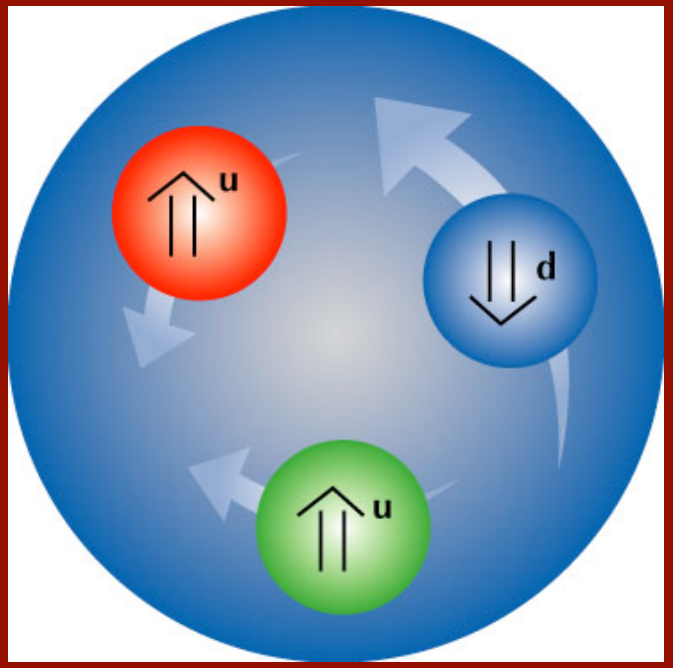
Welcome to Mind-Blowing Physics

Tuesday March 20, 2012



Today's Warm-up:

Look at the posters and books around the room and pick one to look at.

Take a piece of paper and write down something you didn't already know that you learn from reading it and something you want to learn more about this week..

Today's Agenda
Cosmology

- 8:15-9:30 Dr. Hair's presents on the Big Bang
- 9:30-9:45 Class Wiki and how to use it
- 9:45-11:30 Students research topics
- 11:30-12:30 Lunch (here or caf)
- 12:30-1 Dessert with Prof. Caldwell
  (Please be prompt!)
- 1-1:30 Prof. Caldwell presents
- 1:30-3 Questions and Answers

Remember the expectations for class

- Be on time.
- Be on task.
- Usual school rules apply.

Also

- Respect others.
- Pay attention.
- Keep brain turned on, at all times.
- Be a good representative of Hanover High

Cosmology: What is it?

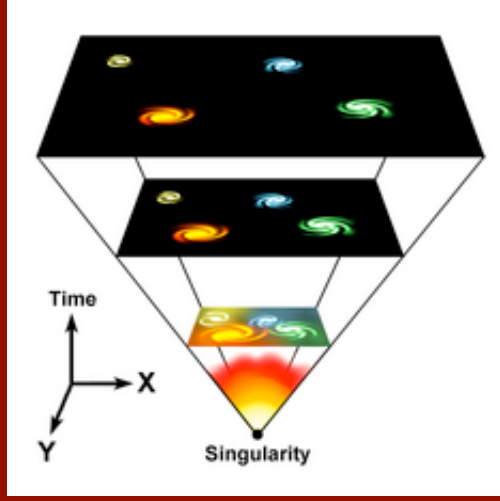
Cosmos- = universe, order, system

-ology = word, reason, plan

"a branch of astronomy that deals with the origin, structure, and space-time relationships of the universe" (Merriam-Webster On-Line)

Handout: If you don't know, just guess. At the end of the day we will see how much you learned by looking at these questions again.

The Big Bang Model



- Current model for the start of the universe.
- All of space underwent a HUGE expansion, about 14 billion years ago, referred to as the Big Bang.
- There was no "explosion" from a center. Space itself expanded, taking energy and matter along. The Big Bang was everywhere, not centered in one place.
- All the observable universe was densely packed into a tiny volume. Space expanded rapidly and is still expanding.

Three Key Pieces of Evidence for the Big Bang

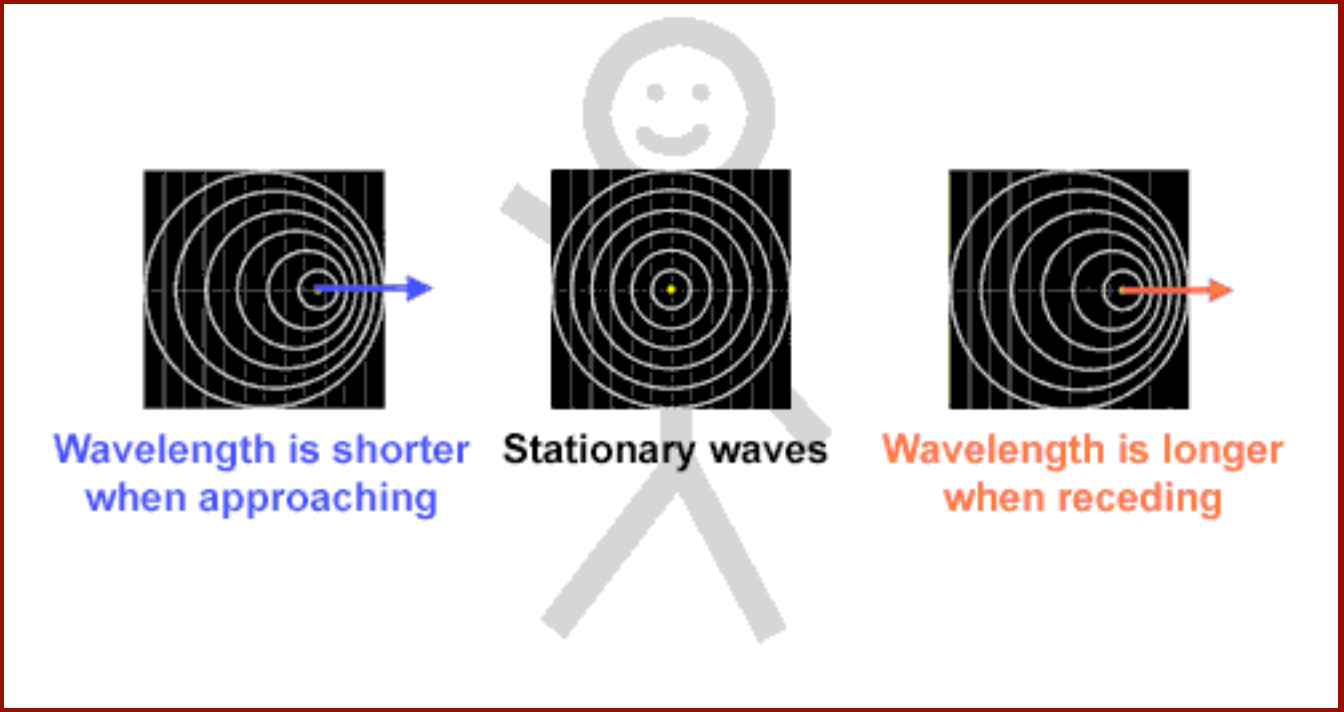
1. The expanding universe: Galaxies are moving farther apart.
2. The distribution of atoms in the universe: 75% H, 25% He
3. Cosmic microwave background: Light that was emitted after the big bang and has cooled to microwave frequencies and is observed everywhere.

Evidence #1: The Expanding Universe

- In the 1920's Edward Hubble saw that galaxies were moving farther apart. Their light was RED-SHIFTED.
- The idea that the universe is expanding means it must have been smaller and smaller, the farther back in time you go.
- Working backwards, he predicted a highly dense state of energy and matter, after the big bang.

What is RED SHIFT?

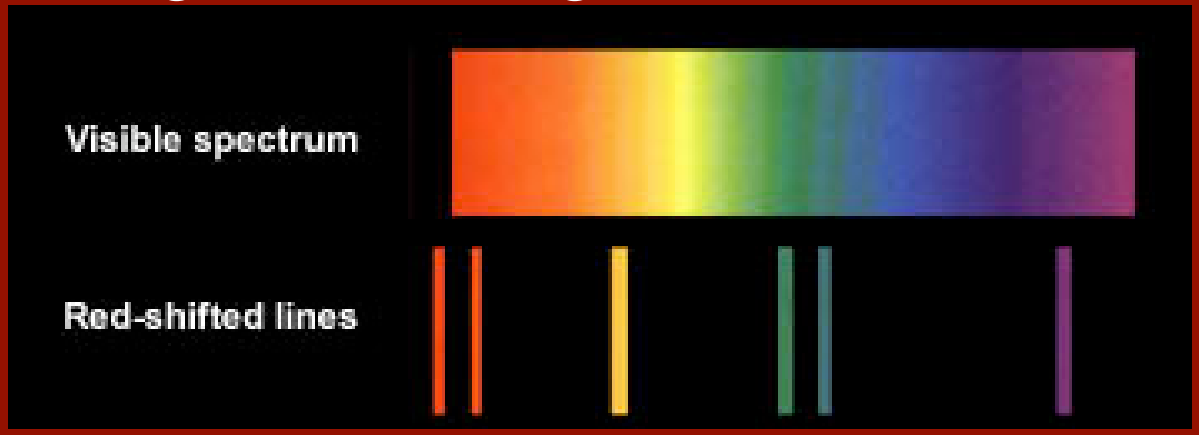
The Doppler Effect happens when the source of a light or sound wave is moving.



Demo: Red-shifted wave on expanded elastic

What is RED SHIFT?

Light emitted by distant galaxies shows wavelengths that are shifted to the red end of the spectrum. This means their wavelengths are longer.



Hubble's conclusion:
The galaxies emitting the light are moving away from us!

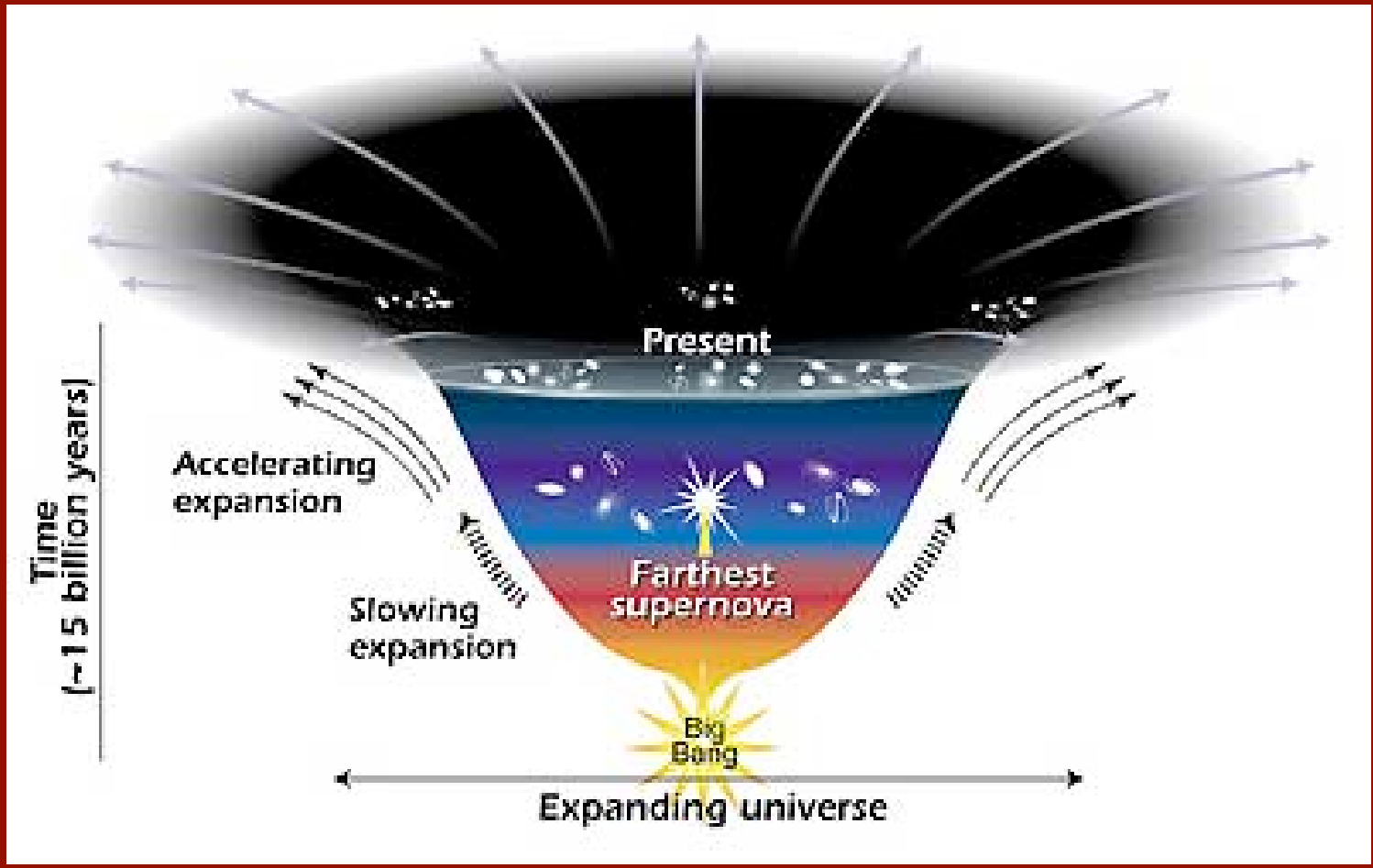
If galaxies are expanding away from us, does that mean we are at the center of the universe?

NO!

In an expanding universe, objects are moving away from every point.

Analogy: Raisins in rising bread dough
Demo: Class members are dense, then expand.
Video: How do we know the age of the universe?

What is the history of the universe?



What happened after the Big Bang?

Planck Time

Before 10^{-43} seconds

Laws of Physics don't apply and we don't understand this period of extreme high energy and density

Grand Unification Epoch

10^{-43} to 10^{-36} seconds Temperature = 10^{29} K

Gravity becomes a separate force

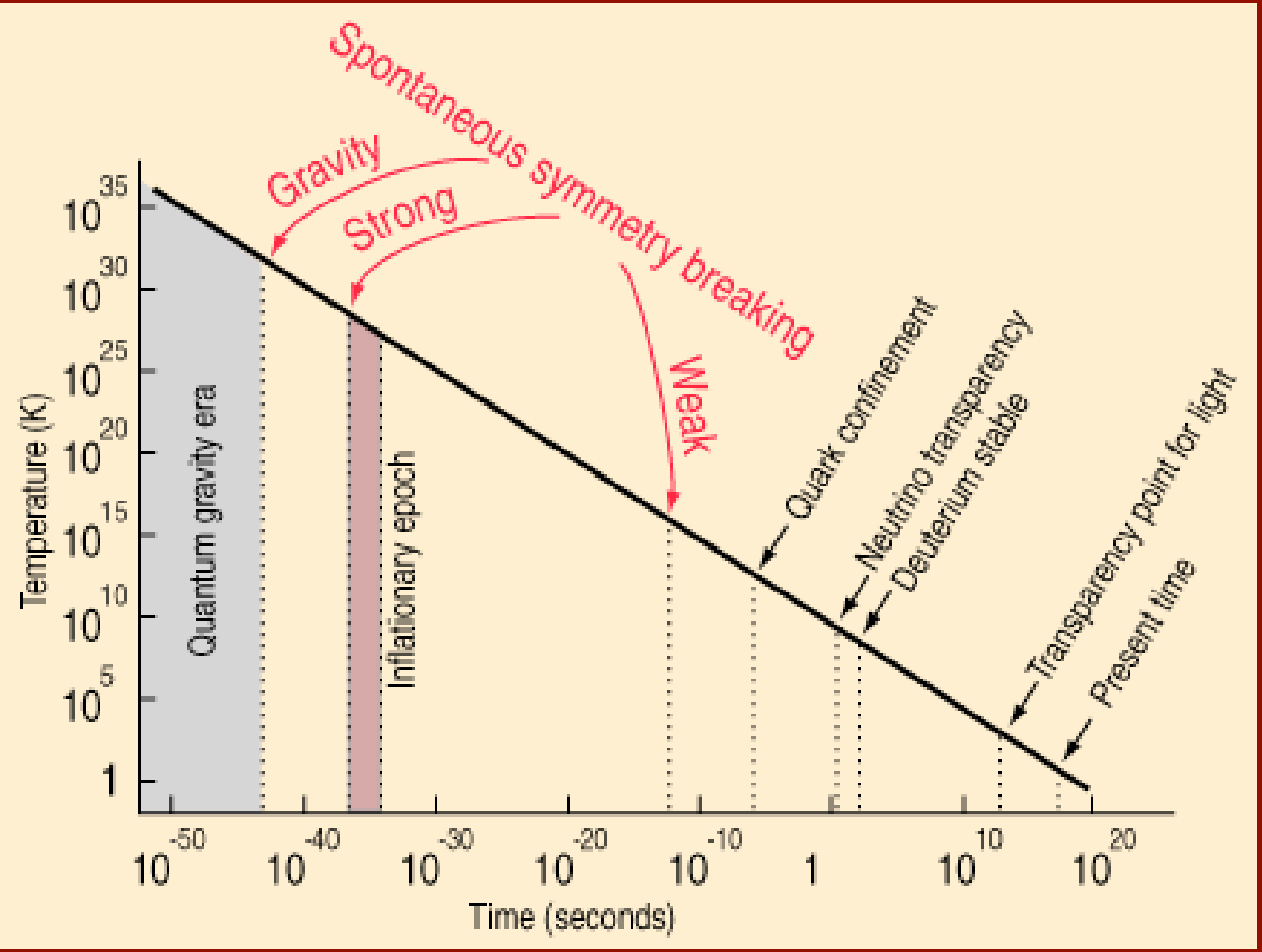
Inflation

10^{-36} to 10^{-32} seconds Temperature = 10^{28} K

Super-fast expansion of space by a factor of 10^{25}

Strong nuclear force separates and this releases lots of energy

Expansion: Temperature cools with time



Then what happened?

Electroweak Era — Temperature = 10^{15} K

10^{-32} to 10^{-10} seconds

Strong nuclear force comes into play and unusual particles form including W, Z, and Higgs Bosons

Particle Era

10^{-10} to 10^{-3} seconds — Temperature = 10^{12} K

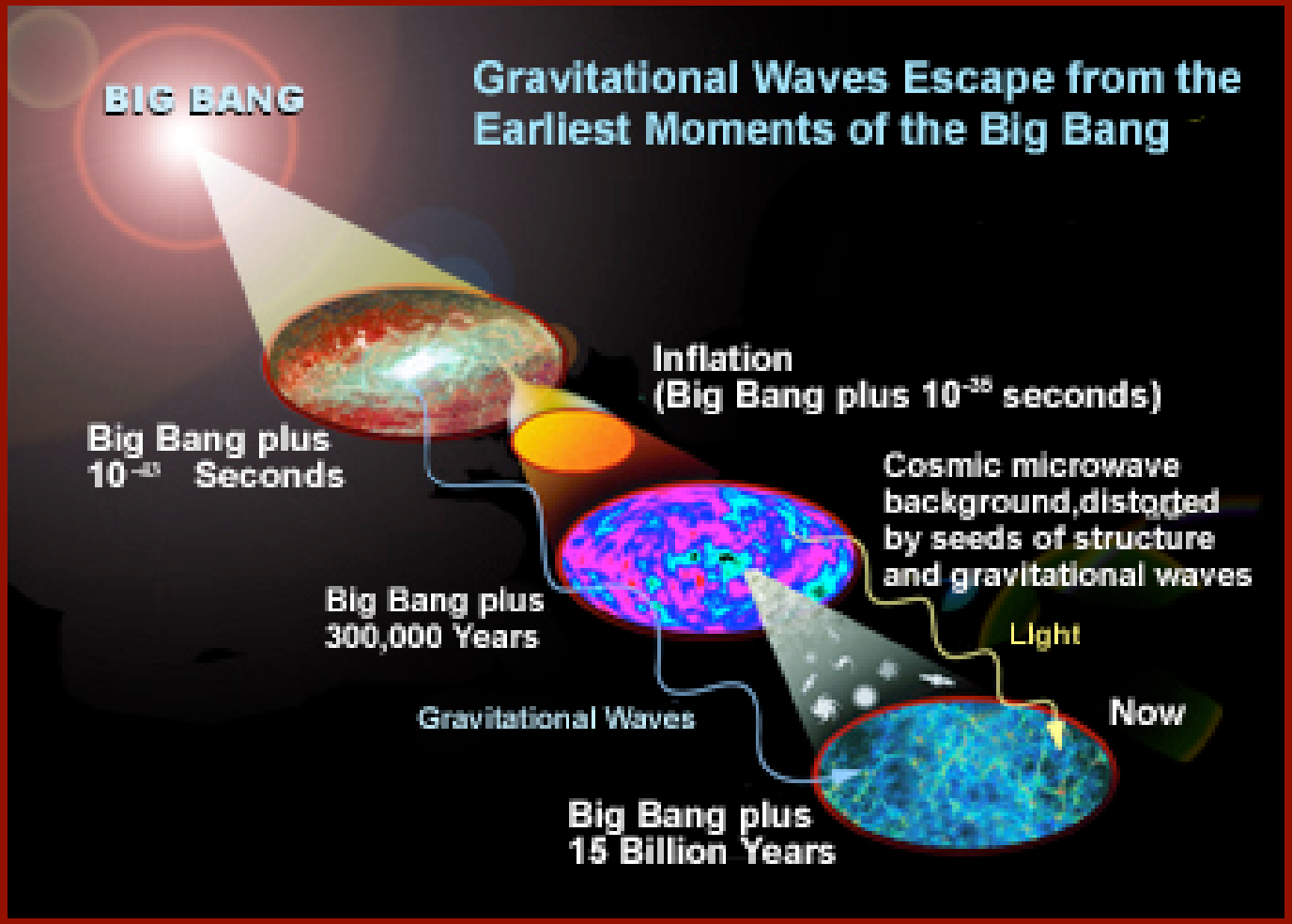
Four fundamental forces are now separate. Quarks, protons, neutrons, electrons, and photons form from energy.

Nucleosynthesis

0.001 seconds to 3 minutes — Temperature = 10^{9} K

Particles undergo fusion and form nuclei, mostly hydrogen and helium. Model of forces predicts 75% H and 25% He, as observed. This is Evidence #2.

Need a visual, to fully blow your mind?



After the first 3 minutes

Nuclei Era

Temperature = 3000 K

3 minutes to 380,000 years

Continued expansion and cooling

Matter is composed of high temperature nuclei and electrons

Atomic Era

380,000 years to 1 billion years

Cooling continues and nuclei and electrons combine to form atoms.

Photons can travel long distances without being scattered or absorbed.

This is the beginning of cosmic background radiation (Evidence #3).

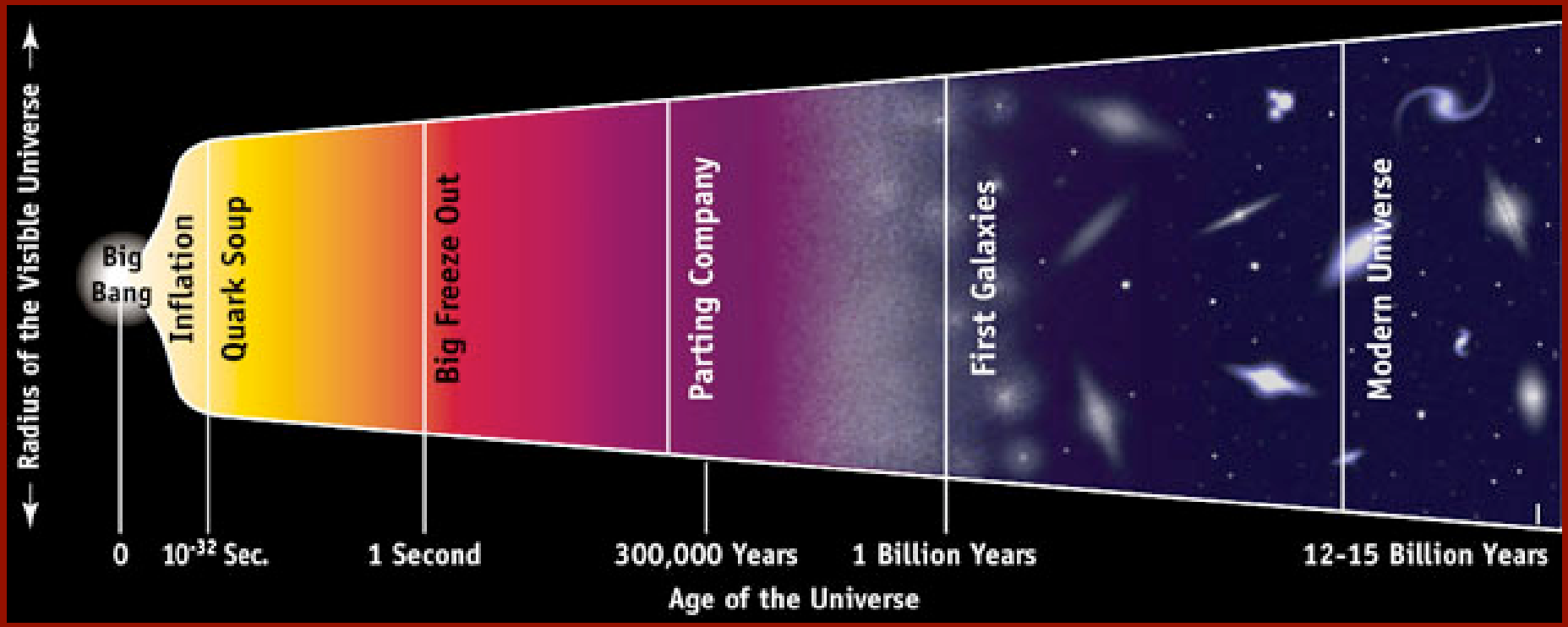
Stars and Galaxies

1 billion-13.7 billion years (now) Today's Temperature = 3.7 K

Gravity attracts masses together to form stars and galaxies.

Cosmic background radiation cools to microwave frequencies (now).

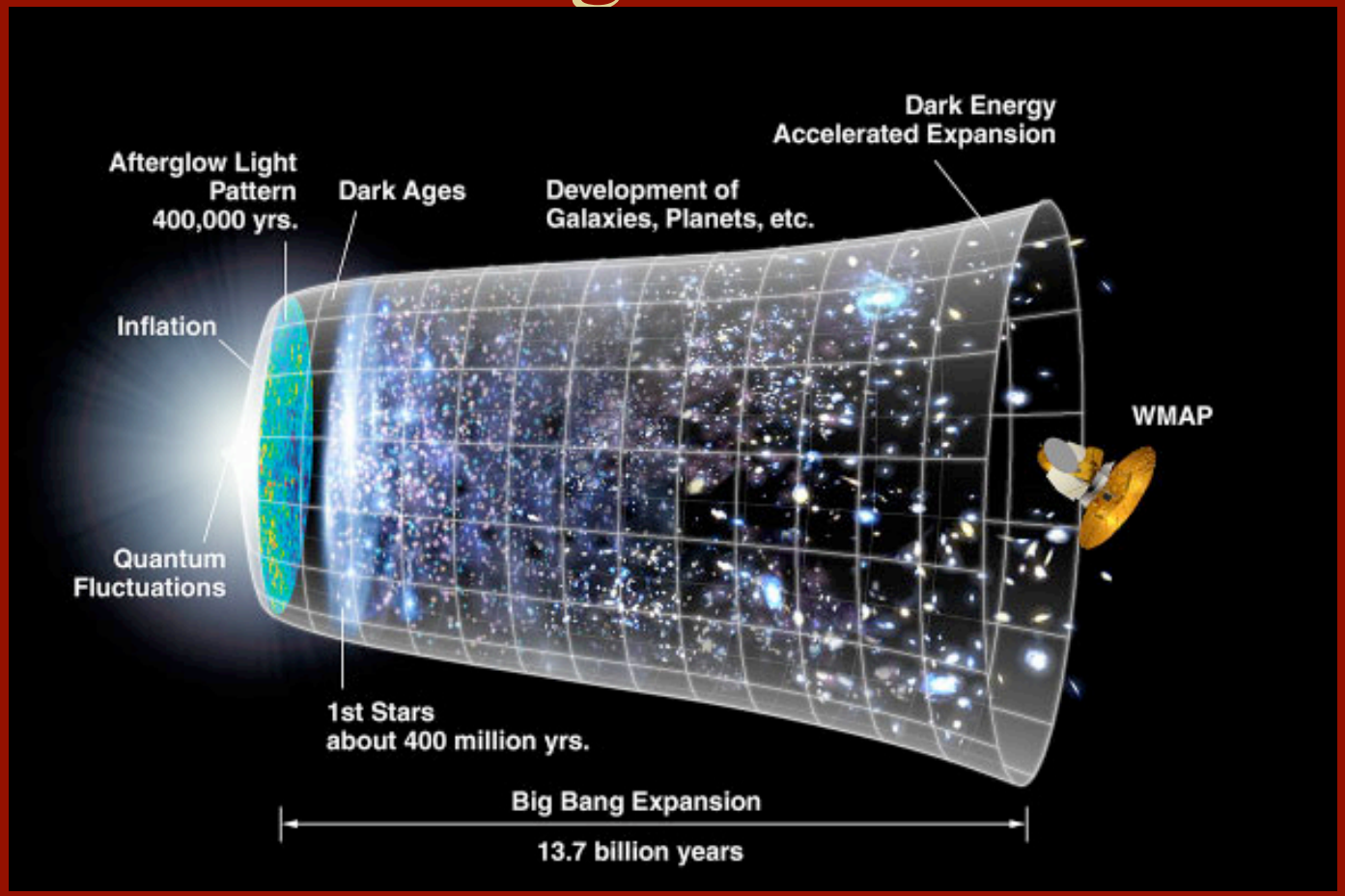
A Summary


Radius of the Visible Universe
Big Bang
Inflation
Quark Soup
Big Freeze Out
Parting Company
First Galaxies
Modern Universe
0
10-32 Sec.
1 Second
300,000 Years
1 Billion Years
12-15 Billion Years
Age of the Universe

What is the Cosmic Microwave Background?

- When atoms formed, photons in the universe began to travel through space in straight lines.
- As space expanded, photon energy and frequency decreased and their wavelength increased.
- This process continued and now this radiation has microwave wavelengths and can be detected coming from everywhere.

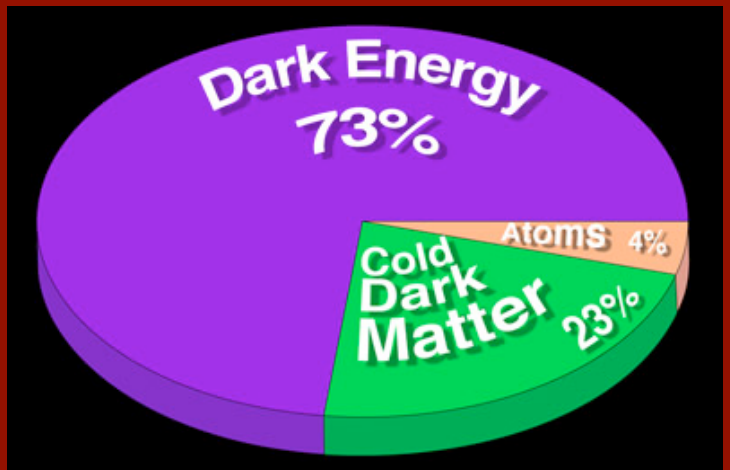
How do scientists study the cosmic background radiation?



Video: We can see light from the big bang
Researchers, Big Bang

The Big Bang is not The Final Answer

- What happened during Planck time?
- Can the universe expand forever? Is it infinite? Open? Closed?
- Can the cosmic microwave background predict the arrangement of galaxies in the universe?
- What is the composition of the universe, based on our best observations?



Video: Researchers, Dark Energy

More Questions to Research

What are the 4 fundamental forces? How do they work?

What is the Higgs Boson and how are scientists learning about it?

That does the Theory of Everything try to explain?

What are matter and antimatter? How were they created in the big bang?

What do studies of the cosmic microwave background tell us?

What is the history of the big bang model? Who thought it up?

Is the universe infinite? Closed? Open?

Sources

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