Week 12, Lecture 1 – Elements in Space

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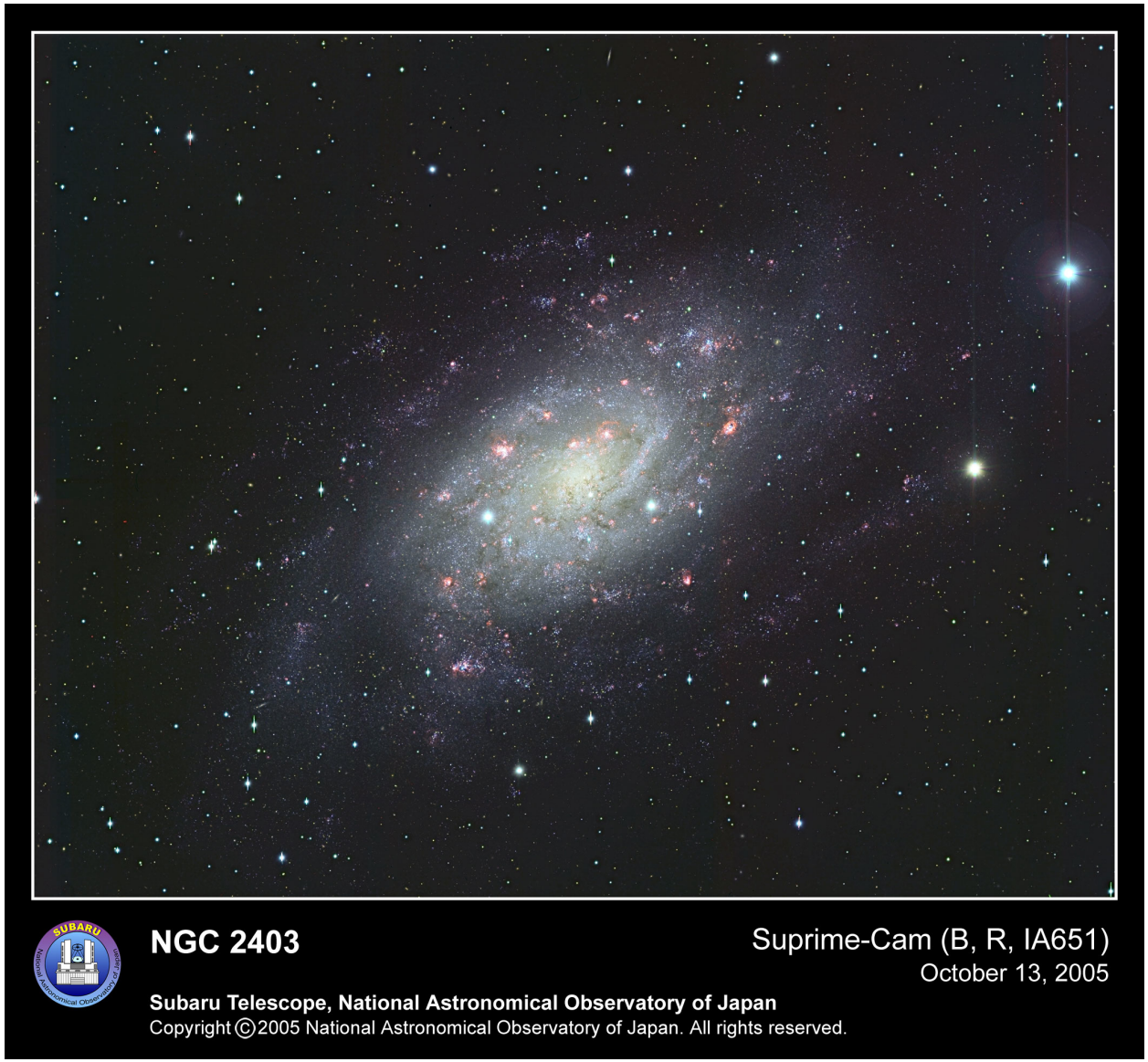
Nuclear Reactions in Space

-- Overview
-- Observational Information
--- Elemental distributions
--- EM distributions
-- Nuclear Synthesis
--- Big Bang
--- Stellar processes
---- simple proton burning
---- catalytic cycles
---- neutron capture
---- explosions

7th Homework due Today



Distribution of Elements

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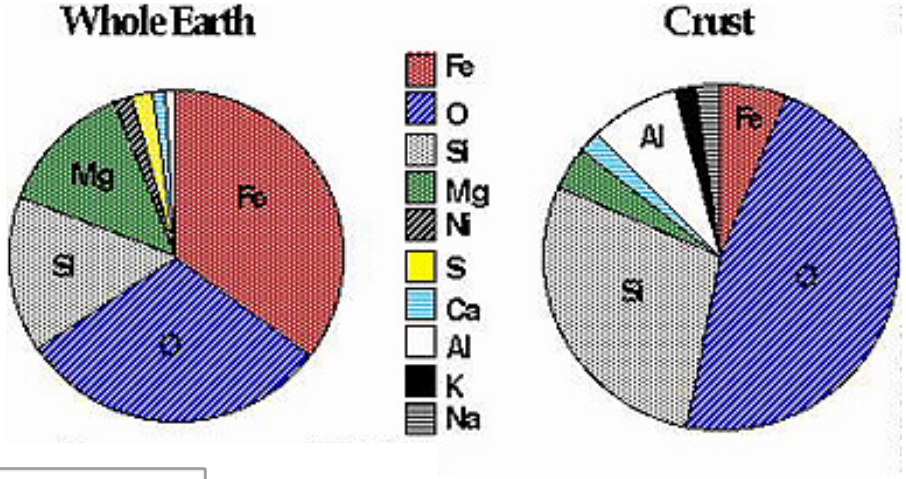
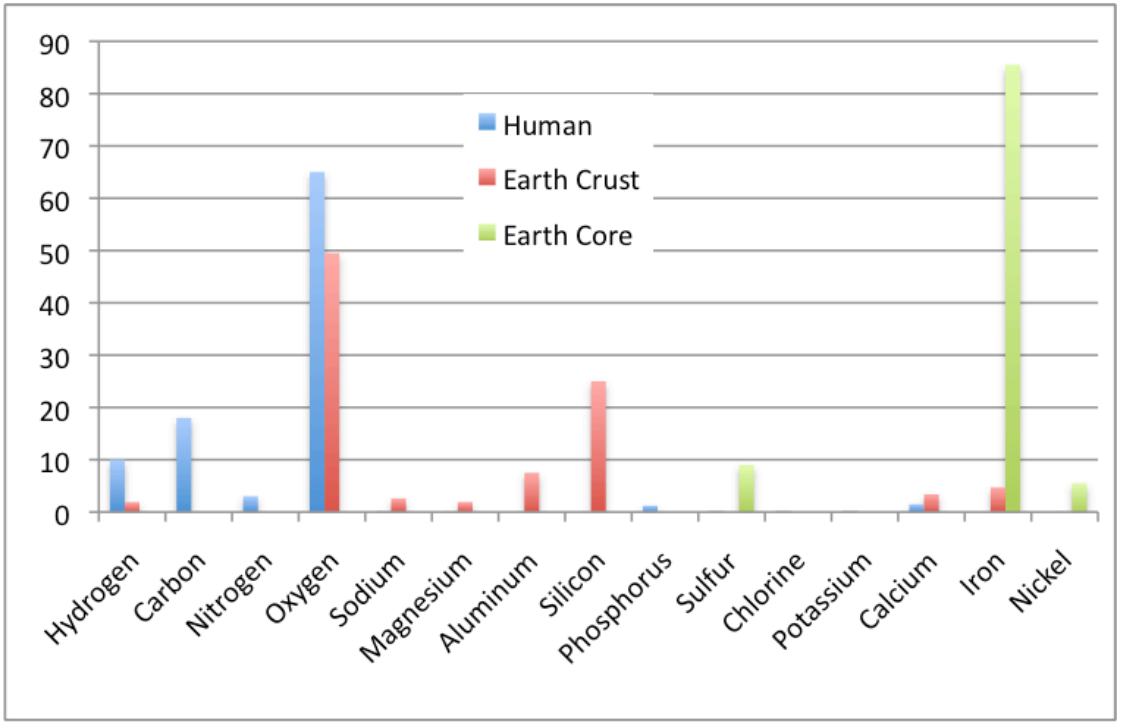
One of the features of nuclei that we have ignored up to this point is the relative distribution of the elements.

Note, the sun is the largest thing nearby…





Stellar Composition Measurements

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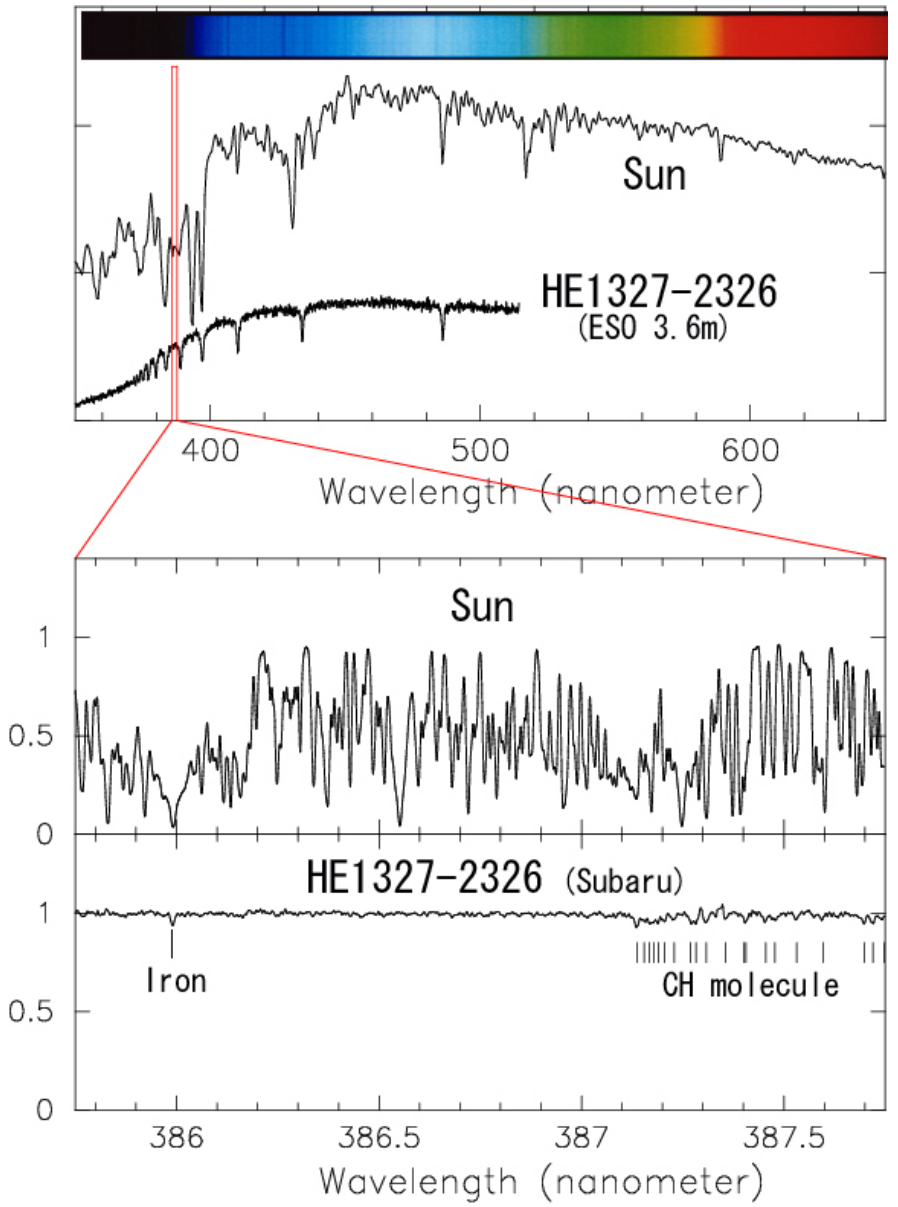
The composition of the sun is measured in a relatively straightforward way using absorption spectroscopy. The sun is emitting a broad spectrum of light and the various elements that are present have characteristic absorption lines … the wrinkle is that the elements are generally ionized in the sun and not neutral.

A very important area of current research is to make detailed measurements of the absorption spectra of distant stars. It turns out that the oldest stars have relatively few heavy elements (metals) and are called "metal-poor" stars.



Distribution of Elements

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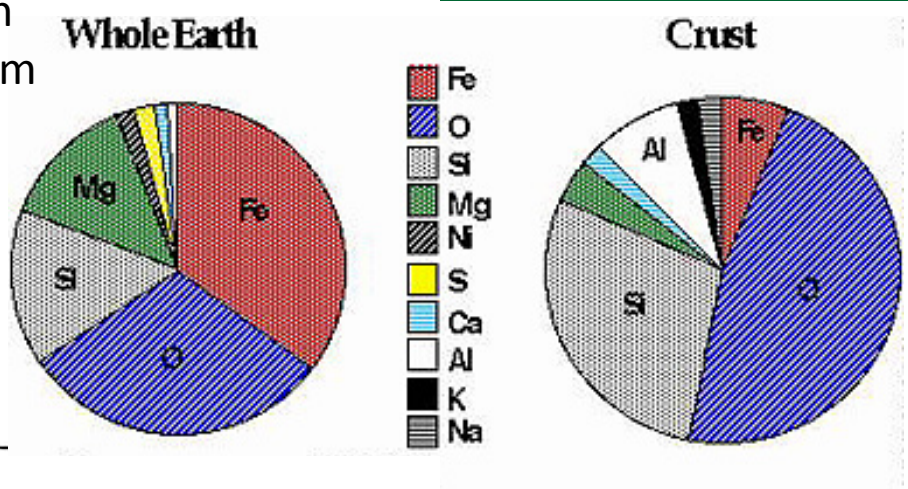
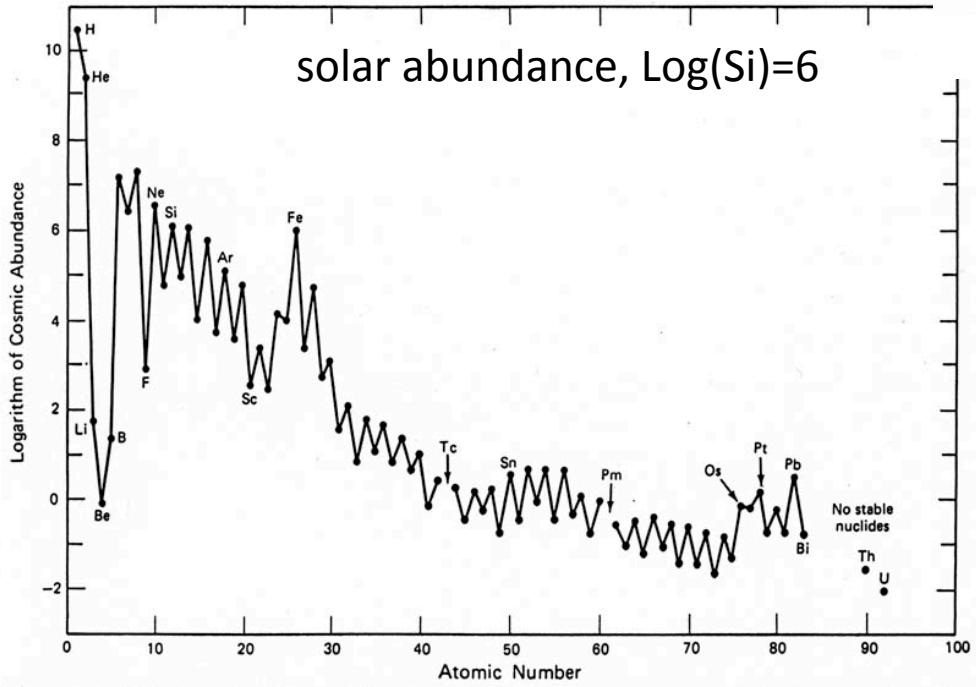
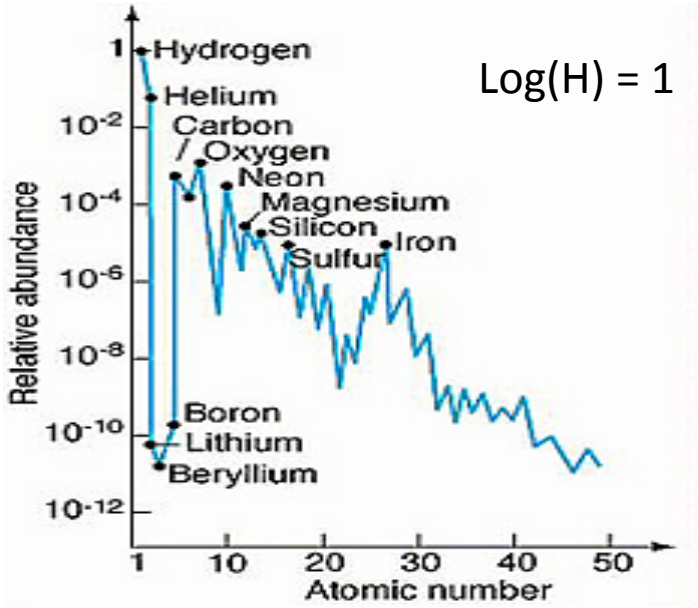
After some work, a relatively complicated pattern for the distribution of elements in the solar system (sun) emerges.

- Odd-even staggering
- Logarithmic decline with Z or A
- Very little Be, Li, B
- Peak at Fe
- Peak near Pb





Similar to Fig. 12.2 in the text



Stellar Temperatures

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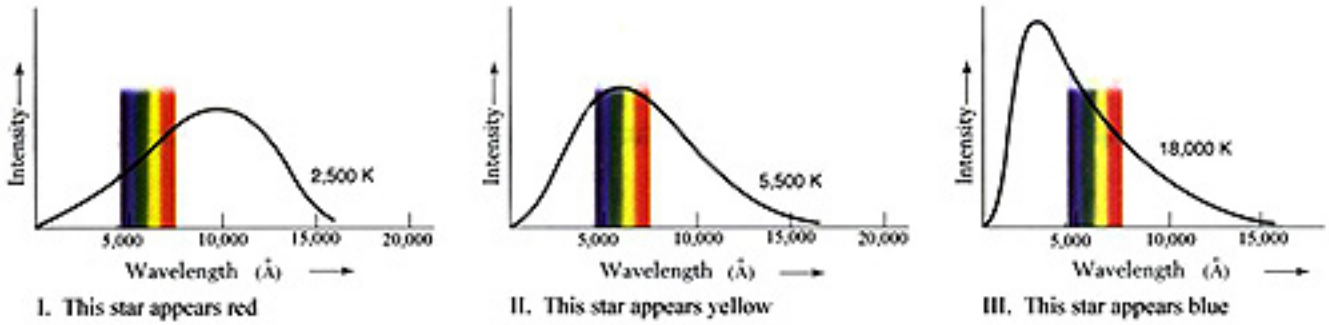
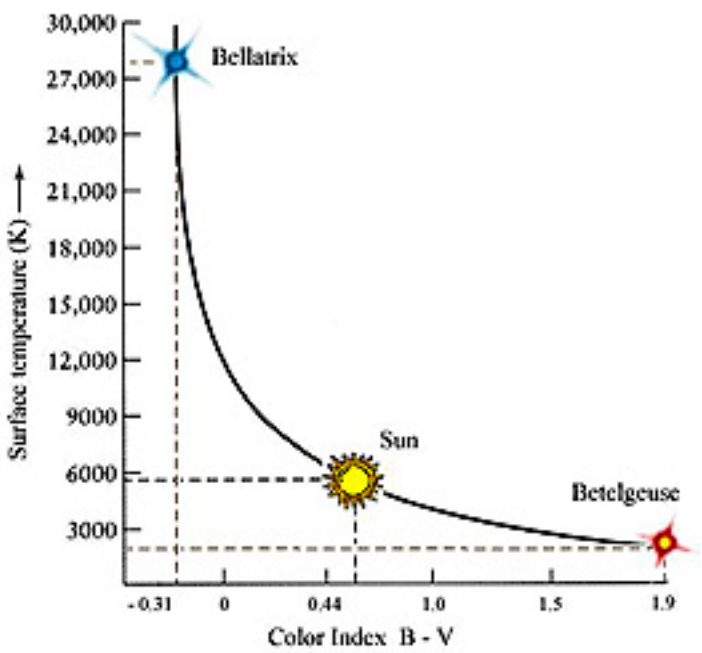
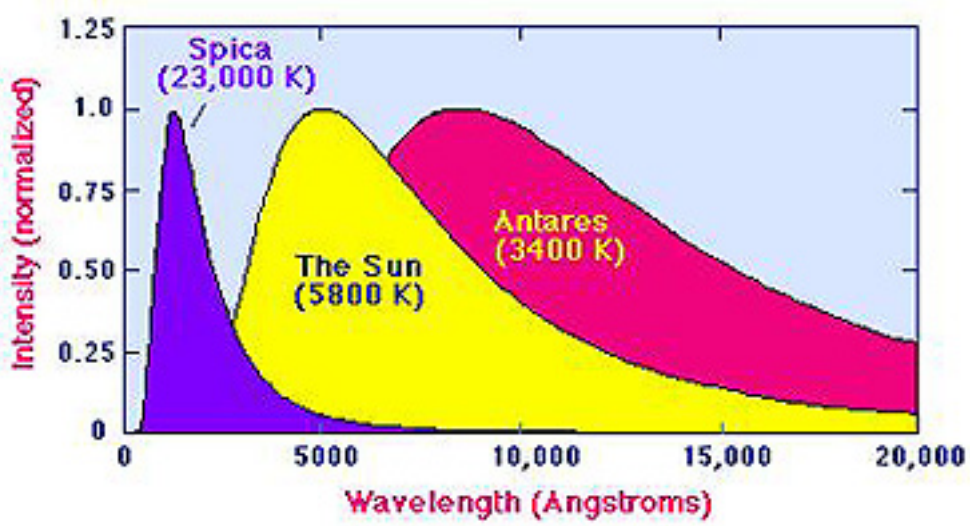
The temperature of the sun is measured through its color as if it is a “blackbody radiator”







The luminosity of the sun can be measured separately, and turns out to be correlated with T.

Temperature for Nuclear Reactions

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We have shown that the Coulomb barrier prevents nuclear reactions under terrestrial conditions. However, what conditions would be required to allow reactions?

For simplicity, consider fusion reactions of the lightest nuclei, i.e., the smallest nuclear charges. What would be the temperature of a hot gas that could have fusion going on? Recall that the thermal kinetic energy of particles in an ideal gas is 3/2 $k_B T$ …

$$KE = \frac{3}{2} k_B T \approx V_{coul}$$

This is a gas temperature that has not been achieved on earth yet. Individual nuclei have been created with such high temperatures but not a substantial number at the same time. This is one of the goals of the various fusion energy programs.

Limited Nuclear Reactions

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Recall that the temperature of our sun is ~6ooo K, so we can see how the kinetic energy distribution compares with the Coulomb barrier for typical light nuclei:

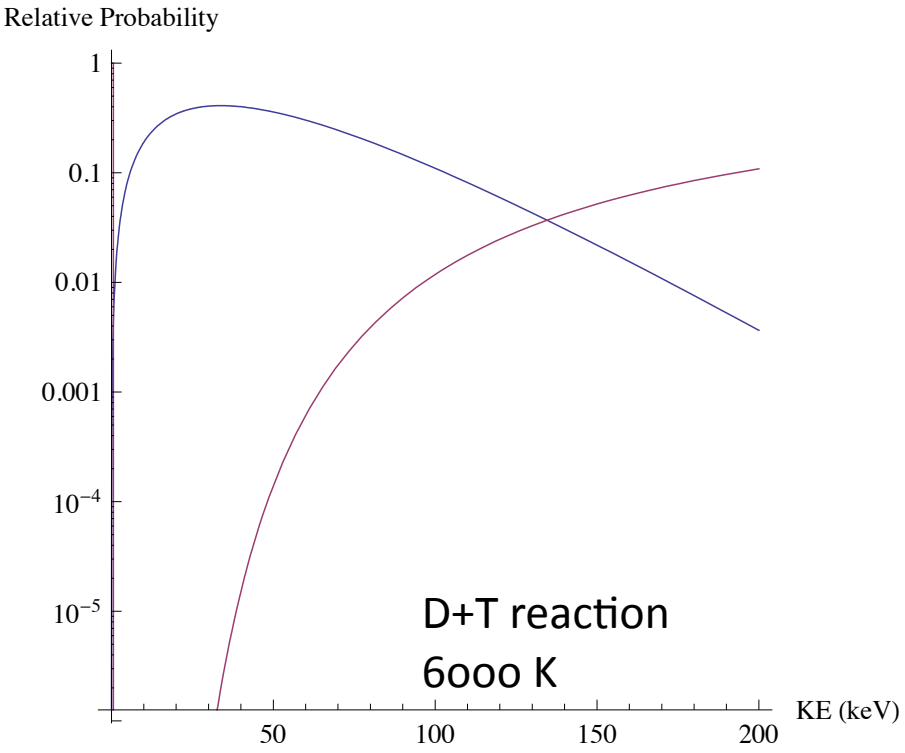
$$P(v) = 4\pi\left(\frac{m}{2\pi k_B T}\right)^{3/2} v^2 e^{-KE/k_B T}$$

$$P(KE) \propto KE\, e^{-KE/k_B T}$$

$$R = \frac{N\sigma\phi}{\lambda}\left(1 - \frac{V_{Coul}}{E}\right)$$

$$R \approx \frac{N\sigma\phi}{\lambda}\left(e^{-Vc/E}\right)$$

$$e^{-x} = 1 - \frac{x}{1!} - + \frac{x^2}{2!} - \cdots \; x < 1$$



Schematic Diagram