ASTR 1020: Stars & Galaxies

April 25, 2008

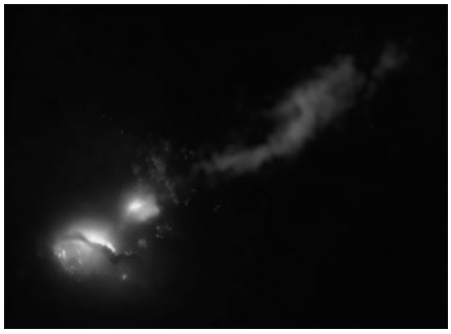
- Reading for next Wednesday: Chapter 13 – Extrasolar Planets.
- *MasteringAstronomy* Homework on The Fate of the Universe is due April 30th.
- Meet at Fiske Planetarium on Monday!
- **Final Exam:** May 5, 4:30 – 7:00 pm; Chapters: 1.1-1.2, 4.1-4.4, 5, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23.

Simulating the Big Bang

Astronomy In the News

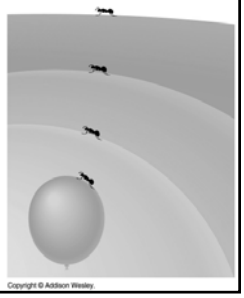
Death Star Galaxy Black Hole

Nicholas Ballas



Today

- Evidence for the Big Bang Theory
- The results of Inflation



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Clicker Question: What is the earliest time in the Universe that we can ***directly*** observe?

a) A few hundred million years after the Big Bang
b) A few hundred thousand years after the Big Bang
c) A few minutes after the Big Bang

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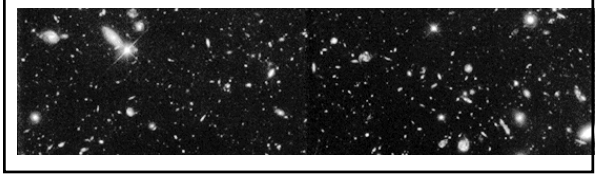
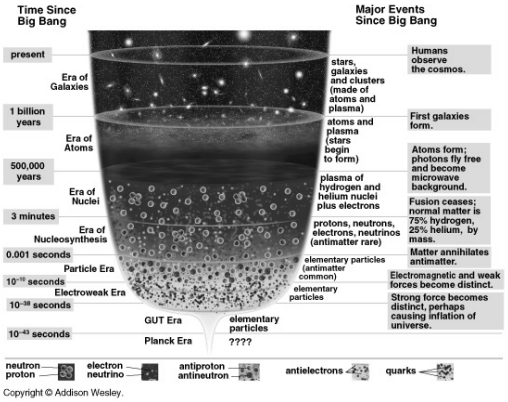
This is the Cosmic Microwave Background.

Era of Atoms and Galaxies (also called Epoch of Reionization)

- About 1 billion years after Big Bang, first stars and galaxies start to form (z=10-20).
- First stars in galaxies ionize gas surrounding the galaxies.



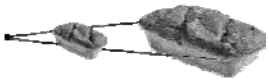


Did the Big Bang Really Happen?

- 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!

Evidence for the Big Bang

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



2) The Cosmic Microwave Background (CMB)

Observed all around us

Remarkably uniform in all directions → something truly universal

Fits theory perfectly- the universe was once opaque and T~ 3000 K

3) Helium is a minimum of 25%

- Everywhere we look there is a minimum amount of helium → universal amount

H → He at millions of degrees

Argues whole universe was millions of degrees for a short time

Clicker Question: If the current density of normal matter in the Universe were 10 times as great as it is now, we would expect to observe

a) More deuterium
b) Less deuterium
c) About the same amount of deuterium

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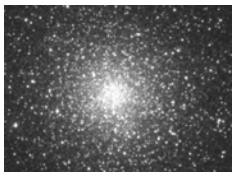
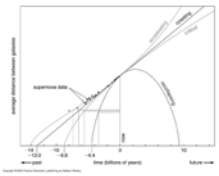
Protons & neutrons fuse to first produce deuterium and the deuterium fuse to produce helium. More baryons in early universe would have increased the rate of fusion and used up more deuterium so there would be less today.

4) Ages of stars

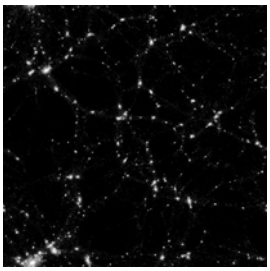
- Oldest stars ~ 13 billion years old
- Consistent with models of expansion containing dark matter and dark energy



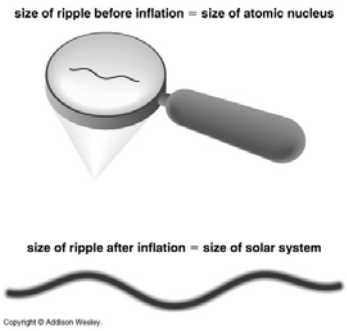


Inflation explains 3 hard-to-explain things

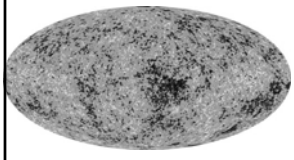
- 1) Where do the little variations that grow to structure come from?

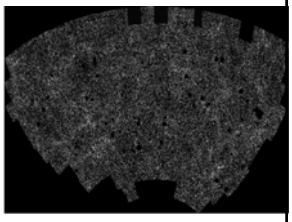


- Quantum mechanics predicts tiny "quantum fluctuations" in the early universe
- Too tiny in size to cause today's structure
- Inflation stretched them to the size needed to make the large structures (millions of light years across) that we see today



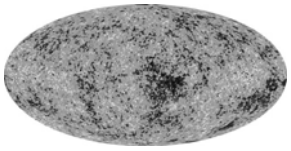
- 2) Cosmic wallpaper and CMB on large scales are similar in all directions





Opposite sides of the universe- 28 billion light years apart, can't yet have communicated what their temperatures, densities should be

- These parts must have been in contact earlier, but then inflation pulled them apart



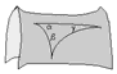
The Universe is Even Bigger than We Thought

- Inflation predicts that the observable universe- 14 billion light years in radius- is only a very tiny fraction of the inflated universe

3.) Universe is close to balanced

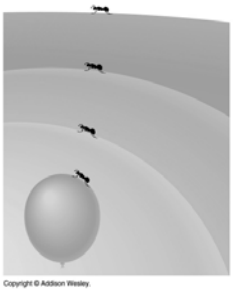
Matter tends to curve space (Einstein's general relativity)

Universe with only 25% of the critical density will be curved outwards →



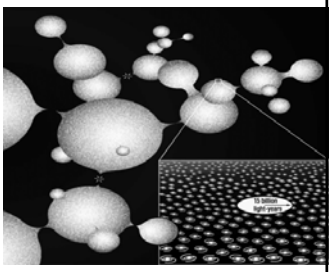
Dark energy tends to flatten it

- Inflation my be responsible for stretching space, setting a balance between dark matter and dark energy



A New Idea: Cosmological Branes

- Extra dimensions folded into a membrane of spacetime.
- Gravity "leaks through" added dimensions & is weakened.
- Collision of "branes" triggers creation of new Universe (bubbles)?



In inflation, our universe may be a minuscule part of one of many bubbles.