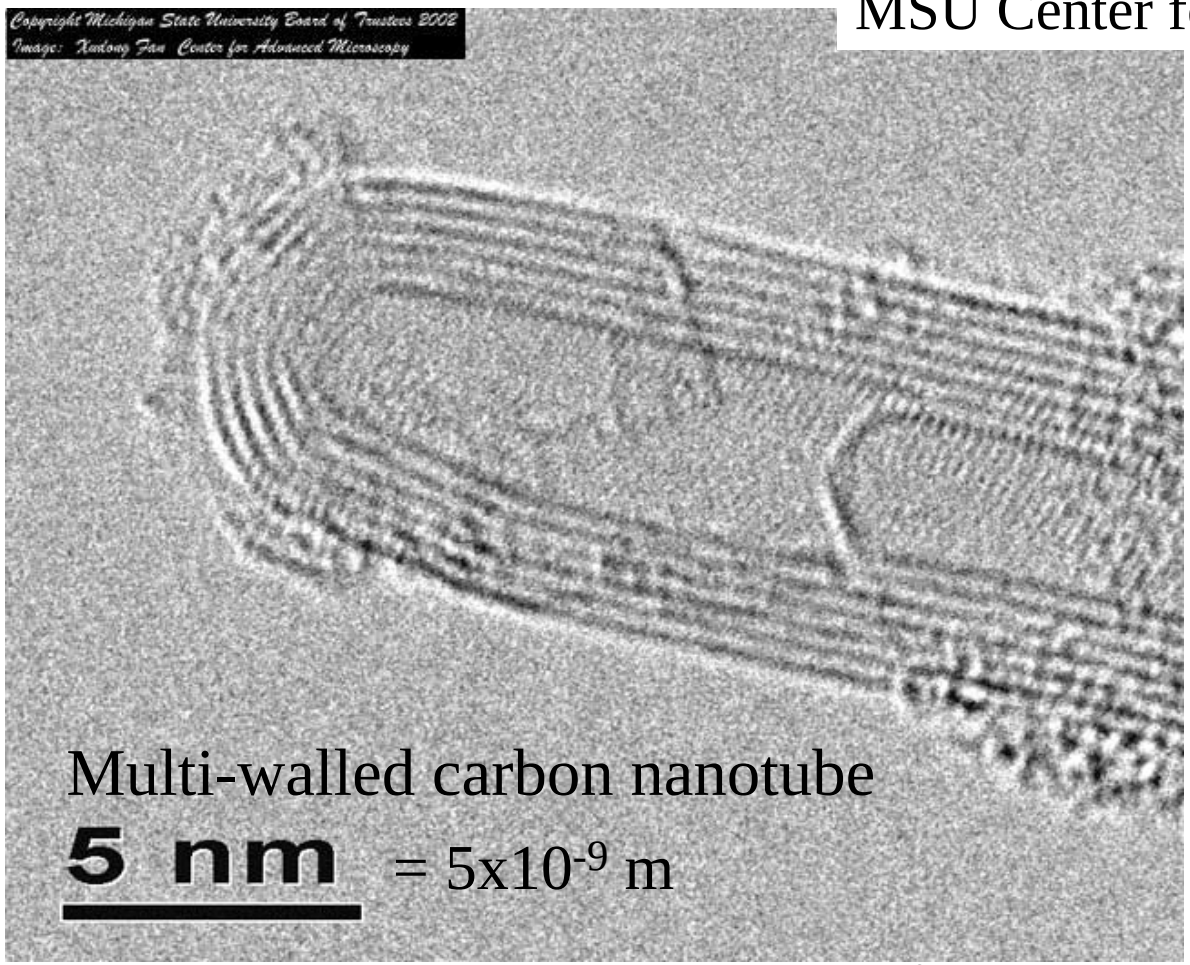
- Announcements:
  - HW#11 (the last) is due Wednesday Dec. 7th
  - Extra credit project on Intelligent Design is available it will be due Dec. 2nd at 5:00pm. Please don't wait till the last minute.
  - Final extra Credit Project – "The limits of science" will be due Dec. 9th at 5:00pm.
  - Exam review 3 has been posted
- I will be away on Thursday. Prof. Schriber will talk about accelerators. He is one of the world's experts.
- What is the Universe made of?

What are the limits of Science?

- Last Tuesday we talked about Astrology and a few other things.
- There is no scientific evidence for astrology. This is not due to a lack of trying.
- Astrology is practiced in many different ways.
- Human nature may be responsible for why astrology appears to have some validity.
- Science is a process of asking questions and searching for answers. Is it a recipe for understanding everything?

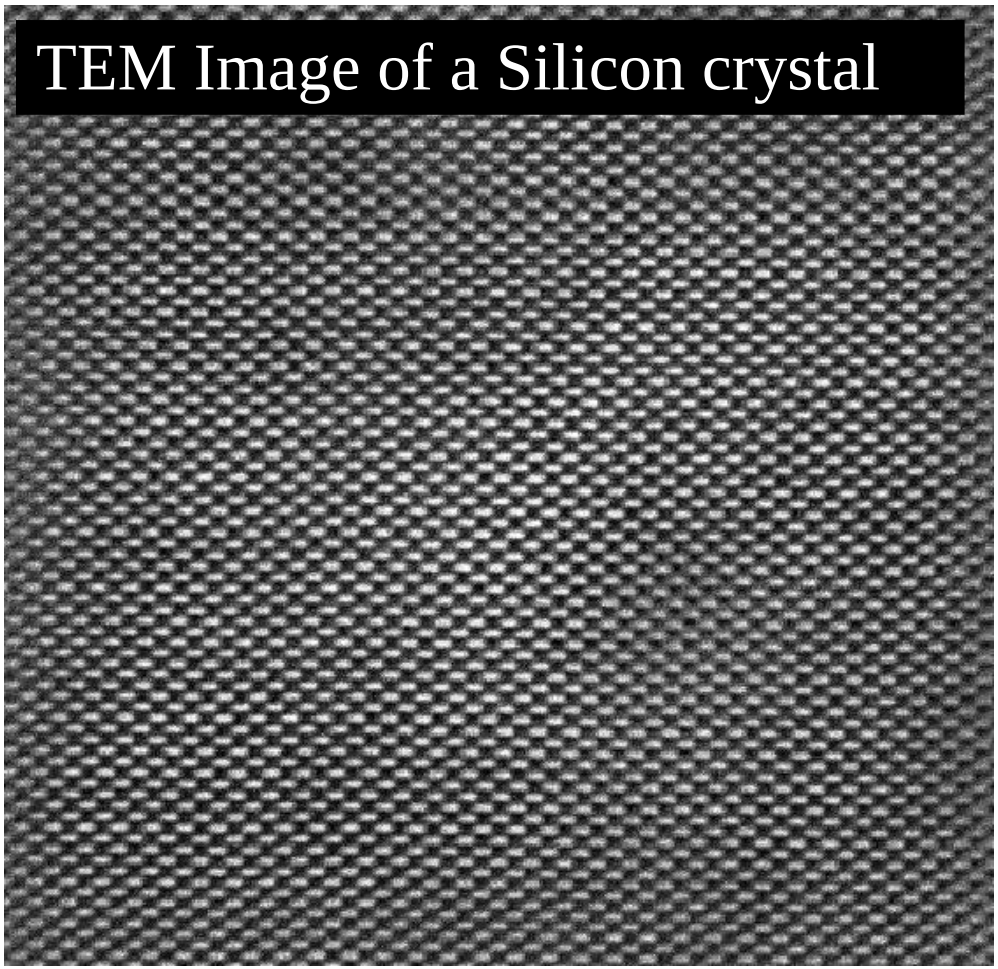
How do we know what things are made of?

MSU Center for Advanced Microscopy



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

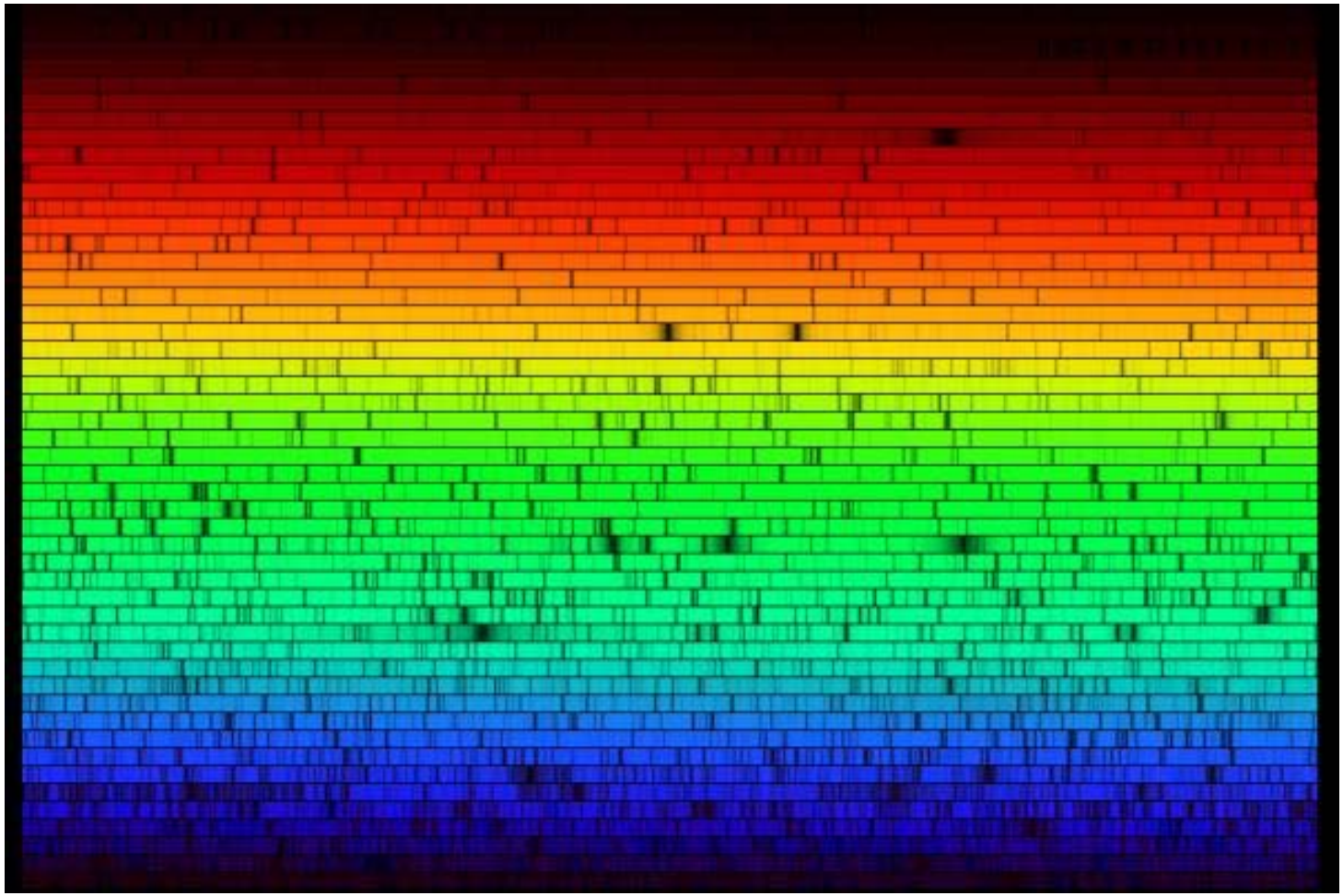
What We Made Of?

- 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
- 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?

What are Stars Made Of?

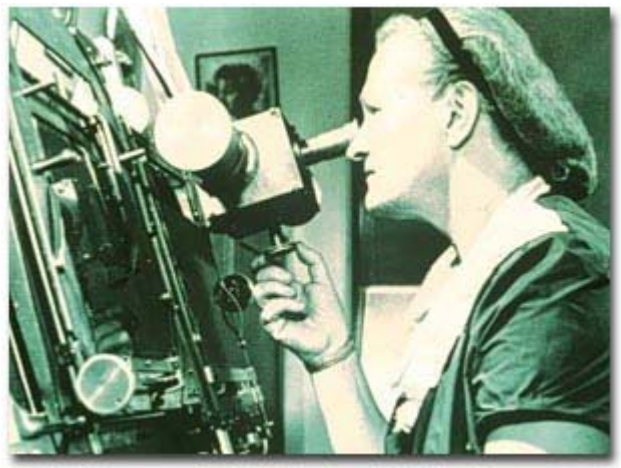
- Cecilia Payne-Gaposchki used absorption spectra of stars to learn that stars are mostly made of hydrogen and helium.
- Broader studies of the universe have found large quantities of hydrogen and helium gas.
- By numbers of atoms the Universe is 91% hydrogen, 8.9% helium, and the rest is everything else.
- This kind of matter is the same type as the matter of which we are made. This is sometimes called luminous matter (if heated it emits a blackbody spectrum).

The absorption spectrum from our Sun

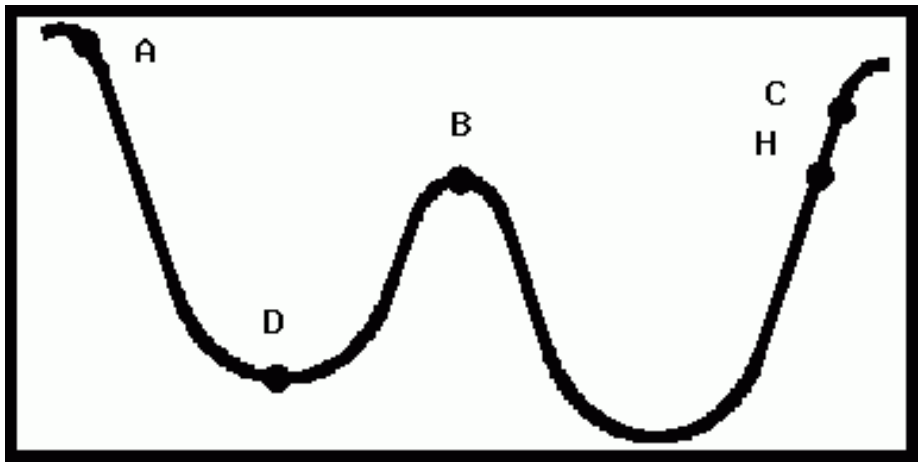


Cecilia Payne-Gaposchki Story

- Studied astronomy at Oxford
- Came to Harvard for graduate study because the only career for women in England in astronomy was teaching
- Was the first person to realize that the stars are mostly made of hydrogen and helium
- Here thesis is widely regarded as the best ever in astronomy.



Homework Problem: Review

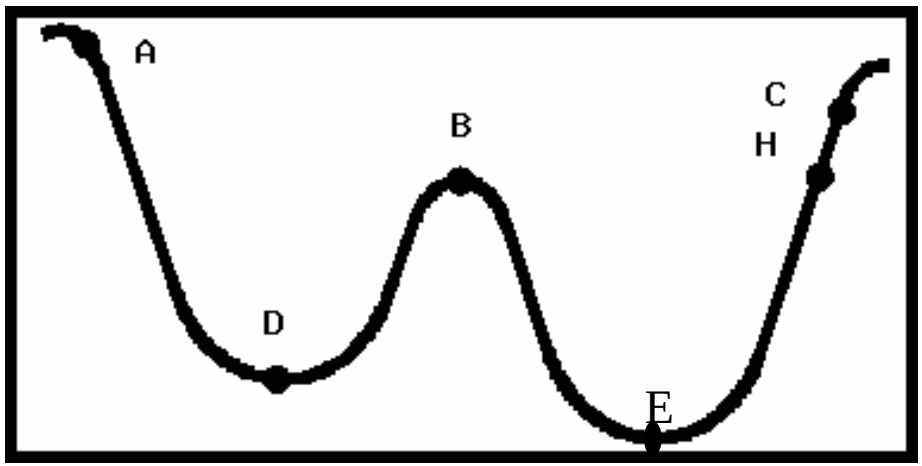


Conservation of energy says that the gain in kinetic energy is equal to the loss in potential energy.

$$KE = \frac{1}{2}mv^2 \quad PE = mgh\,; \frac{1}{2}mv^2 = mgh \rightarrow h = \frac{v^2}{2g}$$

Examples: At A the bead is speeding up. At D it is the fastest, but instantaneously not changing speed in the x. At D acceleration is +y direction. At B acceleration is in –y direction. Speed at B and H is same, but the velocity is not.

Clicker Questions



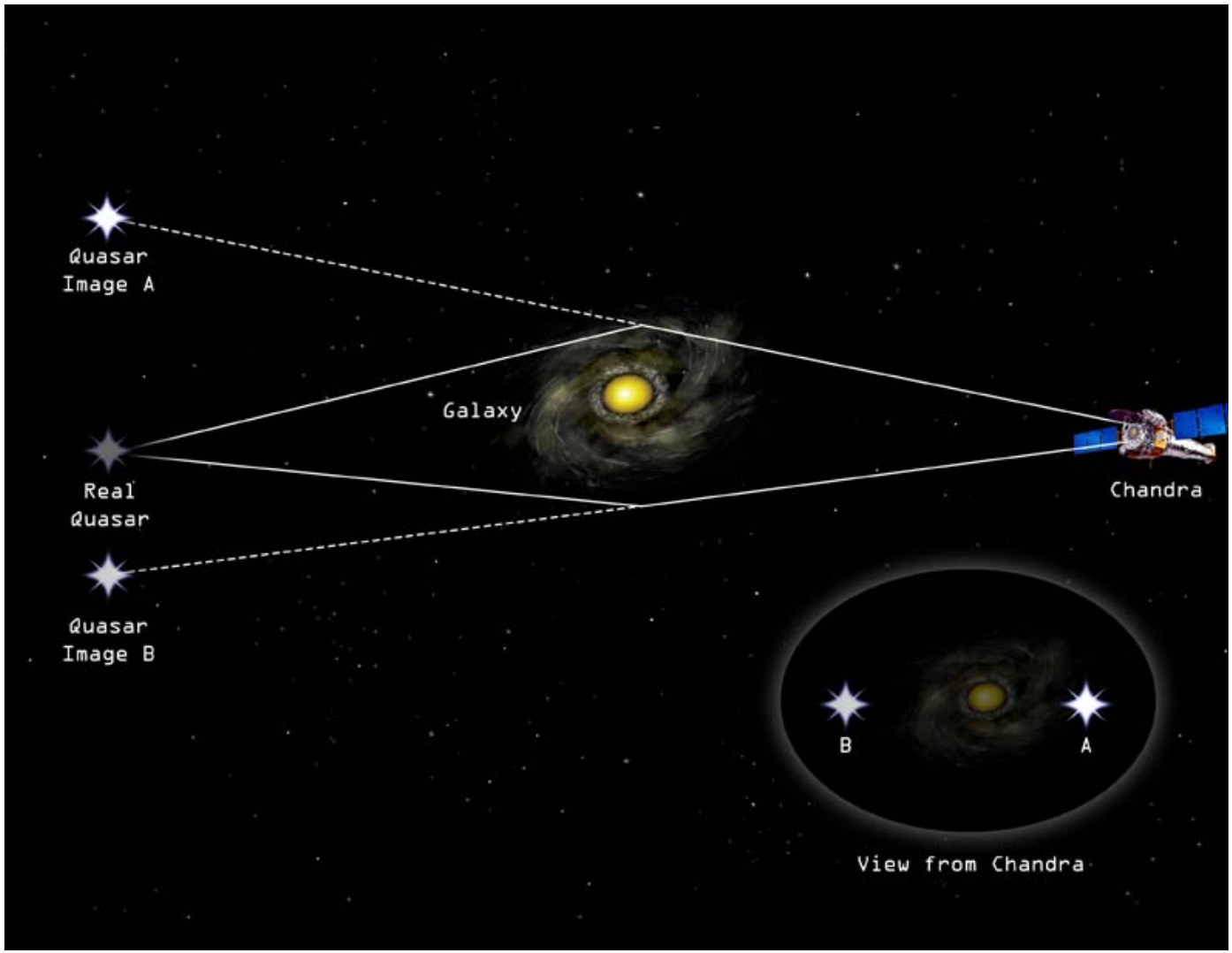
- Where is the bead moving the fastest?
- Where is the bead moving the slowest?

Hint: The height is related to the speed.

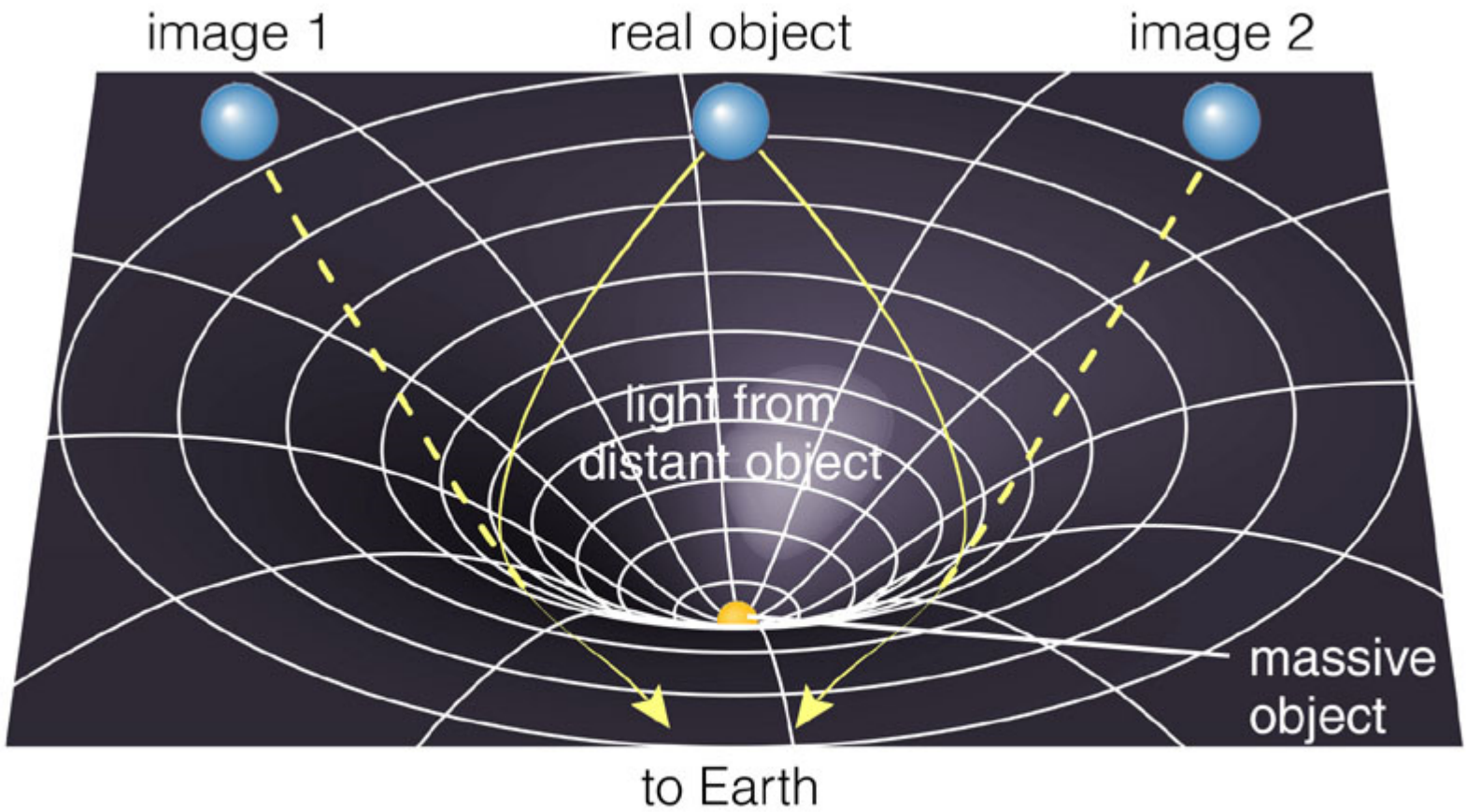
Is there anything else?

- 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./

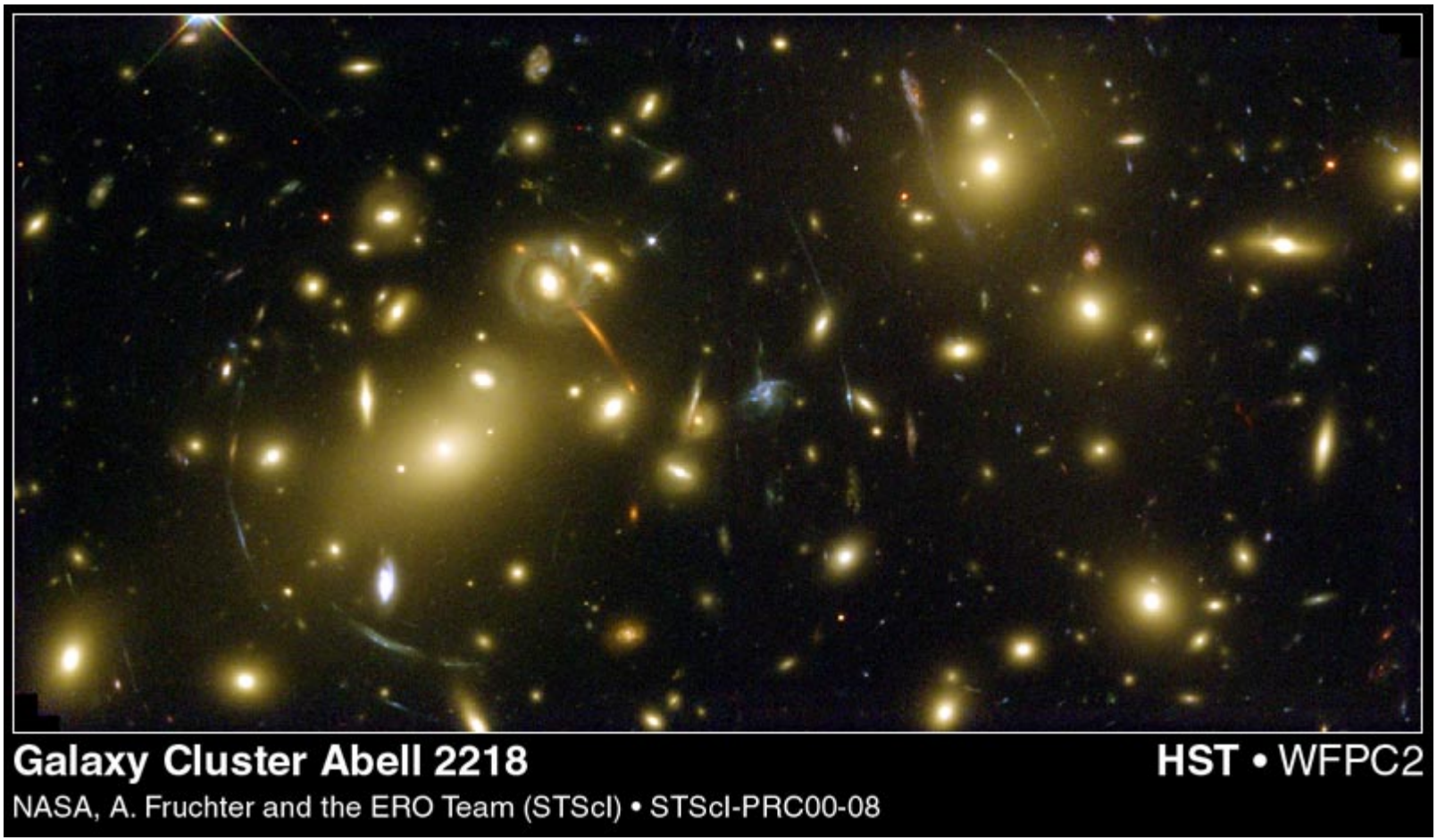
Gravitational Lensing



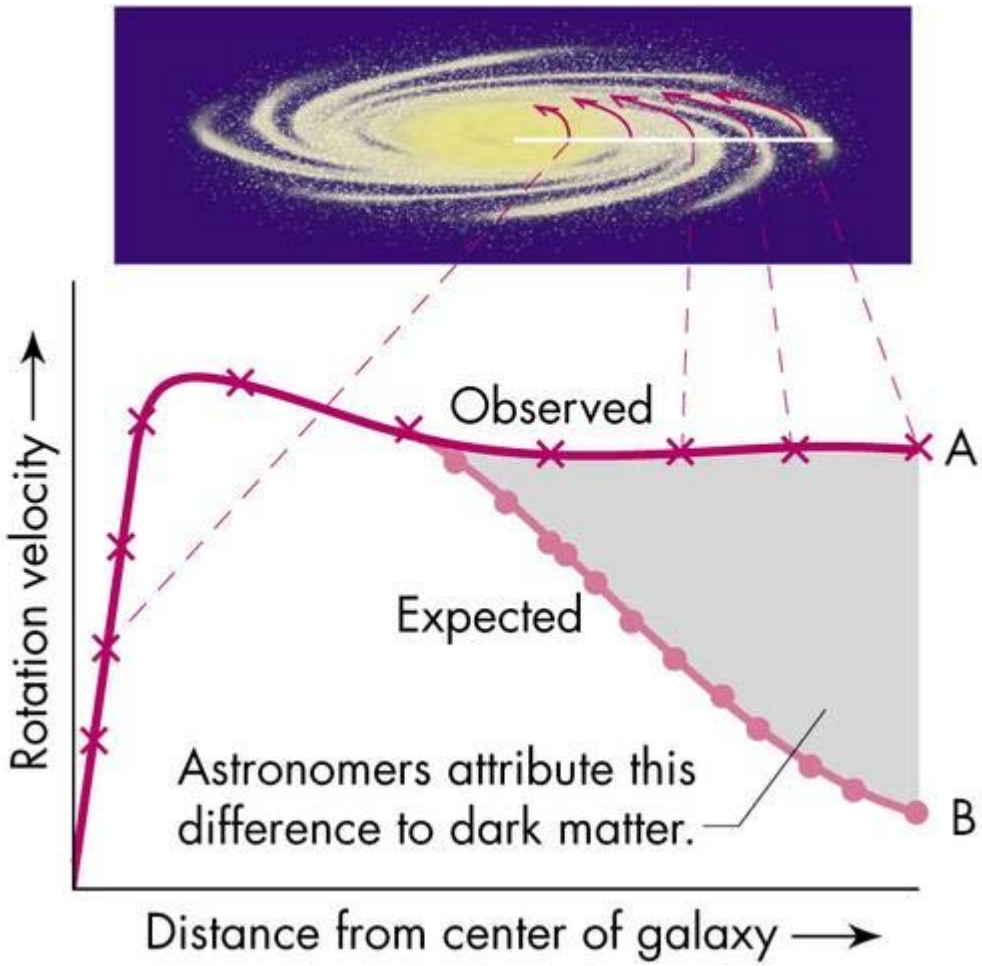
Gravitational Lensing results from General Relativity



A Fantastic Picture



Rotation Curves

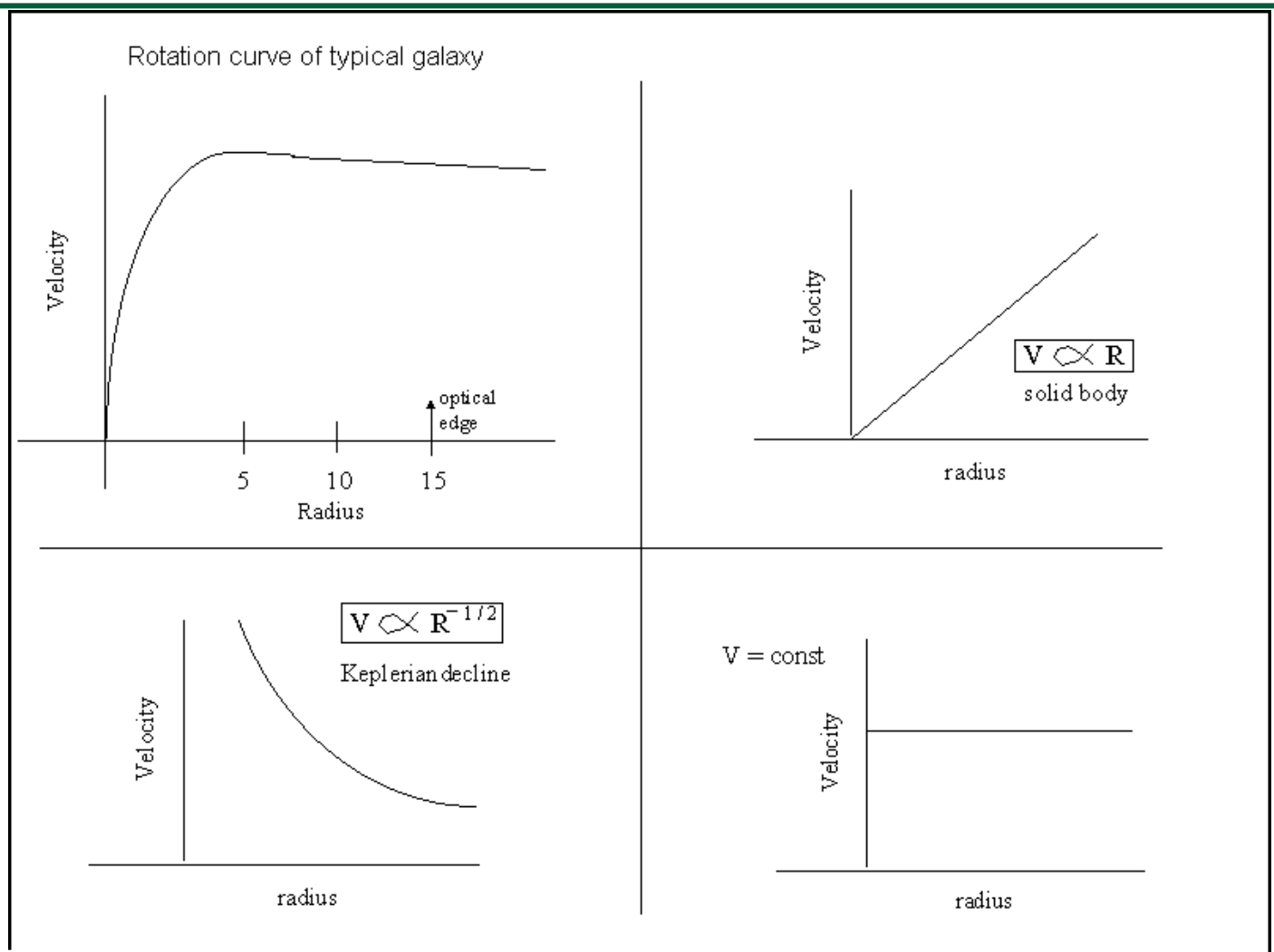


Rotation implies acceleration

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

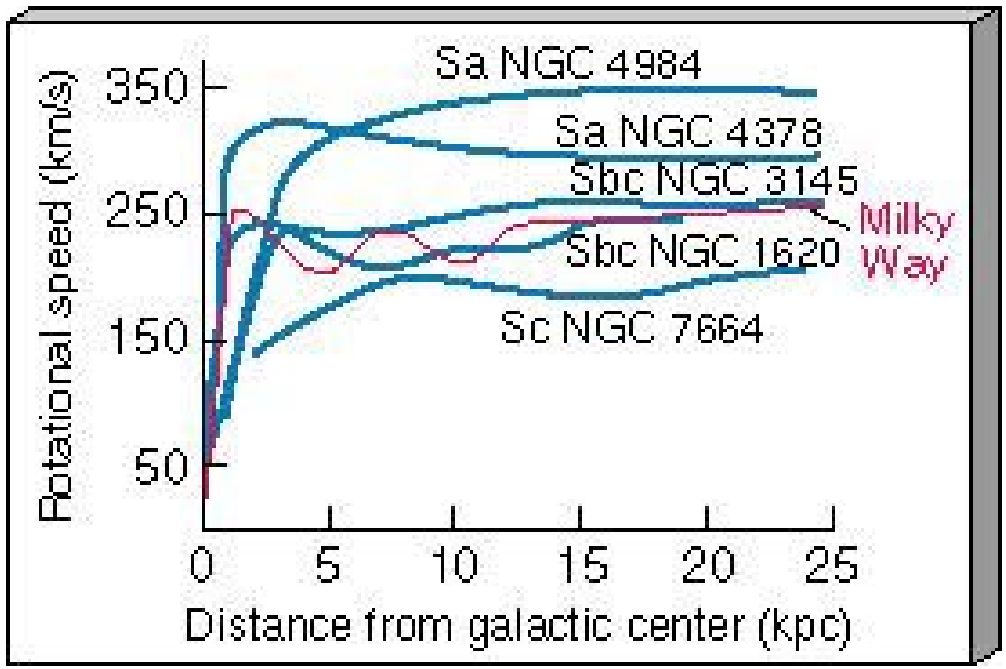
There is more rotation and hence more gravity than expected at large radii.

Rotation Curves for Various Objects



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

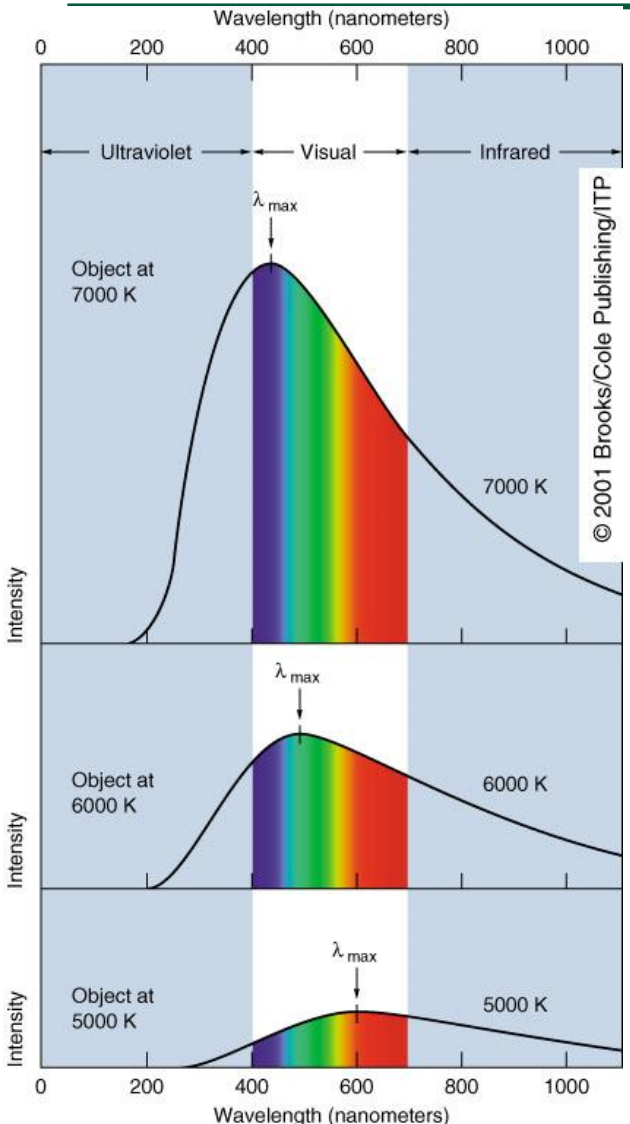
Most galaxies show this behavior



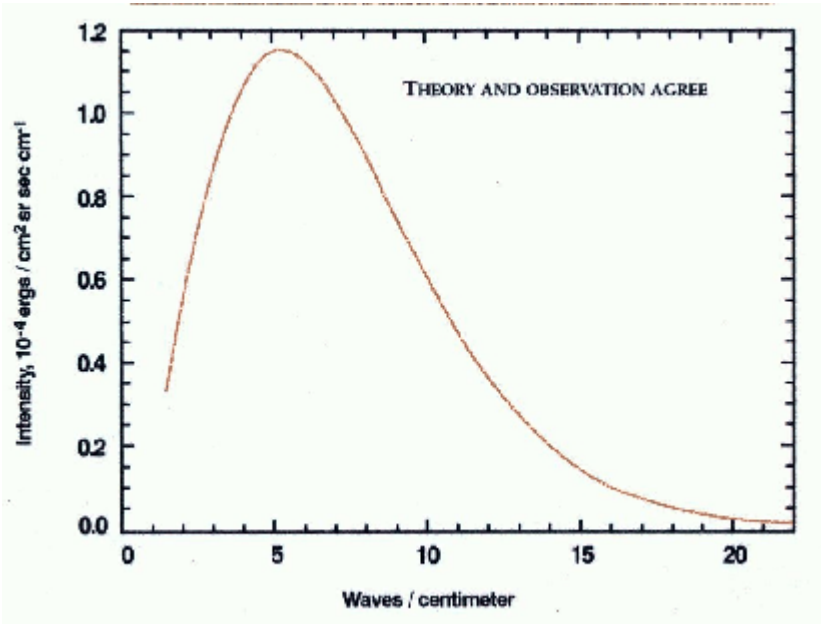
Conclusions: Galaxies contain a fairly uniform distribution of dark matter. We don't know what this stuff is.

The local density is 5.38E-28 kg/cm^3

Cosmic Microwave Background Radiation



The Universe



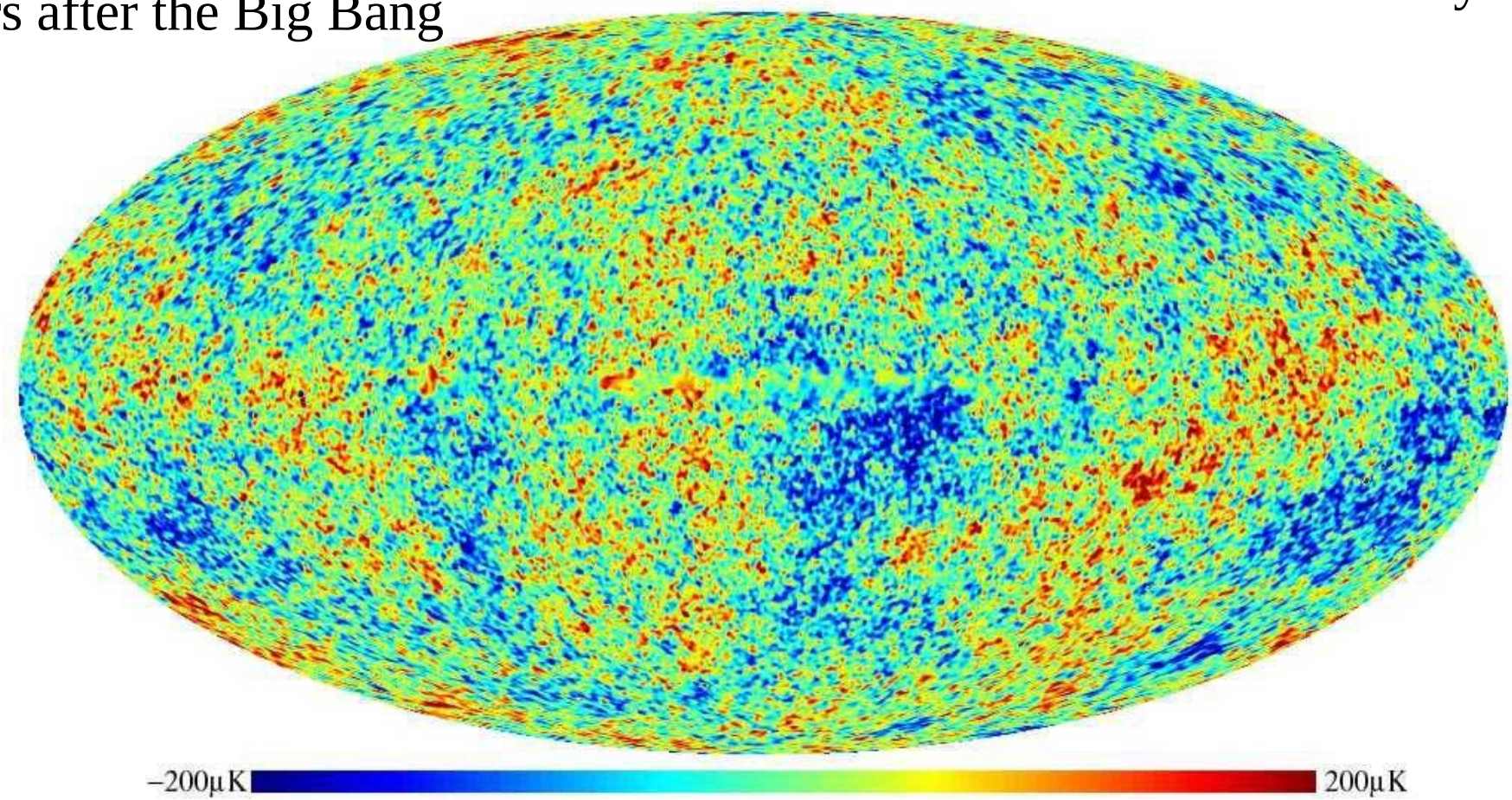
Temperature
2.738 Kelvin

Hot objects (Stars)

Fluctuations in the Cosmic Background

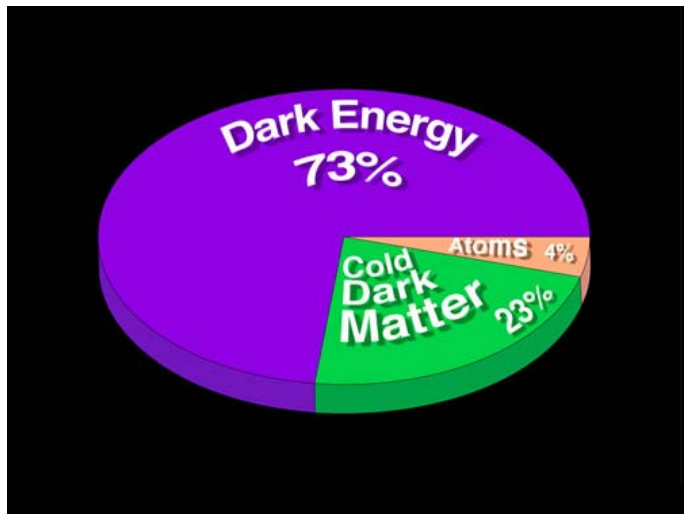
Image of the universe at about 300,000 years after the Big Bang

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 is 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.
  - Particles may interact by the weak force
  - People are looking for WIMPs (Weakly interacting massive particles)
- The new accelerator at CERN in Switzerland may discover supersymmetric matter. Supersymmetric matter is one candidate for cold dark matter.