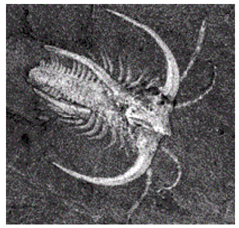
29 Oct

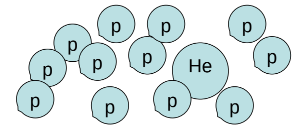
1. A fossil is a remnant or trace of the past. What is a fossil from the Big Bang?



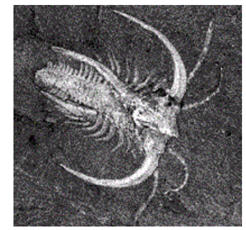
Fossil from Burgess Shale

Helium Production in BB—29 Oct

- 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?



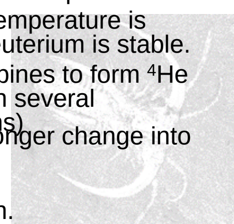
Fossil from Big Bang



Fossil from Burgess Shale

Neutrons/protons when deuterium forms (review)

- 0.001s
  - Temperature = 400 BK
  - E=40 MeV is much greater than cost to be a neutron
  - n:p = 1:1
- 3 min
  - Temperature = 1 BK
  - E=0.1MeV is much less than cost to be a neutron
  - n:p = 1:7
- As universe cools, #n/#p drops.
- Deuterium forms from n & p
  - p + n ↔ deuterium + energy
  - E=0.1MeV
  - Deuterium is fragile
- If temperature is too hot (E>0.1MeV), deuterium gets broken apart.
- When temperature is cool, deuterium is stable.
- ^2H combines to form ^4He (through several reactions)

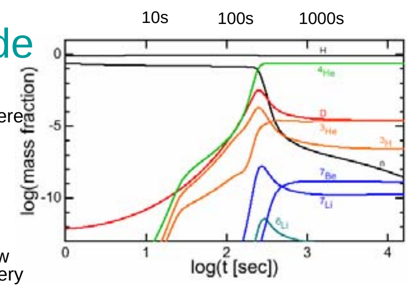


- Neutrons in deuterium are safe; they no longer change into protons.
- #n/#p is a fossil from the universe at 3 min.

How ^4He is made

1. When U was 10s old, what were the two most abundant constituents?
   A. H & ^4He
   B. H & n
   C. H & D (^2H)
2. Same for 10,000s (3hr).
3. When U was 10,000s old, how much D (^2H) was there for every ton (1000kg) of matter?
   A. 1 kg
   B. 100 g
   C. 10 g
   D. 1 g

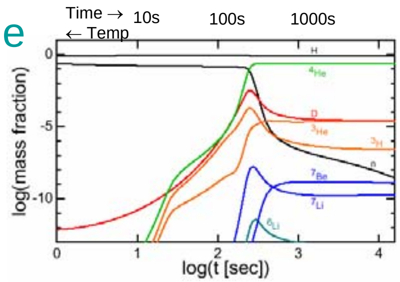
- Need to understand why elements changed during the first 3 minutes.



- Model of how amount of element changes with time.

How ^{4}He is made

- What changed during the first hour?
  - At 1 s, neutrons & protons; minute amount of ^{2}H (D).
  - Ratio n/p dropping slowly
  - ^{2}H, as well as ^{3}H and ^{3}He increases staring at 30s.
  - ^{4}He increases
  - At 200 s, ^{2}H, ^{3}H, and ^{3}He drops. ^{4}He stays high.
  - At 10,000s (3hr), U is primarily ^{1}H & ^{4}He with trace amounts of others.

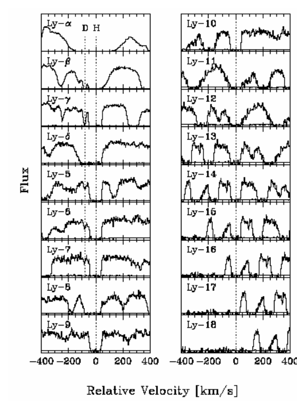


- Need answers
  - Why does n/p drop even before 10s? Very few neutrons are being incorporated in ^{2}H.
  - What is beginning to happen at 30s? Why does it start then?

"Collecting the Fossil"

- ^{4}He, ^{7}Li, ^{2}H, & ^{3}He are made in BB.
  - Lots of ^{4}He
  - Trace amounts of ^{7}Li, ^{2}H, & ^{3}He. Diagnostics.
- Measure abundances with spectra of "primordial objects"
  - First stars in our galaxy, made before much of the material had been processed through stars.
  - Dwarf galaxies, where material is processed through stars very slowly.
- Deuterium ^{2}H has same spectra as hydrogen ^{1}H but slightly shifted.
  - Abundance of ^{2}H: Strength of ^{2}H spectral line compared with ^{1}H line.

400km/s=d wavelegnth = wl/750



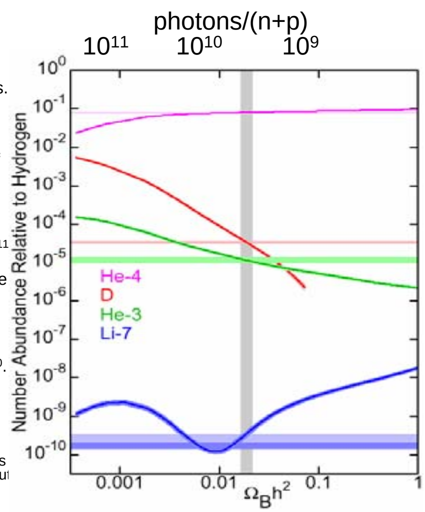
O'Meara, et al., 2001, ApJ 552, 718.

Results

- Horizontal bars are measurements.
- Lines are models for differing amounts of photons/(n+p)
- The temperature of the radiation from the BB tells us the number of photons.

2. How many ^{1}H nuclei are there for every ^{2}H nucleus according to the measurements?
3. The model for photons/(n+p) = 10^{11} is inconsistent with the measurements. The measured ^{4}He is too ___.
   A. High
   B. Low

- Measurements are consistent with models for photons/(n+p) = 4×10^{10}.
  - 7Li is slightly off
  - Understanding of BB (and nuclear physics and astrophysics of stars and galaxies) is confirmed.
  - Surprise: Most of neutrons and protons are not in stars. Lots in gas between galaxies. Location of about 50% is not known.



Ned Wright's Cosmology Notes