Astronomy 330:

Extraterrestrial Life

This class (Lecture 4):

Origin of Universe

Next Class:

Origin of Elements

Music: *Galaxies*– Laura Veirs

Presentations

- The presentation schedule has been decided by random selection.
- It is posted in the schedule section of the webpage.
- Make sure to check those dates ASAP.

Presentations

- I will keep you to 10-12 minutes with up to 5 minutes of questions. (Peers should deduct points if too short, or I will.)
- Any speculative claims *MUST* have a scientific reference source.
  - Can't just claim that monkeys live on the Moon.

Presentations

- Can give presentation in any format you want.
- But, over last few semesters:
  - 97.9% powerpoint/keynote/opd
- If presentation is electronic, I want to see draft version 1-2 days in advance
  - Email me
  - Or, on box, email me URL location
  - Or USB Flash Drive (present to me class BEFORE)

Oral Presentation

1. How relevant is the general topic to this class (e.g. search for extraterrestrial life)?
2. How interesting is the topic for the general class audience?
3. Rate the extent of the speakers knowledge on the topic?
4. Rate the quality of the overall presentation?
5. Does the research have a solid scientific basis?

These questions are rated 1-10 out of 10 scale by your peers!

Layout

- Nice colors/fonts— not too much
- Images required— usually 1 per page is necessary
- Videos are fine (be careful of how software stores them)
- Sound is fine (be careful of how software stores them)
- Too much of anything could lose you points with audience
- Last slide must be a list of references used to find information, images, videos, or music

Common Mistakes

- Too much text on a slide.
- Too long (only 2% are too short).
- Background graphics or color makes text hard to read.
- Reading the slides is boring, use as points but not the whole message.
- 10-12 minutes is not as long as it sounds.

Are we alone?

Life as we know it requires **CHON** or **HONC**

Carbon **H**ydrogen **O**xygen **N**itrogen

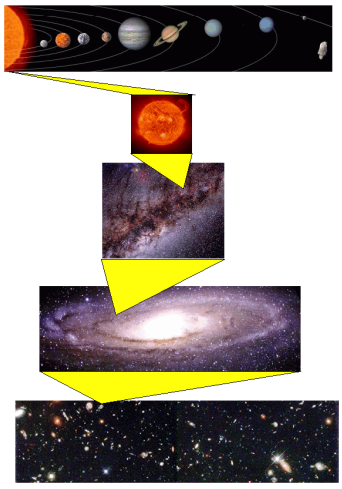
How did we get these elements?

8

Cuba Gooding Junior The Quan!
http://www.urbandictionary.com/define.php?term=quan&defid=11277

9

What is the Universe?
All the matter, energy, and spacetime we can ever detect
Cosmology is the study of the origin, structure, and evolution of the Universe



Astronomy: The Big Picture

Arguably, the biggest fish of all:
Cosmology

- What is the Universe made of ?
- How big is it?
- How old is it?
- How did it form?
- What will happen to it?

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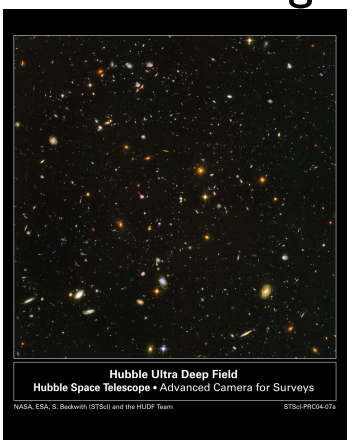
The Night Sky



Question: What do you see?

Answer: Lots of beautiful galaxies.

Question: What else do you see?

Answer: Lots of black sky.

Question: Why?

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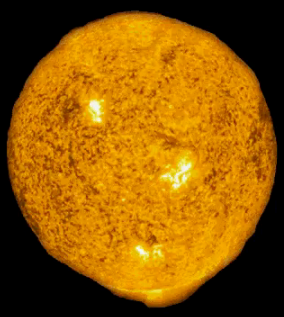
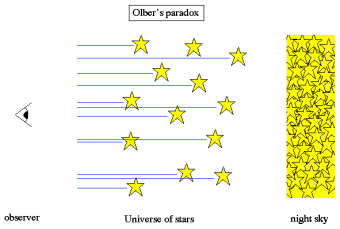
Deepest view of the sky, but it is still dark

Olber's Paradox



Olber's Paradox

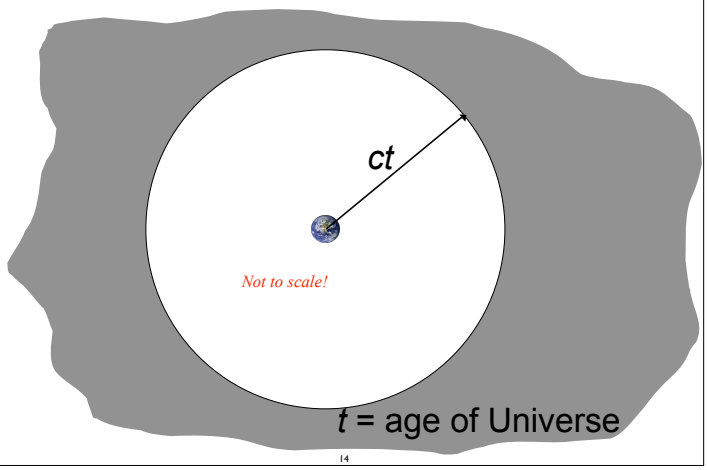


Question: So why do we have a black sky?

Not many stars hidden by dust, which would heat up and radiate thermally.

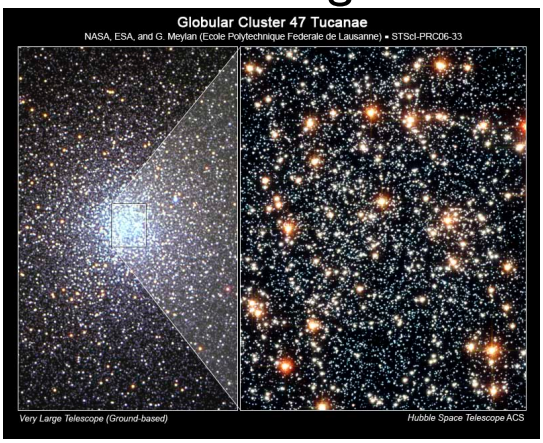
Universe must have a finite age.

Observable Universe



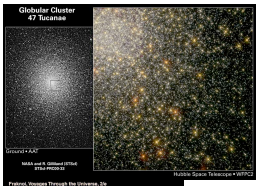
The Universe is finite in age.
Not necessarily in extent.

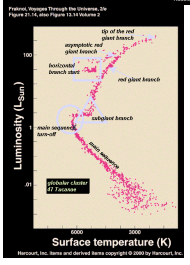
Stellar Ages

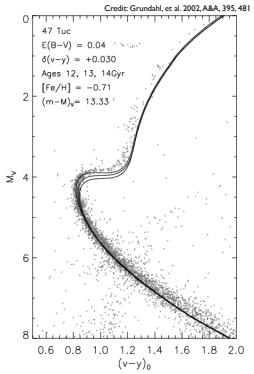


In addition, stellar ages in some of the oldest objects— Globular Clusters— limit the age of the Universe.

Cluster Ages







Question: What should we take from this figure?

Answer: Minimum age for the Universe.

Age of the Universe is limited by ages of these stars.

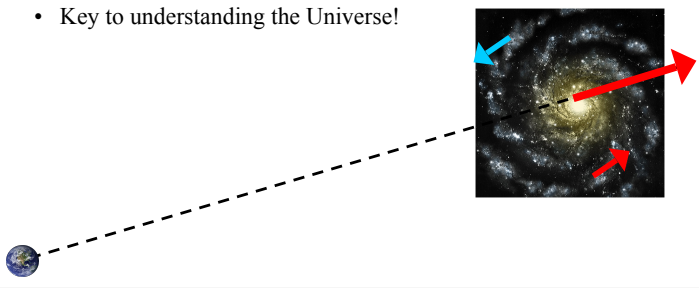
How are Galaxies Moving?

It's 1928 and Edwin Hubble is measuring how galaxies move. What does he find?

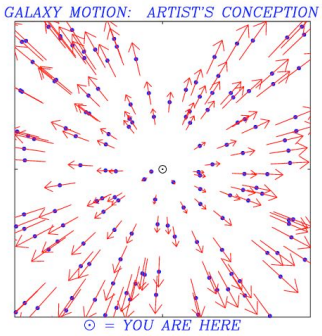
a) More galaxies receding than approaching.
b) More galaxies approaching than receding.
c) About equal numbers of each.

What Does This Mean?

- Most galaxies are moving away from us.
- The farther away, the faster they are moving away.
- Or $V = H_o \times D$
  - $H_o = 72$ km/s /Mpc
- What does this mean?
- Key to understanding the Universe!



Hubble's Law



Draw what Hubble observed.

Simple interpretation is not galaxy motion.

But the Universe is expanding!

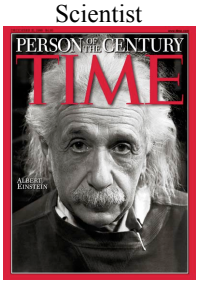
In a homogenous Universe, what does the farther away the faster the galaxies move away mean?

Interpretation

Egoist

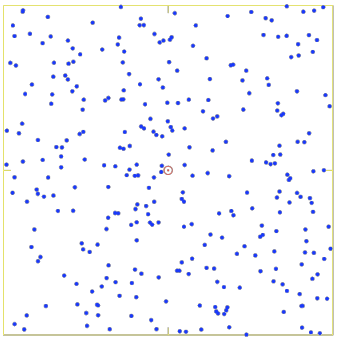
I am the center of the Universe!

Scientist

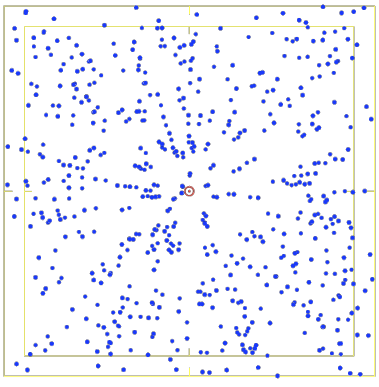


The Universe is Expanding!

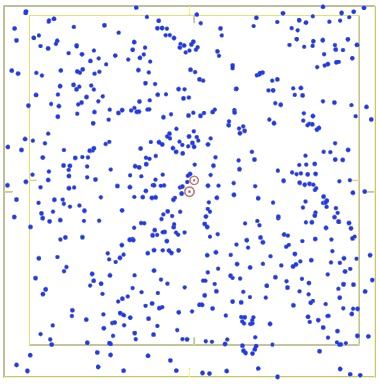
Gives the Impression of Being Special



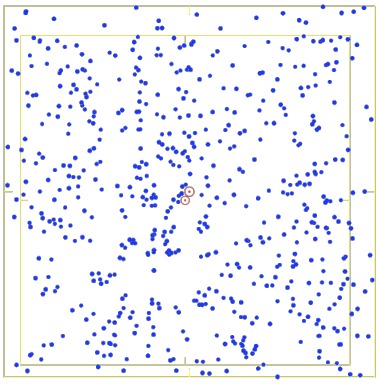
Gives the Impression of Being Special



Gives the Impression of Being Special

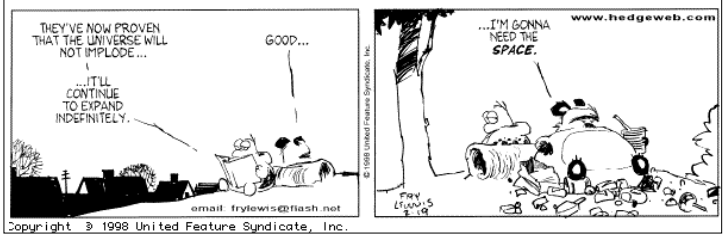


Gives the Impression of Being Special



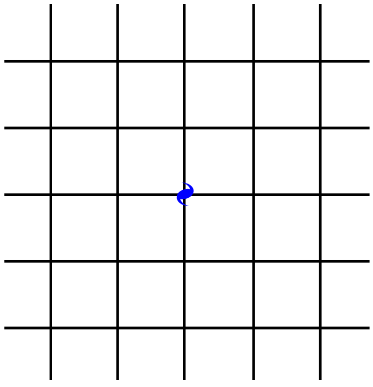
The Expanding Universe

- To describe the motion of all the galaxies in the Universe, we use General Relativity (due to gravitation effects)
- General Relativity predicts that we live in an *expanding Universe*.
  - Einstein didn't buy it at first, so made a cosmological constant to get rid of it.
- In other words, space is stretching in all directions. This completely explains Hubble's Law.

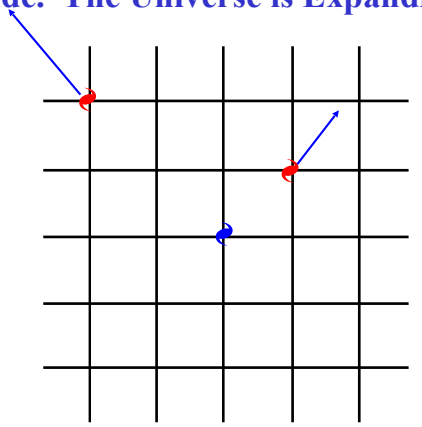


We'll talk about General Relativity more later, but it describes how the mass of objects (in this case all of the matter in the Universe) can distort space/time.

The Universe is Expanding.



Dude. The Universe is Expanding.



Question

We measure nearly all galaxies to be moving away from the Milky Way. This means that

a) aliens have affected our measurements.

b) we are the center of the Universe.

c) its inverted, we are the ones moving.

d) dark matter causes galaxies to move apart

e) the Universe is expanding.

iClicker

E

Are We Expanding?

Other forces hold us together.

Atomic nuclei:
- strong nuclear force

Molecules & ***Life***:
- electromagnetic forces

Stars systems, Galaxies, clusters of galaxies:
- gravity

Brooklyn isn't expanding!

No

But on very large scales, expansion wins!

Brooklyn Is Not Expanding

Annie Hall (1977)

What do you think?

The Universe is expanding, how do you feel about that?

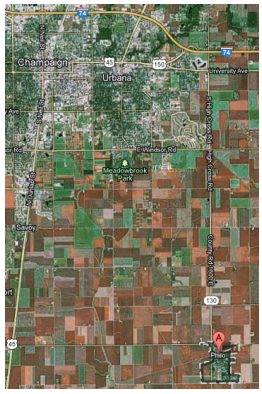
http://www.calresco.org/ewp/confuse.htm

A) 

B) 

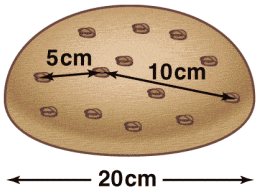
C) 

Center of the Universe



Analogy– Raisin Bread?

The raisins are like galaxies.



MAP3804O4

Raisins stay the same size, like Brooklyn.

Question

Why is the Universe expanding, but the Earth is not?

a) What are you talking about Willis?

b) We are held together by stronger forces.

c) Aliens have affected our measurements.

d) We are expanding, have you looked at people lately?

e) The Universe is just a figment of my imagination.

iClicker

E

What is Universe expanding into?

Nothing!

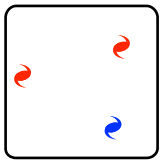
What is North of the North Pole? Can't really answer.

Reality

- The analogies are just to help us visualize, don't get stuck in the specifics.
- The Universe has no center.
- The Universe has no edge.
- Concept of time and space began with the Universe, can not apply the concepts so easily.

http://universe.gsfc.nasa.gov/images/reach-for-the-universe.jpg

Consequences of Expansion



As space expands, mass stays constant while volume increases

$$\frac{M_{\text{Now}}}{V_{\text{Now}}} > \frac{M_{\text{Later}}}{V_{\text{Later}}}$$

Density is decreasing!

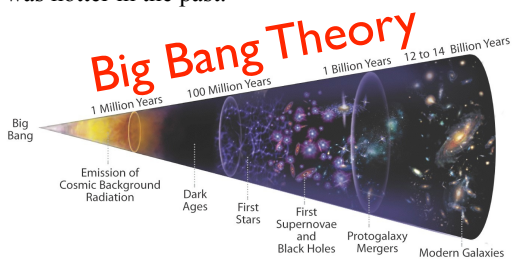
Universe was denser in the past!

What does this mean?

1) Universe is expanding.

2) Universe was more dense in the past.

3) Universe was hotter in the past.



Evidence supports!

What was the Big Bang?

Not an explosion!

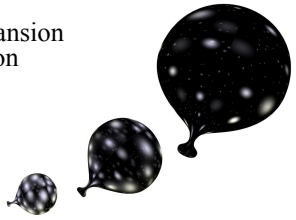
The *beginning* of spacetime, and all matter and energy.

Occurred everywhere all at once 13.8 billion years ago!

The origin of the Universe can be described by the idea of the Big Bang. Where did the Big Bang happen? The Universe is homogenous & isotropic.
Occurred everywhere at once
Not an explosion into empty space.
The Universe was suddenly filled with energy – hot and dense
The beginning of spacetime, matter, and energy

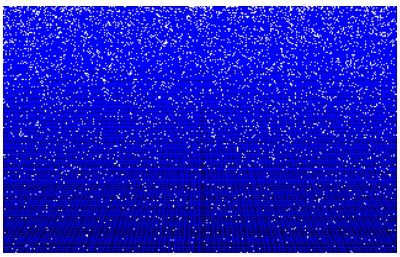
Common Misconception

- Its common to think of the expansion of the Universe like an explosion
  - Galaxies hurled away from each other through space
- This is incorrect!
- Einstein's Theory of Relativity tells us that spacetime itself is expanding!
  - Like an inflating balloon



The Big Bang

- No special points or locales
- Expansion of **all** space
- As spacetime expanded, the Universe became less dense and cooler
- Eventually forming the stars and galaxies we see today



http://www.atlasoftheuniverse.com/bigbang.html

Question

Where did the Big Bang occur?

a) In the center of the Earth?

b) Inside an alien laboratory.

c) Beyond the edge of the observable horizon.

d) Everywhere

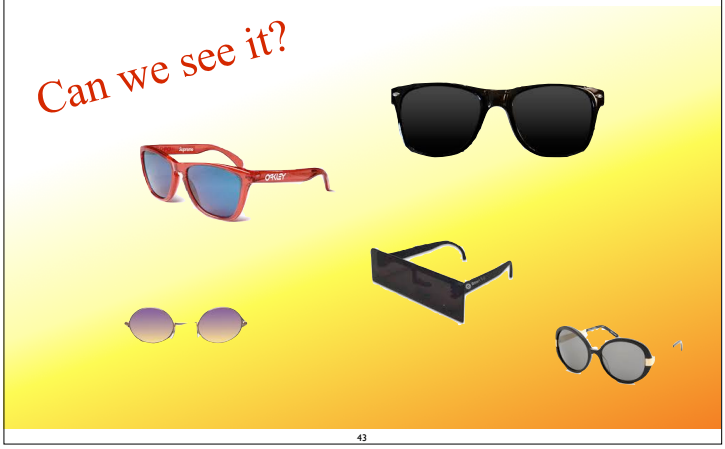
e) The 6-pack last Saturday morning, 1:35 am.

iClicker

E

What was the Big Bang?

Can we see it?



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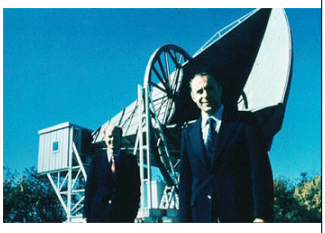
Arno Penzias & Robert Wilson

Used surplus Bell Labs 20-foot horn-shaped antenna to look for radio signals from space.



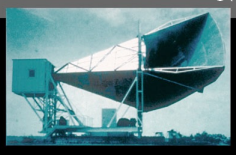
Excess "noise" that was isotropic at 3 degrees Kelvin.

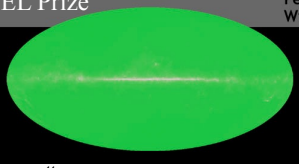
Rivets and pigeon droppings - "toughest year of our lives"

"looked for dung but found gold, which is just opposite of the experience of most of us."
- van Kaminow,

Consultation with Princeton theory group led to recognition that relic radiation had been found.

1965 NOBEL Prize Penzias and Wilson





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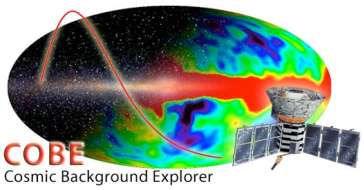
Born in Ukraine, defected to US in 1934. Gamow developed Hot Big Bang model in 1948 with Ralph Alpher and Robert Hermann. Predicted Temperature of 3 K for relic radiation. Prediction of Hot Big Bang contrary to popular Steady State Cosmology theory.

Robert Dicke, a professor at Princeton, theoretically showed that in a hot big bang, a relic radiation should exist at 3 degrees Kelvin. Dicke along with collaborators Wilkinson and Rolle decided to look for relic radiation around 3 K. On seeing Penzias & Wilson's result, said "We'll boys, we've been scooped"

This radiation is called the **Cosmic Microwave Background**.

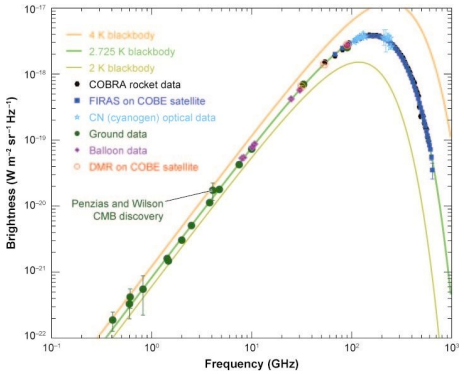
COBE Satellite

Launched in 1989 for full sky and better sensitivity of this
Cosmic Microwave Background



DIRBE: Diffuse Infrared Background Experiment to find cosmic infrared background. Important for star formation and understanding dust in Universe.
FIRAS: Far Infrared Absolute Spectrophotometer to find absolute temperature of CMB.
DMR: Diffuse Microwave Radiometer to map CMB

CMB Blackbody

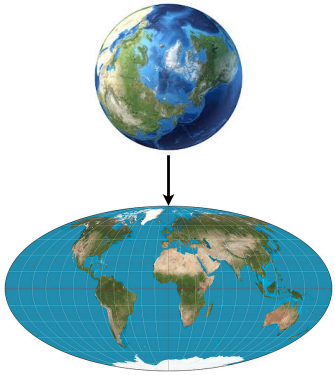


Credit: Samtleben et al. 2007, ARNPS, 57, 245

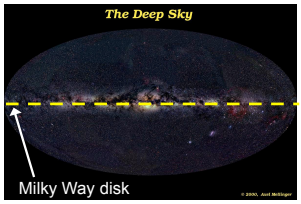
The sky is not dark. It is full of a diffuse glow from the Big Bang. CMB can be seen as a "blackbody" curve. A blackbody is thermal radiation from a source that is described by only its temperature: example of pizza oven or lava or even the Sun.

This Big Bang glow is perfectly consistent with blackbody radiation of 2.725 Kelvin. Amazing!

Reading Sky Maps



Mollweide projection



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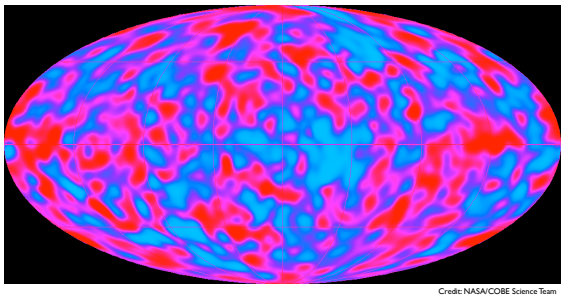
CMB



Credit: NASA/COBE Science Team

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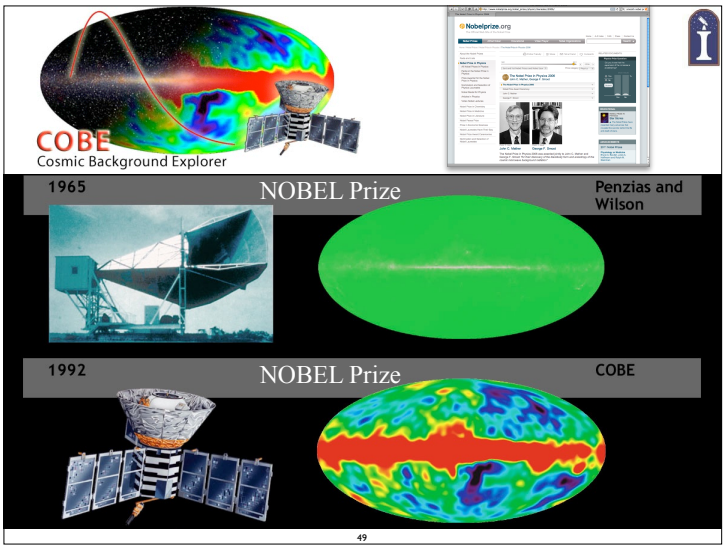
Temperature map is very smooth. But if you play with the scale, you notice small signals. First we can actually see our movement against the CMB. From these data, our local group of galaxies appears to be moving at 630 km/s relative to the CMB causing the blue and red shift. If one removes that (and any Galaxy contamination), we are left with small VERY small variations in the signal. It is not perfectly flat. Differences at the ~0.004 Kelvin level. Wow.



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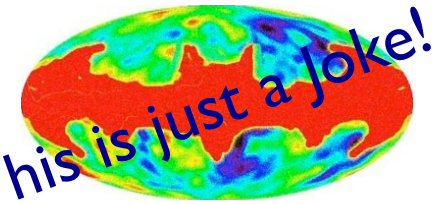
COBE Signal

Unknown fluctuations signal us to look for a deeper meaning ...



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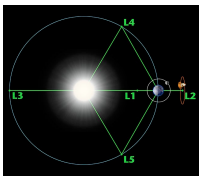
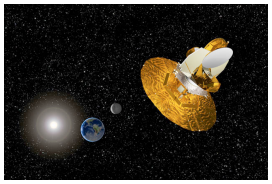
WMAP Satellite

Launched in June 2001:

Located at L2 (four times further than moon from Earth

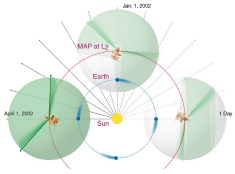


Credit: NASA/WMAP Science Team



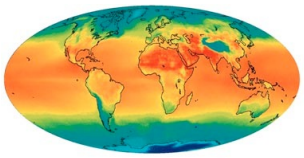
Differential measurements of the sky

W added to name after Wilkinson died.



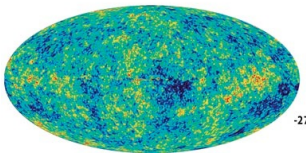
WMAP Satellite

Baby Picture of Universe



Earth Temperatures

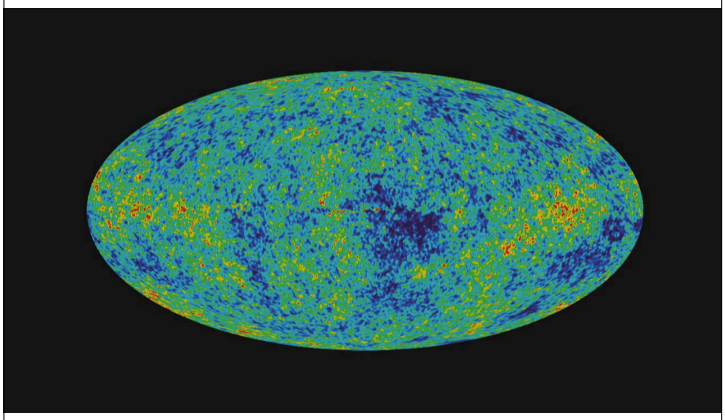
-63° -13° 37°
Centigrade
June 1992

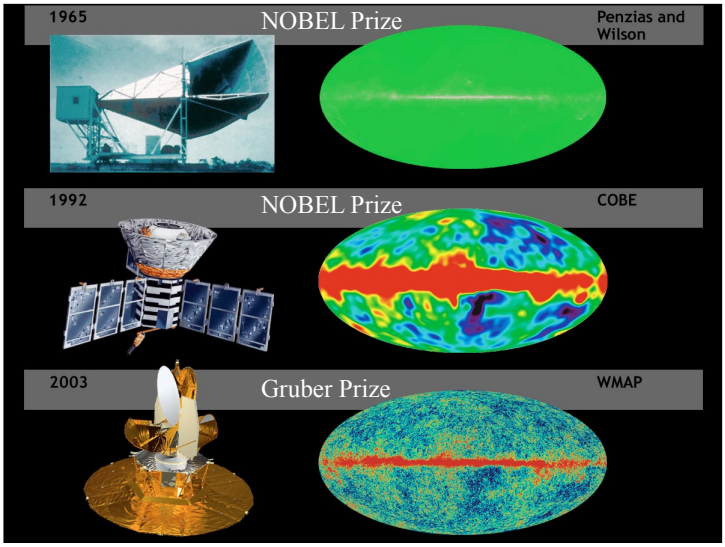


Microwave Sky Temperatures

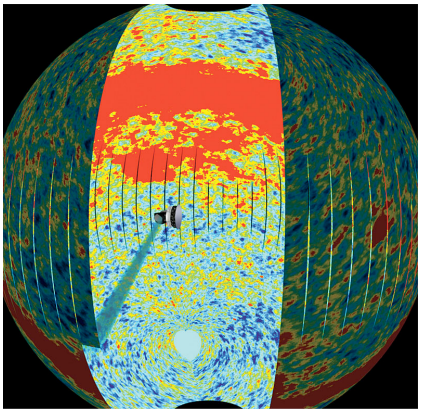
-270.4252° -270.4250° -270.4248°
Centigrade
380,000 Years after Big Bang

Viewing the CMB





Plank Satellite



Launched in 2009

started observing
July 2009

ran out of cooling
June 2012

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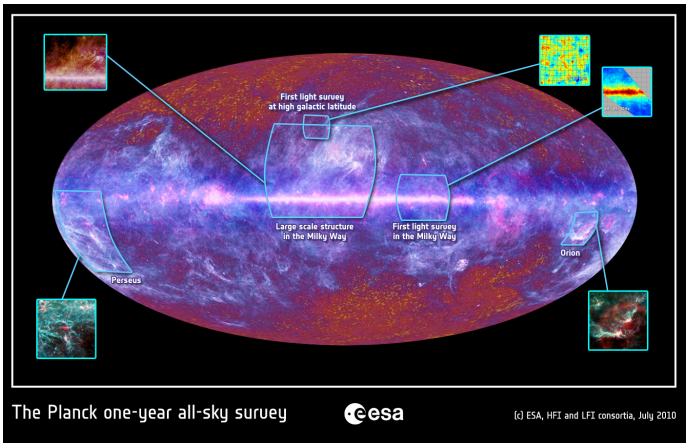
Plank Satellite



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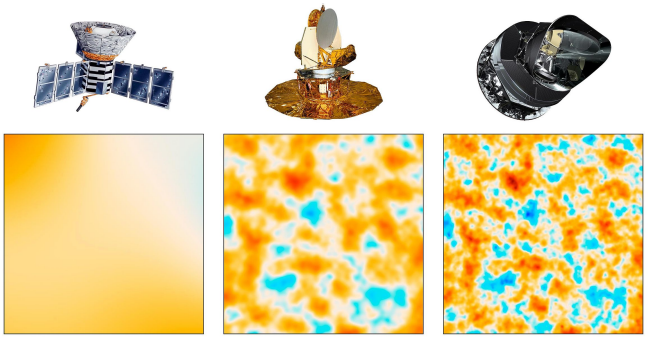
TURIN, ITALY—At a press briefing here this morning, the European Space Agency (ESA) released the first full-sky image of the universe's microwave radiation taken by its Planck satellite, which was launched just last year. (Here's a preview of the mission in Science.) Although it may be 2012 before the space observatory accumulates enough data to answer questions about the early universe, this initial snapshot developed from observations between August 2009 and May 2010 shows that the satellite is "very healthy, and all the instruments are working, sometimes better than expected," says Nazzareno Mandolesi, director of the Institute of Space Astrophysics and Cosmic Physics in Bologna, Italy. One of Planck's goals is to image the so-called cosmic microwave background (CMB) with unprecedented resolution. This radiation represents the first photons to escape from being tied up with matter as the universe cooled after the big bang. CMB "is the light that appeared 379,000 years after the big bang of the universe. ... It's the first light of the universe." Mandolesi says. Planck is already mapping the fine details of CMB at the edges of the sky (top and bottom of picture), but the microwave radiation from the dust and gas in the Milky Way obscures a large portion of its view (center of the map). It will take several years of data analysis to factor out the radiation from the galactic plane and get a clear full-sky picture of CMB. Once available, however, the CMB map should resolve competing theories of how the universe underwent a period of inflation after the big bang and provide other cosmological answers. The scientists responsible for the ESA satellite are being protective of the flood of data streaming back to them from space. Mandolesi notes that the image released today has had its data "degraded" so that other researchers can't easily utilize it for the time being. "We don't want to be scooped," he says. ESA plans a more comprehensive release of Planck's initial data in 2011.



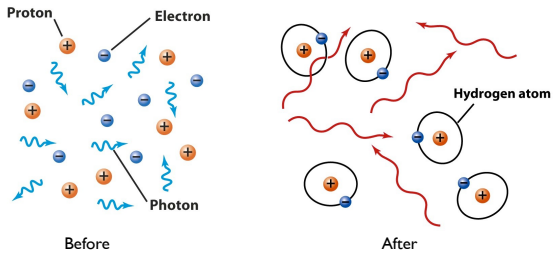
COBE WMAP Planck

Results so far:

Universe is 13.8 billion years old!
(Uncertainty of 37 million years)

Based on Plankck data: Universe is 13.798±0.037 billion years old, and contains 4.82±0.05% ordinary matter, 25.8±0.4% dark matter and 69±1% dark energy. The Hubble constant was measured to be 67.80±0.77 (km/s)/Mpc

What is the CMB?



The temperature at equilibrium is approximately 50,000 K

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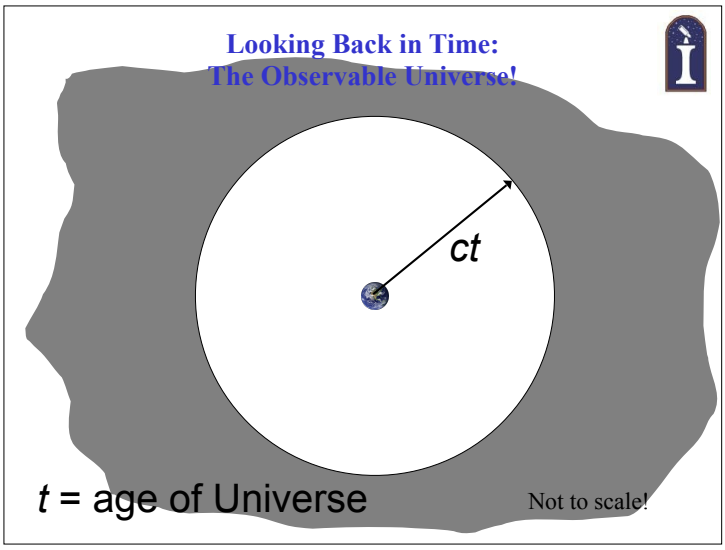
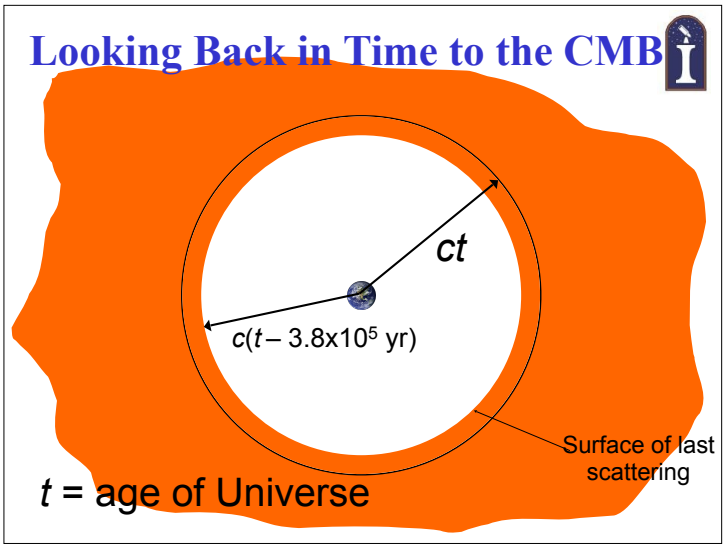
When the Universe was opaque to light, then suddenly it was transparent. This happened about 370,000 years after the Big Bang


Looking Back in Time:
The Observable Universe!
ct
t = age of Universe
Not to scale!


Looking Back in Time to the CMB
ct
c(t – 3.8x10^5 yr)
Surface of last scattering
t = age of Universe

Question

What is the cosmic microwave background radiation?

a) the leftover radiation from countless dorm microwaves.

b) alien transmissions.

c) leftover thermal radiation from the Big Bang.

d) radiation released during quark confinement

e) radiation released when Helium became neutral

iClicker

E

Very Early Universe

Since Big Bang works well so far, we have confidence to think about very early times:

$t << 1$ sec !

- Temperature and energies are ***ultrahigh***

Q: How to probe such high energies?

Hint: the players are in Illinois and Europe

Fermilab, ***Batavia IL***

CERN, ***Geneva Switzerland***