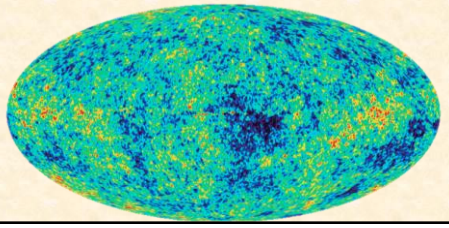
ASTR 1020: Stars & Galaxies

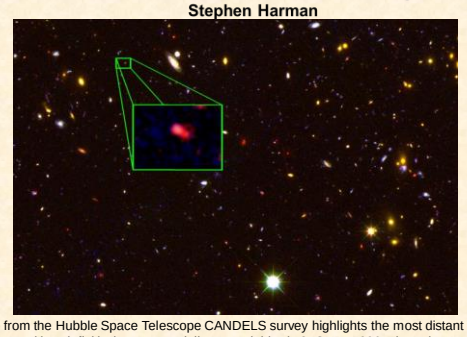
December 6, 2012

- Reading: Chapter 22, sections 22.3-22.4 .
- *MasteringAstronomy* Homework on The Fate of the Universe is due tonight.
- Must submit all *MasteringAstronomy* homeworks by Dec. 14 at 7:30 pm.
- Any requested grade corrections & extra credit papers must be submitted to Lucas by 3 pm on Dec. 13.
- Final Exam is Dec. 14 at 7:30 pm.



Astronomy in the News: **Most-Distant Galaxy Found—and Yes, It's Far, Far Away**

Stephen Harman



This image from the Hubble Space Telescope CANDELS survey highlights the most distant galaxy in the universe with a definitively measured distance, dubbed z8_GND_5296. The galaxy's red color alerted astronomers that it was likely extremely far away, and thus seen at an early time after the Big Bang (z=8, age of Universe when light left was only 700 million yrs).

Last Time

The Creation of the Universe

1.) Planck Era: before physics as we know it existed.
2.) GUT & Electroweak Eras: Four forces came into being.
3.) Particle Era: Origin of matter.
4.) Nucleosynthesis (fusion) Era: Helium is born.

Today

- From 3 minutes after the Big Bang until Now
- Cosmic Microwave Background
- Evidence for the Big Bang Theory

Reading Clicker Question: At the beginning of the Universe

A. the temperature was extremely high, more than the core of the Sun.
B. the density was enormously high.
C. matter could turn into energy and vice versa.
D. all of the above
E. A and B

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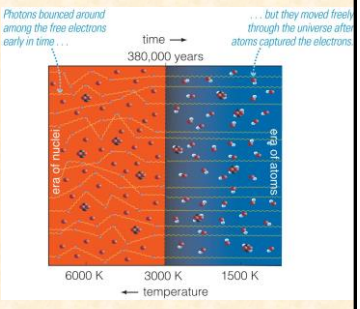
Era of Nuclei

- Dense clouds of protons (hydrogen nuclei), helium nuclei, electrons, neutrinos, photons
- Temperatures too hot for electrons to combine with protons– electrons ionized by energetic photons
- Universe is made of naked nuclei, not atoms with nuclei + electrons
- Lasts for about 380,000 years

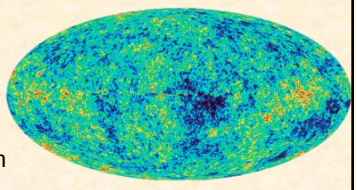
Era of Atoms

- Finally cool enough for electrons combine with nuclei to form atoms.
- Photons now "decoupled" = free to fly (the fog lifts!).
- Universe becomes transparent to light.



Light from the Beginning of Time

- This light can be seen with telescopes- all around us!
- Thermal spectrum at 3000 K
  at redshift ~1000.



Above is global map of the Cosmic Microwave Background as measured by the Planck satellite.

The Cosmic Microwave Background

- Discovered by accident by Arno Penzias and Robert Wilson in 1965
- Direct evidence for HOT early universe → Big Bang
- 1978 Nobel Prize

Clicker Question: Remembering Wien's Law

=>Wavelength maximum = 2,900,000 nm / T (K)

If T = 2900 K (expected temperature at z=1000), what is wavelength of the peak of the thermal spectrum?

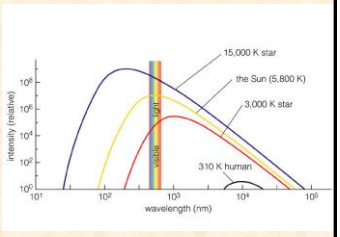
a) 100 nm
b) 1000 nm
c) 1,000,000 nm

- 2,900,000 nm / 2900 K = 1000 nm.

Remember that visible light is 400-700nm

→ Near infrared, spilling towards red/visible, similar to the coolest red stars.

- We should see a red glow all around us?



Clicker Question: But why is the sky black?

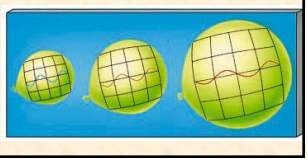
- The universe has expanded by a factor of 1000…

What is the current wavelength of the peak of this radiation?

a) 1000 nm

b) 1 nm

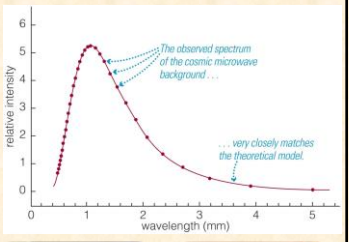
c) 1,000,000 nm = 1 mm



- 1+z ~ 1000
- Wavelength will be BIGGER because universe is now bigger:
- Wavelength emitted x (1+z)
  = wavelength observed now

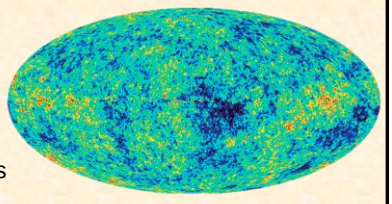
1,000 nm x 1000 = 1,000,000 nm = 1 mm
Microwaves!

- Perfect thermal spectrum peaking at ~1 mm (Nobel prize in 2006 to Mather & Smoot)
- ~ 3 degrees K
- Contributes to communications static (TV)



Cosmic Microwave Background (CMB)

- Mapping of CMB shows TINY fluctuations: 1 part in 100,000.
- Seeds of galaxies, clusters that will collapse due to gravity.



Why is the sky dark?

Did the Big Bang Really Happen?

- How can we tell what happened so long ago?
- About 14 billion years ago
- Mostly unobservable, not repeatable
- Some of it at temperatures beyond our ability to even understand how physics works!


COSMOLOGY
Trying to describe the size of the Big Bang