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## 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?



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## 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?



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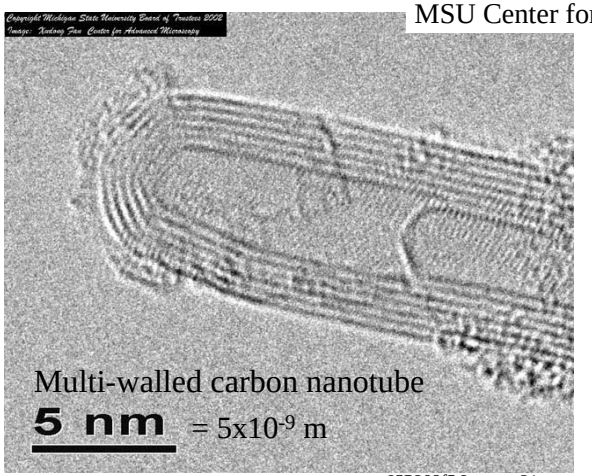
## How do we know what things are made of?

MSU Center for Advanced Microscopy




TEM Microscope



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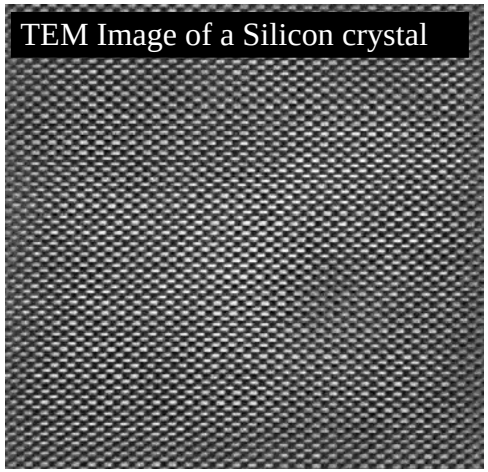
## The highest magnification possible




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
- 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?

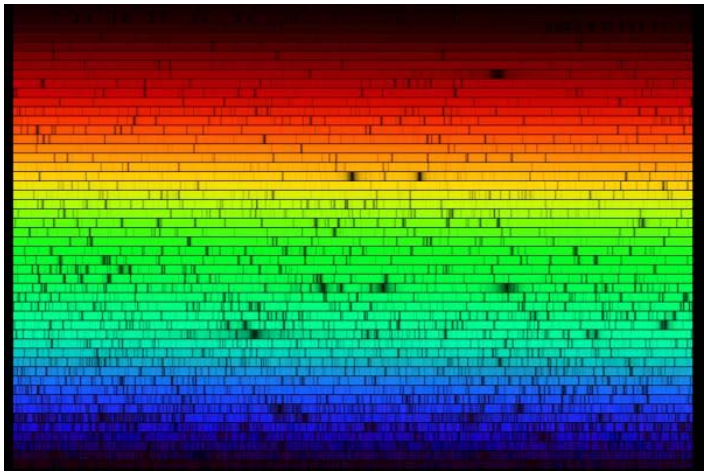


## What are Stars Made Of?

- 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).



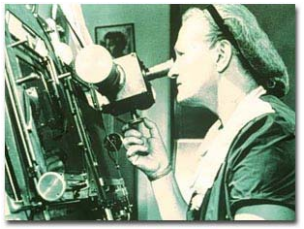
## The absorption spectrum from our Sun



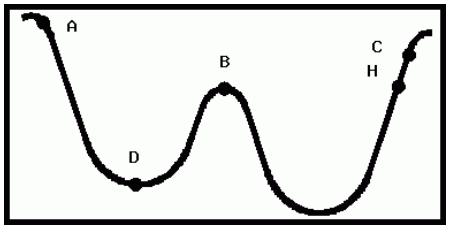


## Cecilia Payne-Gaposchki Story

- 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.

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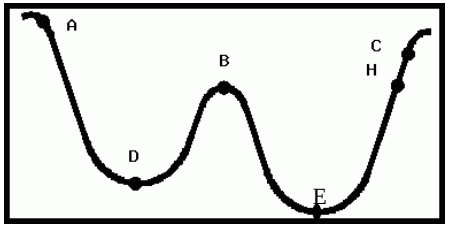
## Clicker Questions




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

Hint: The height is related to the speed.



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## 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./



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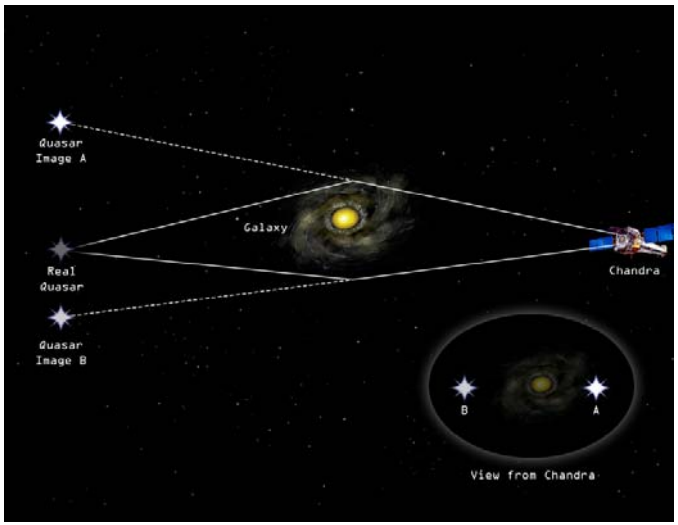
## Gravitational Lensing



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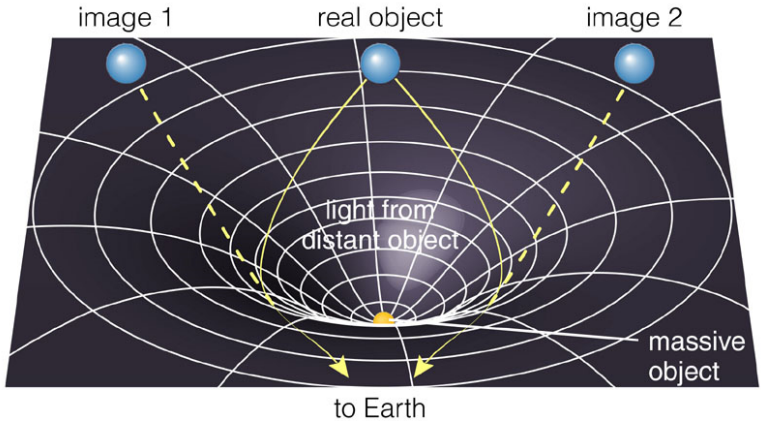
## Gravitational Lensing results from General Relativity



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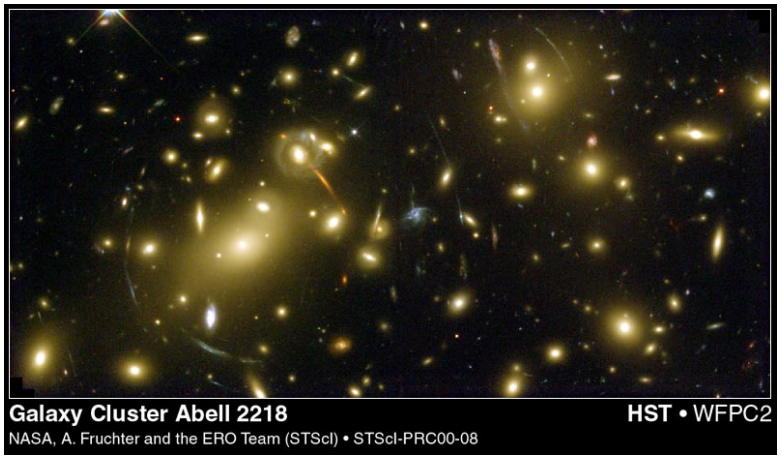
## A Fantastic Picture



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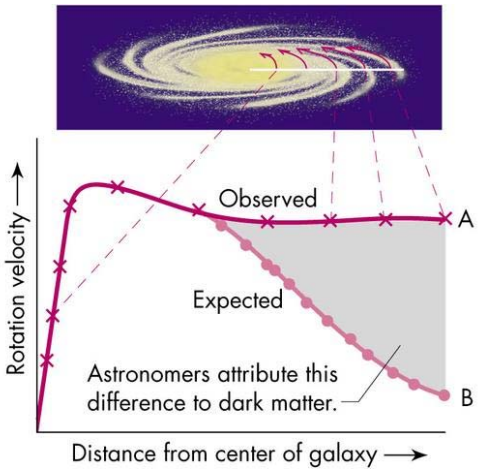
## Rotation Curves




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.



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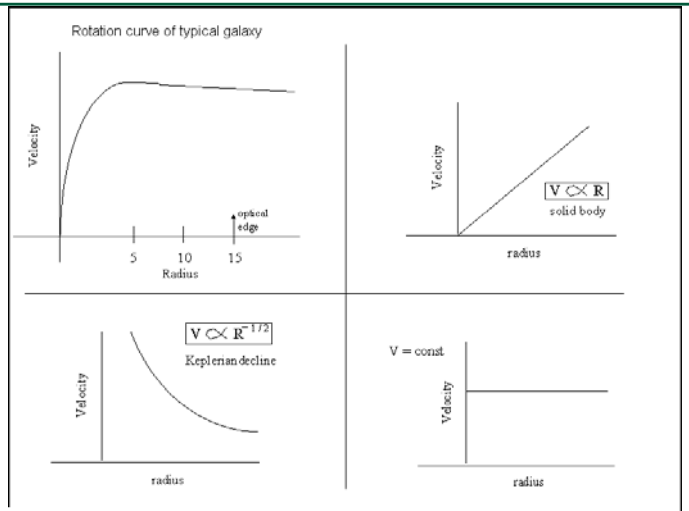
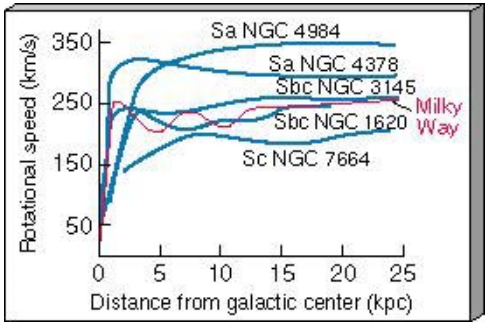
## Rotation Curves for Various Objects




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

## Most galaxies show this behavior

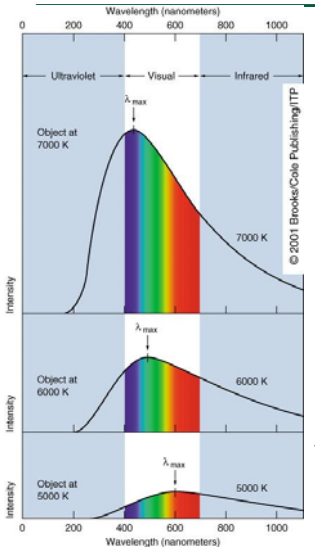



Conclusions: Galaxies contain a fairly uniform distribution of dark matter. We don't know what this stuff is.
The local density is 5.38E-28 kg/cm$^3$

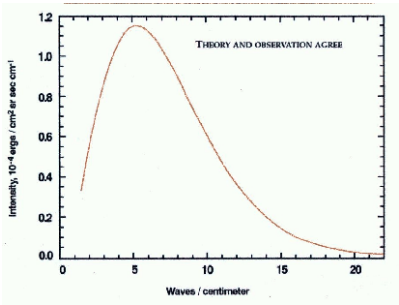




## Cosmic Microwave Background Radiation




The Universe




Temperature
2.738 Kelvin

Hot objects (Stars)

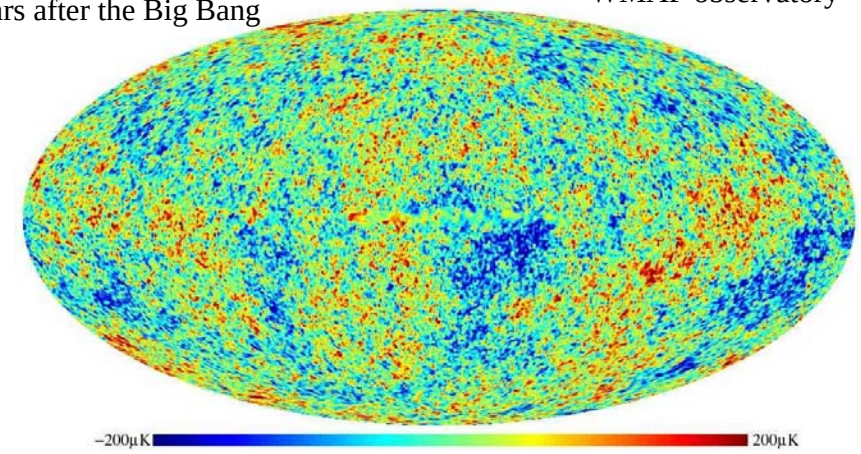




## Fluctuations in the Cosmic Background

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

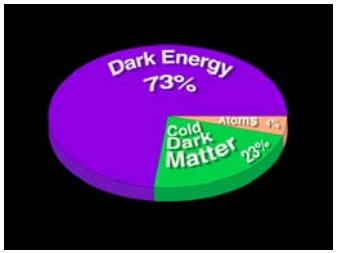
WMAP observatory






## 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.

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# 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.