Origin of Isotopic Variations

The Big Bang and all that stuff

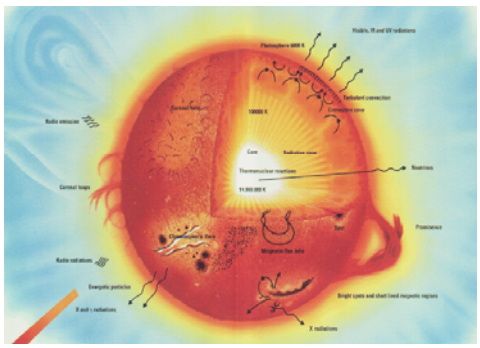
A Short Course VU March, 2009

Peter Swart University of Miami

Formation of the Solar System

- New stars and planetary systems form from the debris Supernova. It is possible that the material in the solar system had been cycled through several supernovae since the big bang. The Sun formed from a cosmic cloud about 6 billion years ago.
  - Gas gradually moved together under the influence of gravity.
  - As the gas moved together it become hotter and denser and eventually was pressed together so closely that nuclear fusion ensued. Surrounding the new sun was a flattened disk of gas and dust.

The Sun

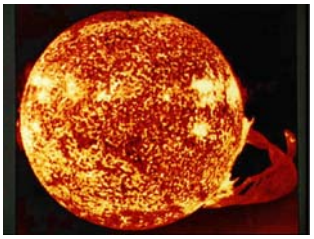


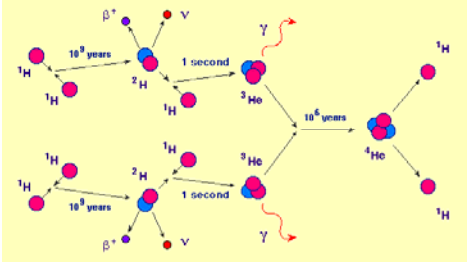
Sun Stats

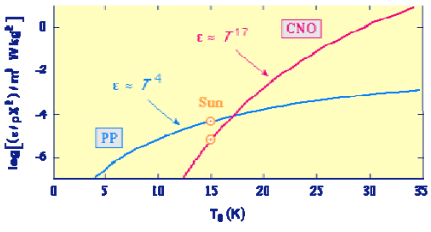
Mass (kg)	1.989e+30
Mass (Earth = 1)	332,830
Equatorial radius (km)	695,000
Equatorial radius (Earth = 1)	108.97
Mean density (gm/cm^3)	1.410
Rotational period (days)	25-36*
Escape velocity (km/sec)	618.02
Luminosity (ergs/sec)	3.827e33
Magnitude (Vo)	-26.8
Mean surface temperature	6,000°C
Age (billion years)	4.5

Principal chemistry

- **Hydrogen 92.1**
- **Helium 7.8**
- **Oxygen 0.061**
- **Carbon 0.03**
- **Nitrogen 0.0084**
- **Neon 0.0076**
- **Iron 0.0037**
- **Silicon 0.0031**
- **Magnesium 0.0024**
- **Sulfur 0.0015**







H burning – He production

P-P chain I:

$^{1}_{1}H \; ^{1}_{1}H \; ^{2}_{1}H \; e \; _{e}$

$^{1}_{1}H \; ^{2}_{1}H \; ^{3}_{2}He$

$^{3}_{2}He \; ^{3}_{2}He \; ^{4}_{2}He \; 2^{1}_{1}H$

69%

P-P chain II:

$^{1}_{1}H \; ^{1}_{1}H \; ^{2}_{1}H \; e \; _{e}$

$^{1}_{1}H \; ^{2}_{1}H \; ^{3}_{2}He$

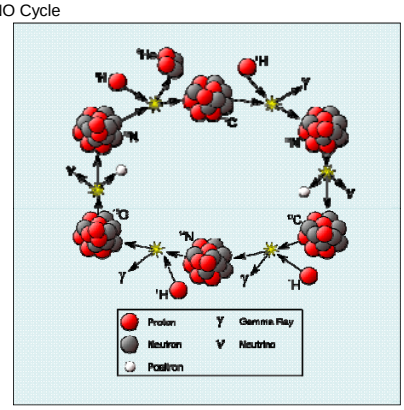
$^{3}_{2}He \; ^{4}_{2}He \; ^{7}_{4}Be$

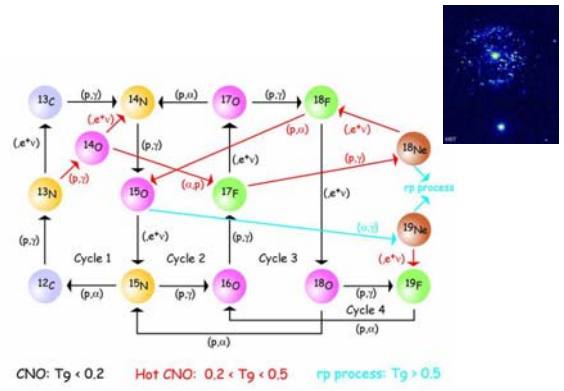
$^{7}_{4}Be \; e \; ^{7}_{3}Li \; _{e}$

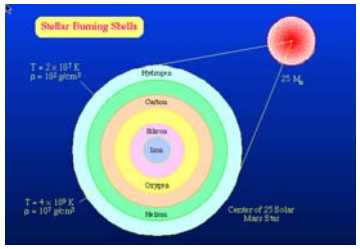
$^{7}_{3}Li \; ^{1}_{1}H \; 2^{4}_{2}He$

31%

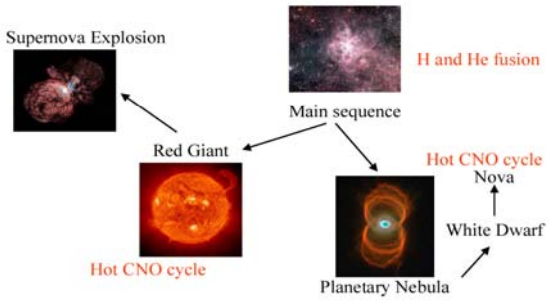
CNO Cycle

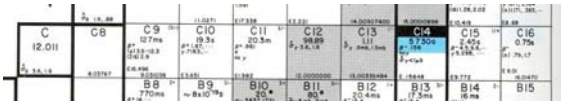


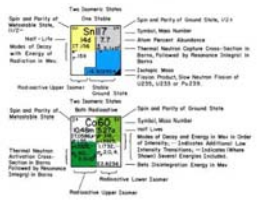

Cycle 1
Cycle 2
Cycle 3
Cycle 4
rp process
CNO: Tg < 0.2
Hot CNO: 0.2 < Tg < 0.5
rp process: Tg > 0.5


Stellar Burning Shells
Hydrogen
Carbon
Neon
Iron
Oxygen
Helium
25 M⊙
Center of 25 Solar Mass Star

Stellar Evolution







Nomenclature

$$\delta = \left[\frac{^{13}C/^{12}C_{Sample}}{^{13}C/^{12}C_{Standard}} \right] - 1 \quad \times 1000$$

δ ,del, or delta values are reported in ^{o}/oo or parts per thousand or per mille

Less ^{13}C, δ values are negative or said to be light

Less ^{13}C, δ values are positive or said to be heavy

Standard is PDB (Pee Dee Belemnite)
V-PDB (Vienna Pee Dee Belemnite)

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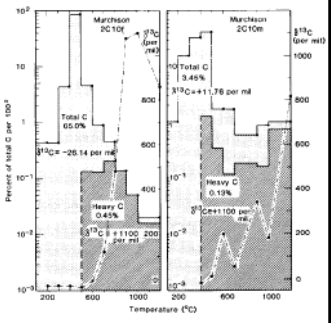
The Origin of Carbon Isotopic Variations



Methodology/Terminology