Astronomy 330

This class (Lecture 4):

The Early Universe

Next Class:

First Stars

Presentation Synopsis due Tuesday!
(grace period until Feb 3rd)

Music: *The Universe is You* – Sophie Ellis-Bextor

Outline

- Pseudoscience vs. real science?
- Pseudoscience is very common in ET life, i.e. UFOs, crop circles, etc.
- Need to be able to identify the two for presentations.

- The early Universe– The origin of H
- The probable fate of the Universe

Science

We especially need imagination in science. It is not all mathematics, nor all logic, but is somewhat beauty and poetry.

Maria Mitchell (1818 – 1889)
Astronomer and first woman elected to American Academy of Arts & Sciences

Scientific Thinking

- It is a natural part of human behavior.
- We draw conclusions based on our experiences.
- Progress is made through "trial and error."

The Scientific Method

1. Make Observation
2. Ask a question
3. Suggest a Hypothesis
   - a tentative explanation
4. Make a prediction
5. Test
6. What are the results?
   - confirm, reject, or modify

These should be the same no matter who conducts the test

Hallmarks of Good Science

- Science seeks explanations for *observed* phenomena that rely solely on natural causes.
- Science progresses through the creation and testing of models of nature that explain the observations as simply as possible.
  ➔ Occam's Razor

Occam's Razor

- *Pluralitas non est ponenda sine necessitate* [Latin]
- Given two equally predictive theories, choose the simpler.

Or

- *The simplest explanation is usually the best.*

Hallmarks of Good Science

- Science seeks explanations for *observed* phenomena that rely solely on natural causes.
- Science progresses through the creation and testing of models of nature that explain the observations as simply as possible.
  ➔ Occam's Razor
- A scientific model must make testable predictions that could force us to revise or abandon the model.

Theory - a model that survives repeated testing

Very different usage than everyday speech!

Bad Scientific Practice

- **Pseudoscience** – masquerades as science, but does not follow the scientific rules of evidence
- **Not science** – establish "truths" through belief

Hallmarks of Psudoscience

1. **Use of vague, exaggerated or untestable claims**
   - Misuse of apparently technical jargon to give claims with the superficial trappings of science.
   - Failure to give details of experiments, so they can be repeated.
   - No controls.

Adapted from wikipedia

Hallmarks of Psudoscience

2. **Over-reliance on confirmation rather than refutation**
   - Over-reliance on testimonial, anecdotal evidence or personal experience.
   - Presents data that seems to support its claims while suppressing or refusing to consider data that conflict with its claims.
   - Reversed burden of proof. In science, the burden of proof rests on those making a claim, not on the critic.
   - Assertion that claims that have not been proven false must be true, and vice versa.

Adapted from wikipedia

Hallmarks of Psudoscience

3. **Lack of openness to testing by other experts**
   - Evasion of peer review before publicizing results. (typically they state that the peers are biased against the claims)
   - Assertion of claims of secrecy or proprietary knowledge in response to requests for review of data or methodology.
   - Requests money to see evidence

Adapted from wikipedia

Hallmarks of Psudoscience

4. **Personalization of issues**
   - Tight social groups can enhance the adoption of beliefs that have no rational basis. In attempting to confirm their beliefs, the group tends to identify their critics as enemies.
   - Assertion of claims of a conspiracy on the part of the scientific community to suppress the results.
   - Attacking the motives or character of anyone who questions the claims.

Adapted from wikipedia

Hallmarks of Psudoscience

5. **Use of misleading language**
   - Creating scientific-sounding terms in order to add weight to claims and persuade non-experts to believe statements that may be false or meaningless.
   - Using established terms in idiosyncratic ways, thereby demonstrating unfamiliarity with mainstream work in the discipline.

Adapted from wikipedia

Compare/Contrast

Science	Pseudoscience
Findings are expressed primarily through scientific journals that are peer-reviewed and maintain rigorous standards for honesty and accuracy.	The literature is aimed at the general public. There is no review, no standards, no pre-publication verification, no demand for accuracy and precision.
Reproducible results are demanded; experiments must be precisely described so that they can be duplicated exactly or improved upon.	Results cannot be reproduced or verified. Studies, if any, are always so vaguely described that one can't figure out what was done or how it was done.
Failures are searched for and studied closely, because incorrect theories can often make correct predictions by accident, but no correct theory will make incorrect predictions.	Failures are ignored, excused, hidden, lied about, discounted, explained away, rationalized, forgotten, avoided at all costs.
As time goes on, more and more is learned about the physical processes under study.	No physical phenomena or processes are ever found or studied. No progress is made; nothing concrete is learned.
Convinces by appeal to the evidence, by arguments based upon logical and/or mathematical reasoning, by making the best case the data permit. When new evidence contradicts old ideas, they are abandoned.	Convinces by appeal to faith and belief. Pseudoscience has a strong quasi-religious element: it tries to convert, not to convince. You are to believe in spite of the facts, not because of them. The original idea is never abandoned, whatever the evidence.
Does not advocate or market unproven practices or products.	Generally earns some or all of his living by selling questionable products (such as books, courses, and dietary supplements) and/or pseudoscientific services (such as horoscopes, character readings, spirit messages, and predictions).

Adapted from http://maxwell.uncc.edu/mcorwin/Powerpoint/Distinguishing%20Science%20and%20Pseudoscience.htm

Example

http://www.stopabductions.com/

Grouped

- In groups of more than 3 and less than 5, discuss pseudoscience compared to science.
- Write a pseudoscience argument for something that one might find on a webpage pertaining to topics of this class (no more than 1 page). (i.e. make some pseudoscience up!)
  - One sheet for the group.

Big Bang

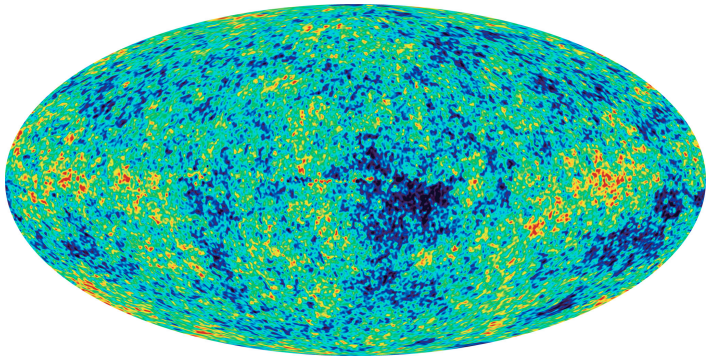
- We spent the last class discussing the Big Bang.
- In the same groups as last time, try to write a 4-5 sentence explanation of the Big Bang to a non-science major friend.

Galaxies

- Back to Cosmology… where did the seeds of today's Galaxies come from?

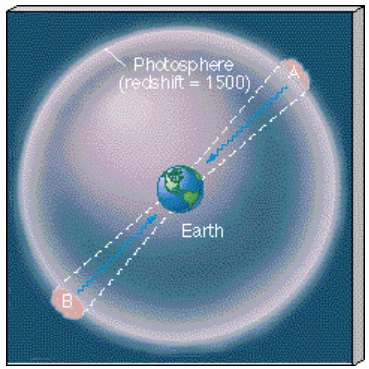
The Seeds of Galaxies

These small perturbations in temperature are the fluctuations (smaller than 1 in a 100,000) that caused the large scale structures we see today. This is what formed galaxies. All of this happened only 400,000 years after the Big Bang.

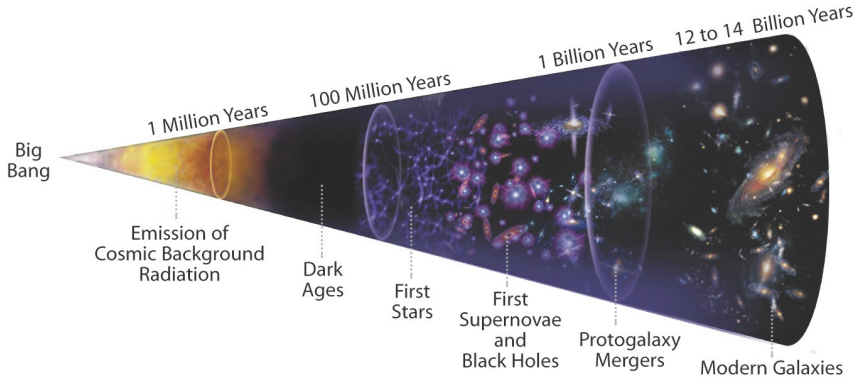


The Isotropy Problem

- The CMB looks very much the same all over the sky
- Thus, regions A and B were very similar to each other when the radiation we observe left them
- But there has not been enough time since the Big Bang for them ever to have interacted physically with one another
- Why then do they look the same?



A Brief History of Time



THE VERY EARLY UNIVERSE

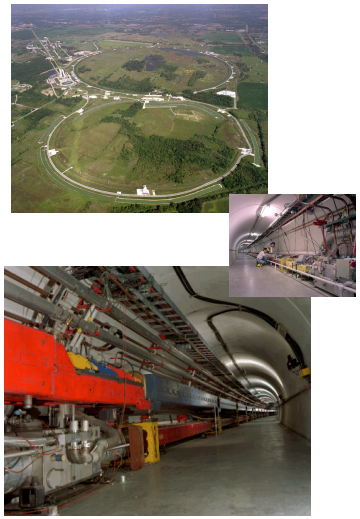
Since Big Bang works well so far, we have confidence to think about very early times:

t << 1 sec !

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

Q: How to probe such high energies?
Hint: it's in the Great State of Illinois

Fermilab



INNER SPACE / OUTER SPACE

Fermilab is a telescope!

Probes conditions in Universe at 10^{-12} s

Universe was 10^{12} K hot!

…but also…

"The Universe is the poor man's accelerator"

Probes conditions inaccessible at laboratories

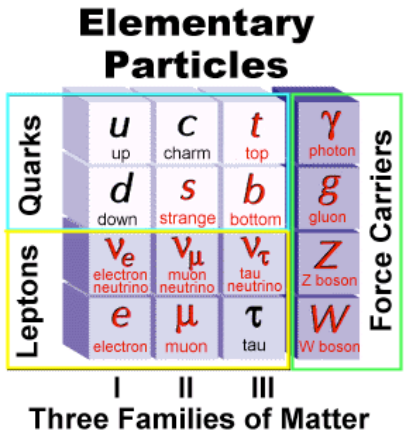
A Little Background Info

To better understand the early Universe, we need to talk about a few topics first:

1. Basic Particles
2. Matter and Anti-matter

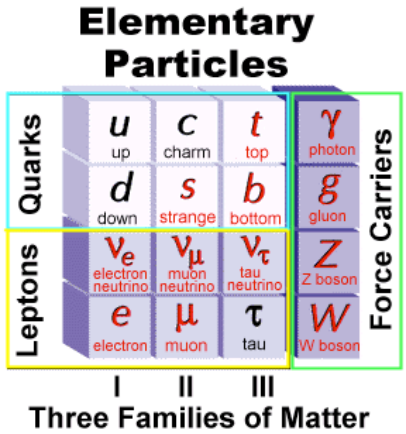
Basic Particles

- There are three types of basic particles in nature
- **Quarks** - matter
  - Building blocks of protons and neutrons
- **Leptons** - matter
  - Electrons and neutrinos
- **Force Carriers** - energy
  - Photons, gluons, gravitons?



http://sol.sci.uop.edu/~jfalward/elementaryparticles/elementaryparticles.html

Basic Particles



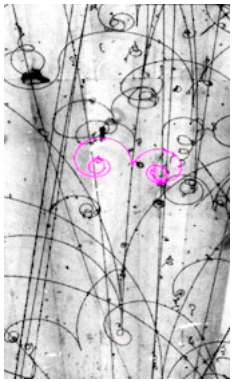
http://sol.sci.uop.edu/~jfalward/elementaryparticles/elementaryparticles.html

The Universe is Made of Matter

- You, and I, and the Earth are all made of matter not anti-matter
- The Moon is made of matter, not anti-matter
- Local "neighborhood" in Milky Way is matter, gas between the stars
- The Universe is made of matter
- How did this come to be?

Matter & Anti-Matter

- Partner for each type of matter particle
  - Anti-electron=positron, anti-quarks, anti-neutrinos
- Anti-matter is stable by itself
  - Can have anti-protons, anti-atoms, anti-rocks, anti-people, anti-stars, anti-galaxies

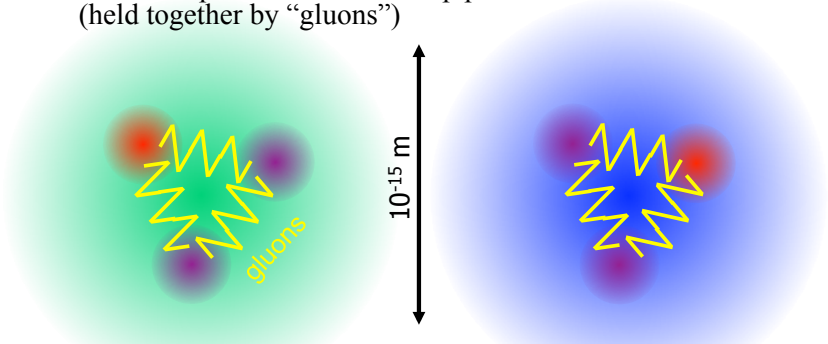


Matter & Anti-Matter

- But when matter & anti-matter partners combine
  - **Annihilation** – matter converted to energy – $E=mc^2$
  - Example: paperclip + anti-paperclip annihilation – Energy release equal to a small nuclear bomb!

Quarks

- The basic particles that make up protons and neutrons (held together by "gluons")

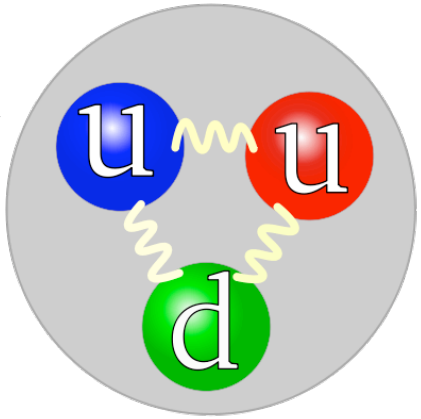


Proton (charge +1) =
2 "up" quarks (+4/3) +
1 "down" quark (-1/3)

Neutron (charge 0) =
1 "up" quark (+2/3) +
2 "down" quarks (-2/3)

Point: Proton = 3 quarks!

- H is made up of a proton and an electron.
- Electrons are around at this point, but no protons yet.
- So, we have to get the quarks to cool down and get together…
- A social for particles…



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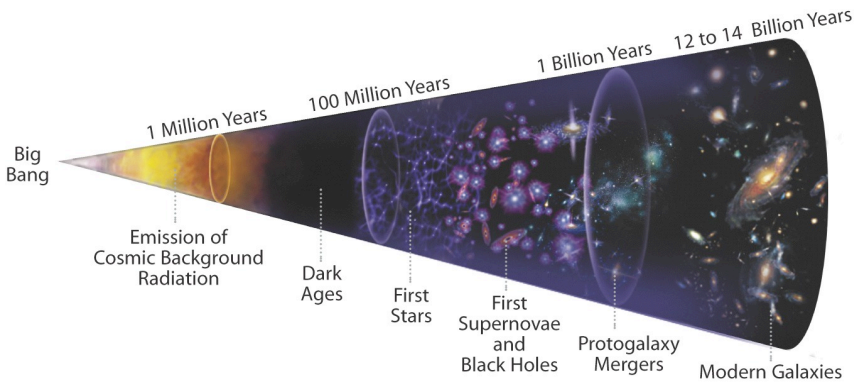
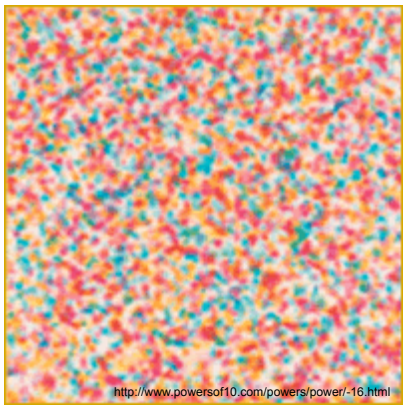


The First Instant (to 10^{-43} sec)

- Incredibly hot (more that 10^{32} K)
- Want a Nobel Prize? Develop a theory to describe this era of the Universe!

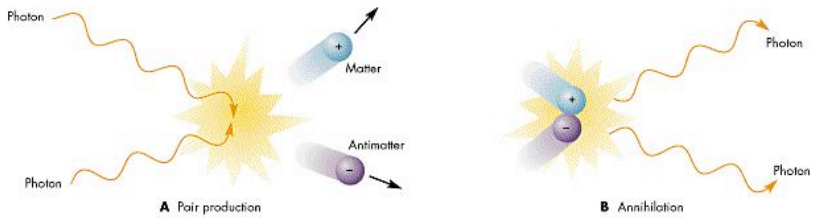
The GUT Era (until 10^{-35} sec)

- GUT = "Grand Unified Theory"
- Sea of free quarks (and anti-quarks) + photons + other basic particles
- Random fluctuations in density



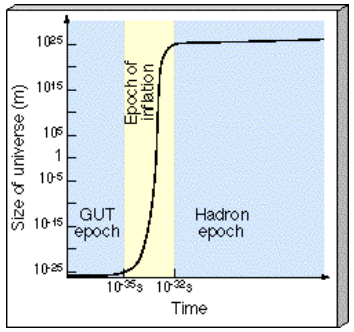
Matter and Anti-Matter

- In the early Universe, the photons were so energetic that photons could convert into matter/ anti-matter pairs
- The particles created would soon annihilate and convert back to energy



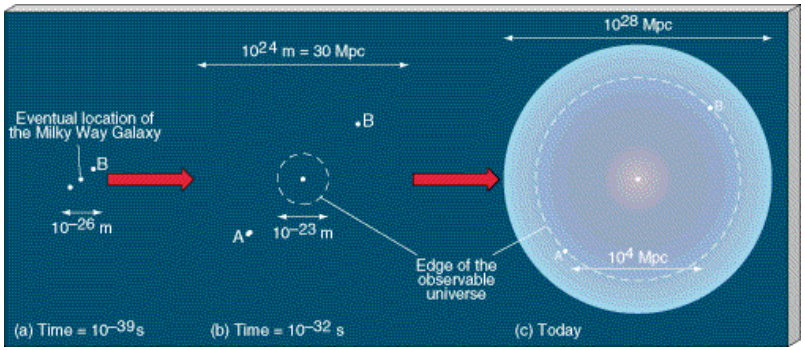
Inflation (10^{-35} to 10^{-32} sec)

- Universe went through a period of extremely rapid expansion
- Expansion by more than a factor of $\mathbf{10^{50}}$!!
- Areas that were close before inflation were now separated by millions of parsecs!



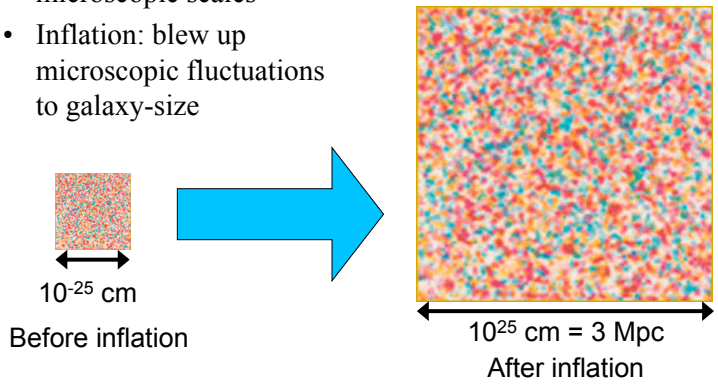
Inflation Solves the Isotropy Problem!

Regions that were close enough to interact in the early Universe were separated by inflation!



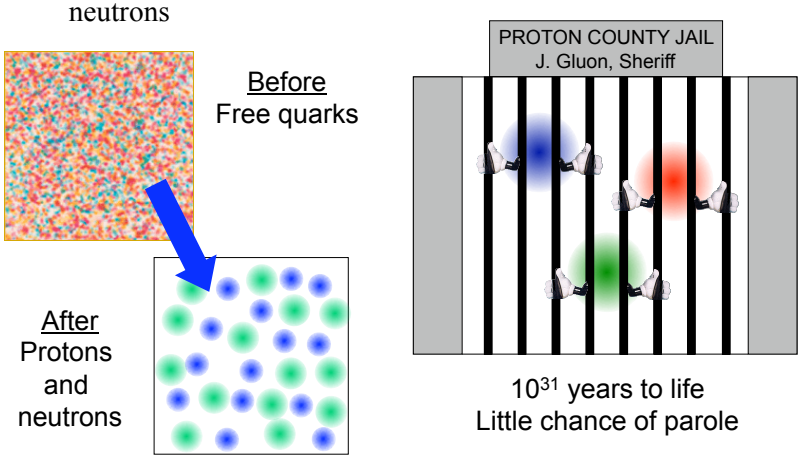
Origin of the CMB Fluctuations

- Early Universe: a sea of particles & energy
- Density was constantly fluctuating on microscopic scales
- Inflation: blew up microscopic fluctuations to galaxy-size



Quark Confinement

- 10^{-6} seconds: free quarks condensed into protons and neutrons



Question

The seeds of Galaxies were due to?

a) Large super structures in the early Universe.
b) Nuclear strong force fields.
c) Quantum fluctuations in quark density.
d) Gravitational instabilities in the fabric of space-time.
e) Unclear reasons.

The Universe

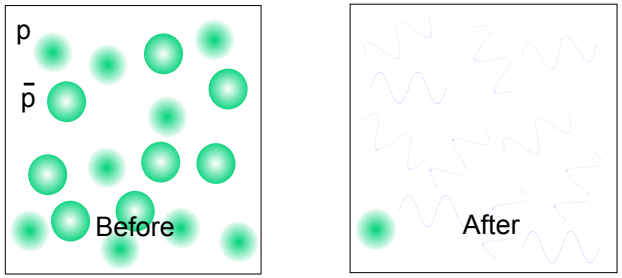
- Began with a Big Bang
  - 13.7 billion years ago
- Still expanding and cooling
  - The rate of expansion is known
- It is BIG
  - As far as we are concerned, it is infinite in any direction
- The universe is homogeneous and isotropic
  - **Homogeneous** - The same "stuff" everywhere
  - **Isotropic** - The same in all directions
- Our place in the Universe is not special
  - Extension of the Copernican revolution
- The center of the Universe is everywhere!

The Universe: Timeline

- Big Bang: 13.7 billion years ago
- GUT era: $+10^{-35}$ second, energy and quarks
- Inflation: 10^{-35} to 10^{-32} seconds, Universe expands by more than 10^{50}!
- Quark confinement: 10^{-32} to 10^{-6} seconds, protons and neutrons form

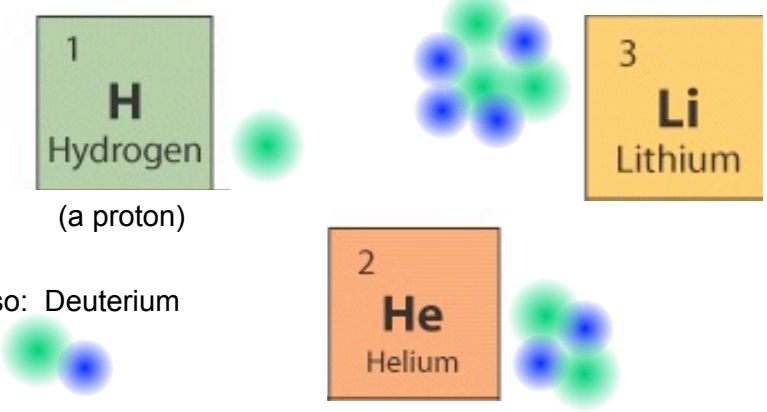
Annihilation of the Anti-matter

- 10^{-4} seconds:
  - Temperature dropped below the level at which photons have enough energy to create proton-anti-proton pairs
  - Remaining pairs annihilated → radiation
  - 1 proton in 10^{9} had no partner! That's us.
  - **The first hydrogen atoms (ionized– no electrons— but there)**



Big Bang Nucleosynthesis

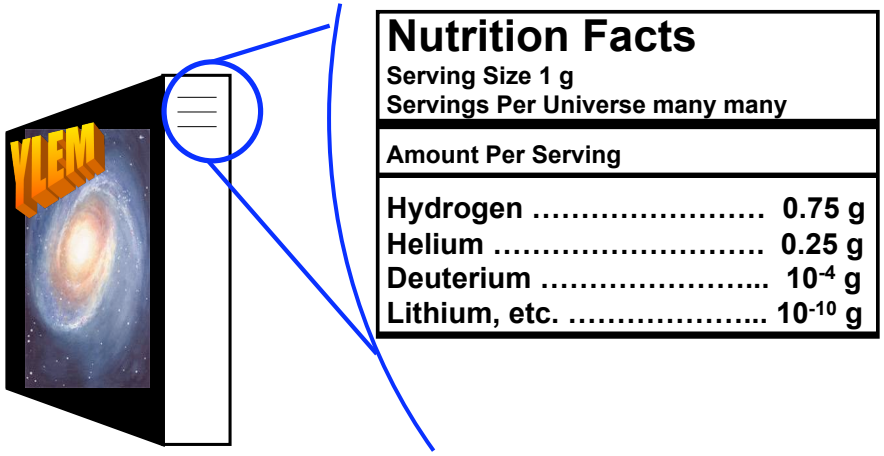
When the Universe was 1 sec to 3 mins old, the temperature fell to 10^9 K and protons and neutrons can "shack-up" to form the first light elements.



(a proton)

Also: Deuterium

End Result:
Big Bang Correctly Predicts Abundances



Nutrition Facts

Serving Size 1 g
Servings Per Universe many many

Amount Per Serving

Hydrogen	**0.75 g**
Helium	**0.25 g**
Deuterium	**10^{-4} g**
Lithium, etc.	**10^{-10} g**