

## ASTR 1020: Stars & Galaxies

April 23, 2008

- Reading: Chapter 23, sections 23.3-23.4 .
- *MasteringAstronomy* Homework on The Fate of the Universe is due April 30<sup>th</sup>.
- 2 more extra credit opportunities at Fiske Planetarium this week and next!
- Meet at Fiske Planetarium next Monday.

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## Astronomy Picture of the Day



**Messier 63: The Sunflower Galaxy**

**Explanation:** A bright spiral galaxy of the northern sky, Messier 63 is about 25 million light-years distant in the loyal constellation Canes Venatici. Also cataloged as NGC 5055, the majestic island universe is nearly 100,000 light-years across, about the size of our own Milky Way.

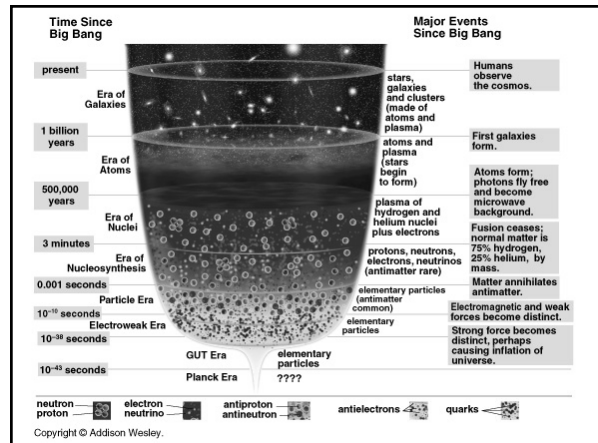
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## Last Time

### 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

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## Today

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

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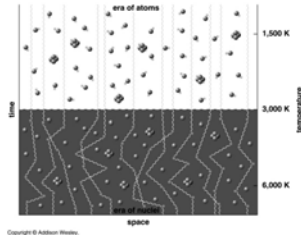
## Era of Nuclei

- 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

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## Era of Atoms

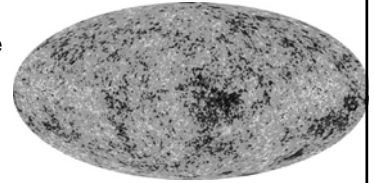
- Finally cool enough for electrons combine with nuclei to form atoms
- Photons now "decoupled" = free to fly
- Universe becomes transparent to light



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## Light from the Beginning of Time

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



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## 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



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## Clicker Question: Remembering Wien's Law

- Wavelength maximum =  $2,900,000 \text{ nm} / T \text{ (K)}$
- If  $T = 2900 \text{ K}$ , what is wavelength of the peak of the thermal spectrum?

- 100 nm
- 1000 nm
- 1,000,000 nm

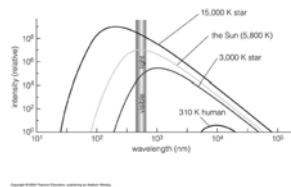
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- $2,900,000 \text{ nm} / 2900 \text{ K} = 1000 \text{ nm}$

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?



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## 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?

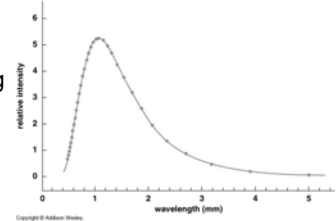
- 1000 nm
- 1 nm
- 1,000,000 nm = 1 mm



- $1+z \sim 1000$
  - Wavelength will be BIGGER because universe is now bigger:
  - Wavelength emitted  $\times (1+z)$   
= wavelength observed now
- $1,000 \text{ nm} \times 1000 = 1,000,000 \text{ nm} = 1 \text{ mm}$   
Microwaves!

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- Perfect thermal spectrum peaking at  $\sim 1 \text{ mm}$  (Nobel prize in 2006 to Mather & Moot)

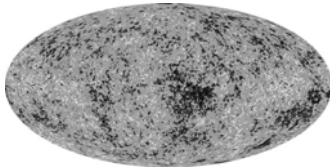


- $\sim 3$  degrees K
- Contributes to communications static (TV)

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## 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?



## Did the Big Bang Really Happen?

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

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## Evidence for the Big Bang

- 1) Expanding Universe
- ... run time backwards....



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