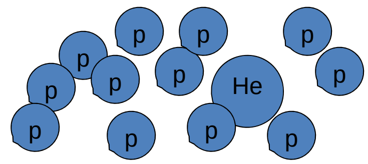
Helium Production in Big Bang—8 Nov

- Homework 8 is on angel. Due noon on Mon, 15 Nov.
- Homework 9 will be due Fri, 19 Nov at start of class. No late papers. Covered on Test 3 (22 Nov).
  - Long assignment. Start early.
- A fossil is a remnant or trace of the past. What is a fossil from the Big Bang?
  - There are 7 protons for every neutron
  - The surface of the sun is 25% He and 75% H.
- What does that fossil tell about the BB?



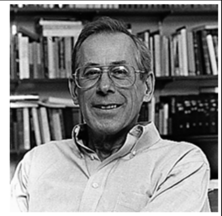
Fossil from Big Bang

Fossil from Burgess Shale

Objectives

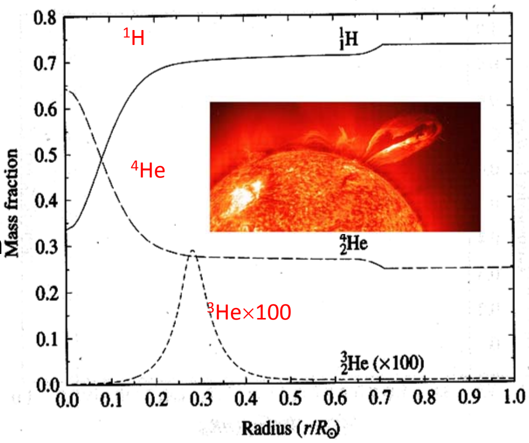
- Describe how the abundance of neutrons is a fossil of the Big Bang.
- What part does the radiation from the Big Bang play?
- Why did the abundance of neutrons change before the "fossil was laid down" and not afterwards?
- How do astronomers "collect the fossils?"

Helium formed when universe was 3 minutes old



Jim Peebles

- How & where were the elements made?
  - Carbon, Iron, Calcium in stars
  - Hydrogen is primordial
  - Helium is too abundant to have been made in stars.
  - Helium was made at 3min.

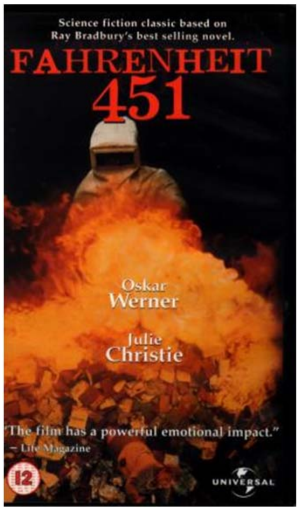


- What part does the radiation from the Big Bang play?

Book-burning Universe

- When the universe was smaller by a factor a (when the distance between us and some object was smaller), the temperature was hotter by a factor 1/a.
  $T = 2.7\text{K}/a.$
- At one time, the universe was too hot to have paper.
  - Paper burns at 451 F = 500 K.
  - In reality, there was no carbon and no paper at that time.

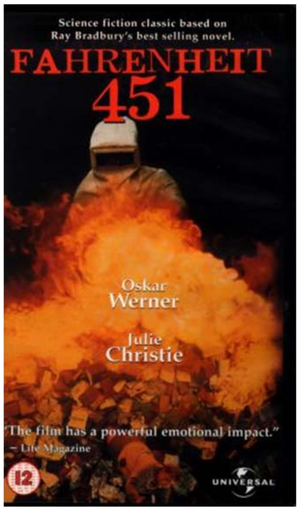
2. Hoag's object is 300 Mpc from the Milky Way. How far was it when the U was just hot enough to burn paper?
   A. 30 Mpc, a=1/10, T=2.7 * 10 = 27K
   B. 10 Mpc, a=1/30
   C. 3 Mpc, a= 1/100
   D. 1 Mpc, a= 1/300



Book-burning Universe

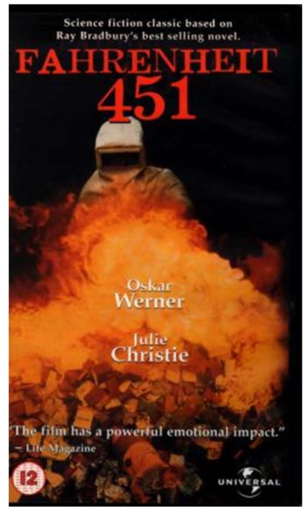
- Key idea: When the universe was smaller (when the distance between us and some object was smaller), the temperature was hotter. <u>There is no obvious limit to the temperature.</u>
- At one time, the universe was too hot to have paper.

1. What other familiar things were not possible at one time? What other reactions might have occurred when the universe was smaller & hotter.



Book-burning Universe

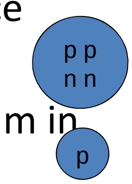
- Key idea: When the universe was smaller (when the distance between us and some object was smaller), the temperature was hotter. <u>There is no obvious limit to the temperature.</u>
- What other reactions might have occurred when the universe was smaller & hotter?
- Events in the universe's life (in reverse order)
- First stars formed
  - When U cooled enough, gravity was able to overcome pressure.
- Recombination: U changed from opaque to transparent
  - Ionization & recombination
  - Free p + e → hydrogen atom
- Production of the first nuclei other than H
  - Nuclear reaction
  - Free protons + neutrons → helium nucleus



- Why did the abundance of neutrons change before the "fossil was laid down" and not afterwards?

Neutrons and protons change identity

- Neutrons can change into protons & vice versa.



1. When hydrogen fuses to become helium in the sun, does the ratio #n/#p change?
   A. Yes.
   B. No.

- (number of neutrons)/(number of protons) changes in fusion reactions.

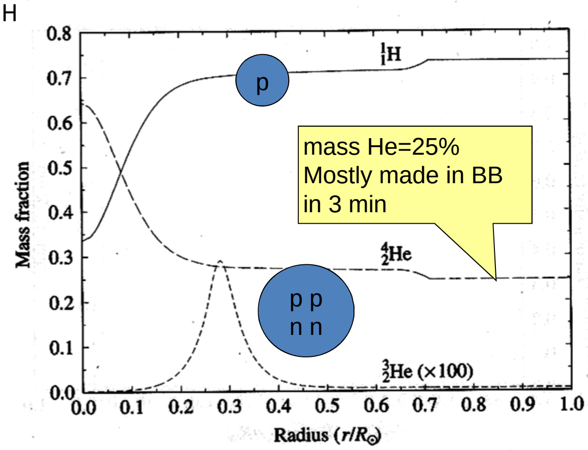
1. Does the (number of neutrons)/(number of protons) change for ^{16}O, the most abundant isotope of oxygen? for $^{14}C \rightarrow ^{14}N + e^{-} + \nu$?
   A. YY
   B. YN
   C. NY
   D. NN

- (number of neutrons)/(number of protons) does not change for stable nuclei.

#n/#p at the present time

- In the outer parts of the sun, the material is nearly primordial.
- He is 25% of the mass, H is 75%. 12 H atoms for every He atom
  - Mass He = 4
  - Mass H = 12
  - Total mass = 16

1. #n / #p =
   a. 1:1
   b. 1:12
   c. 2:14
   d. 4:12
   e. 2:3



Follow the neutrons

- #n/#p=2/14=1/7 now
- Processing in stars changes #n/#p slightly.
  - #n/#p in H and O
    - 8n/(800p+8p)=1/101
- #n/#p has been 1/7 from 3min to now. This is the fossil.
  - As the fossils in the Burgess Shale have not changed their shape since the animal died 505Myr ago, #n/#p has not changed significantly since the universe was 3min. old.