Measuring Stellar Elemental Abundance

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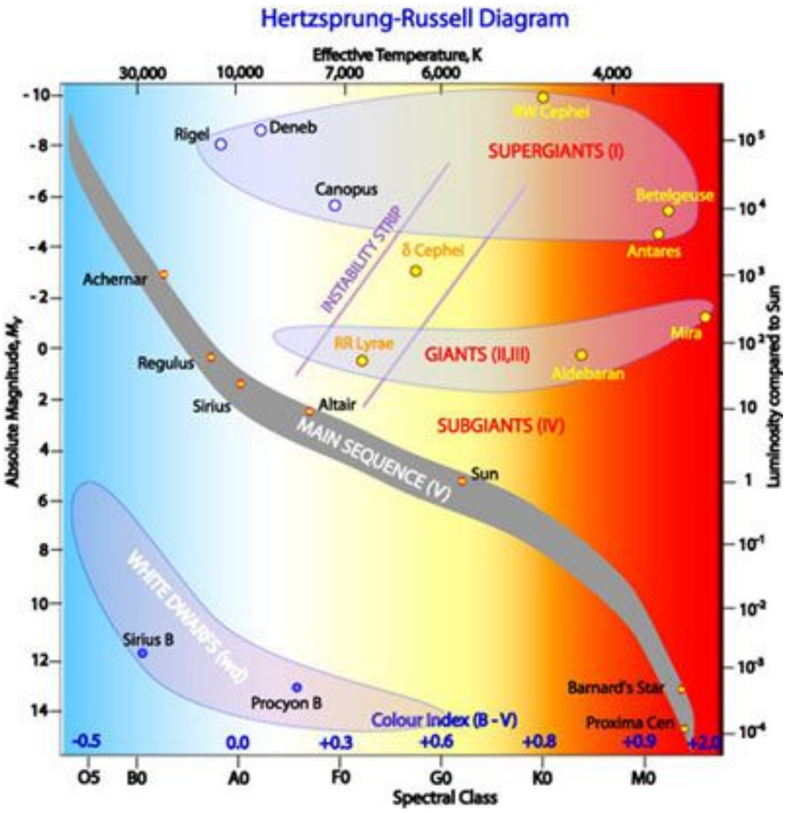
Group 6

Introduction

- It is important for us to know the elemental abundance of stars
- Why?
  - There are more than ten trillion stars in the universe
  - we can know the lifetime of the star (e.g. the Sun) Based on its stellar elemental abundance
- How do we find out the elemental abundance of a star?
- **Curve of Growth Method!**



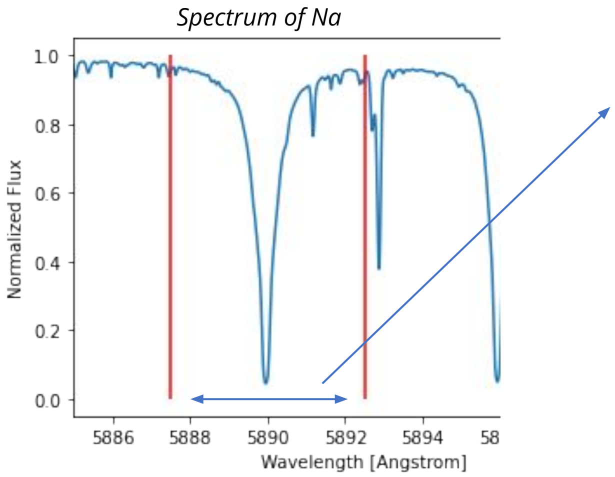
Credit: R. Hollow, CSIRO.

Method

Curve of Growth Method

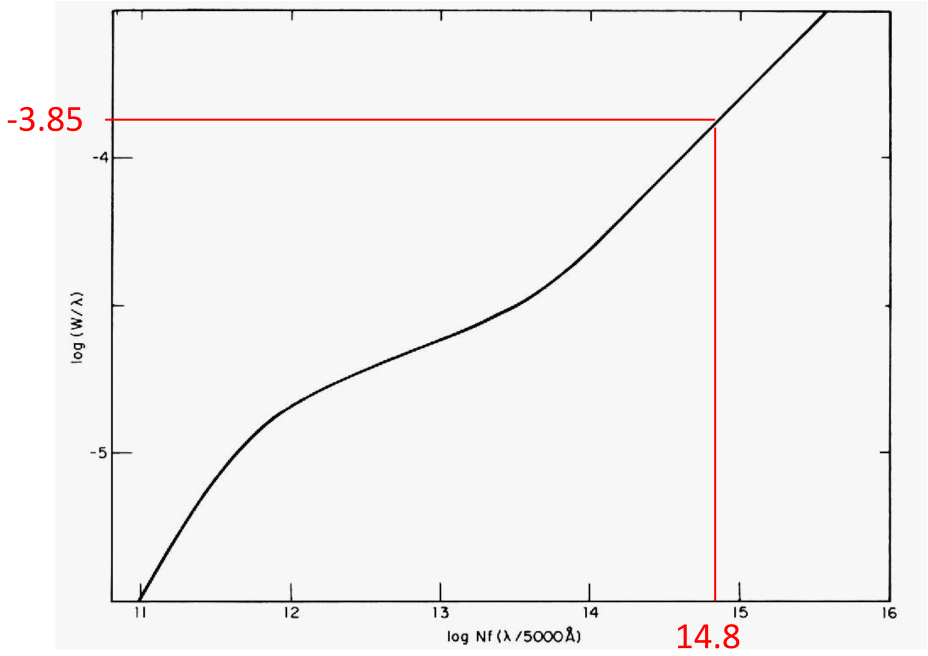
1. Find the number density of ground state Na based on the equivalent width.
2. Find the number density of excited state Na based on the Boltzmann Equation
3. Find the number density of neutral and ionized Na based on Saha Equation
4. Find the column density of Na based on the results of 1-3

Number Density of Ground State and Equivalent Width



Equivalent Width: 0.834 Angstrom

$\log(W/\lambda) = \log(0.83 / 5890) = -3.85$



$\log(Nf(\lambda/5000\,\mathring{A}))\sim 14.8$

λ: 5890 Angstrom

f: 0.65 (Oscillator strength)

Ground Sodium Density

N: 8.24×10^14 atoms/cm**2

Number Density of Excited State and Boltzmann Equation

$$\frac{N_2}{N_1} = \frac{g_2}{g_1}\exp\left(-\frac{E_2-E_1}{kT}\right)$$

N_1 **: Number Density of Ground State**

8.24×10^14 atoms/cm**2

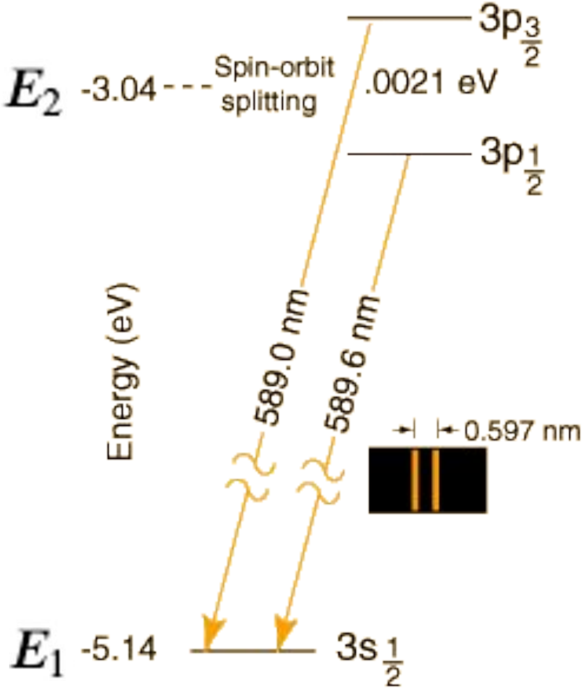
T **: Temperature**

5780 K

$\frac{g_2}{g_1}$ **: Number of degenerate energy states**

Na 5896 has electrons that enter the 3p orbital, which also has 3 degenerate states, so the ratio should be **2**

k **: Boltzmann constant**



Number Density of Excited State

N_2 2.432 × 10^13 atoms/cm**2

Number Density of Neutral and Ionized Na and Saha Equation

$$\frac{Na_{II}}{Na_I} = \frac{2kT}{P_e}\frac{Z_{II}}{Z_I}\left(\frac{2\pi m_e kT}{h^2}\right)^{3/2} \exp\left(-\frac{\chi}{kT}\right)$$

The neutral state number density Na_I is equivalent to N1 + N2.

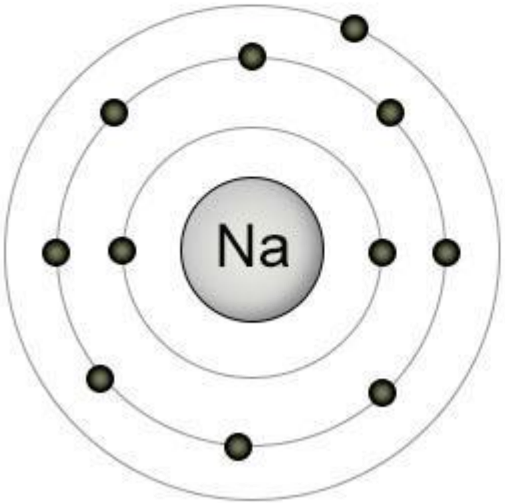
m_e is electron mass,

temperature T = 5780

the ionization energy $\chi = 5.1$ eV,

partition function $Z_I = 2.4$ and $Z_{II} = 1.0$

electron pressure $P_e = n_e kT = 1.0 N \cdot m^{-2}$



Ionized state number density (N_aii)

2.136 *10^18 atoms/cm**2

Column Density of Na

$$N_1 \times \left(1 + \frac{N_2}{N_1}\right) \times \left(1 + \frac{Na_{II}}{Na_I}\right).$$

N_1 **: Number Density of Ground State**

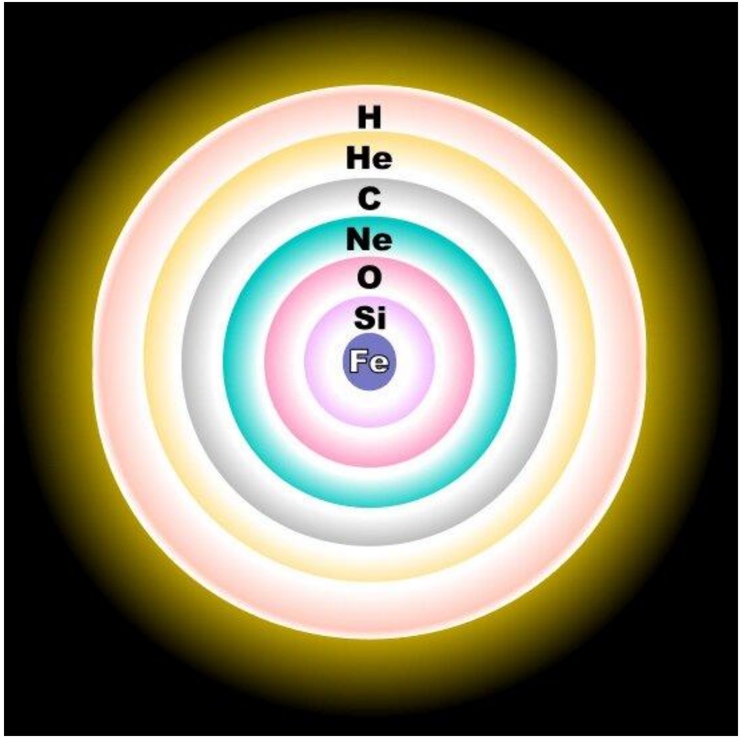
N_2 **: Number Density of Excited State**

Na_I **is equivalent to N1 + N2.**

Na_{II} **: Ionized state number density**

Sodium column density

2.137 * 10^18 atoms/cm**2



Relative Abundance

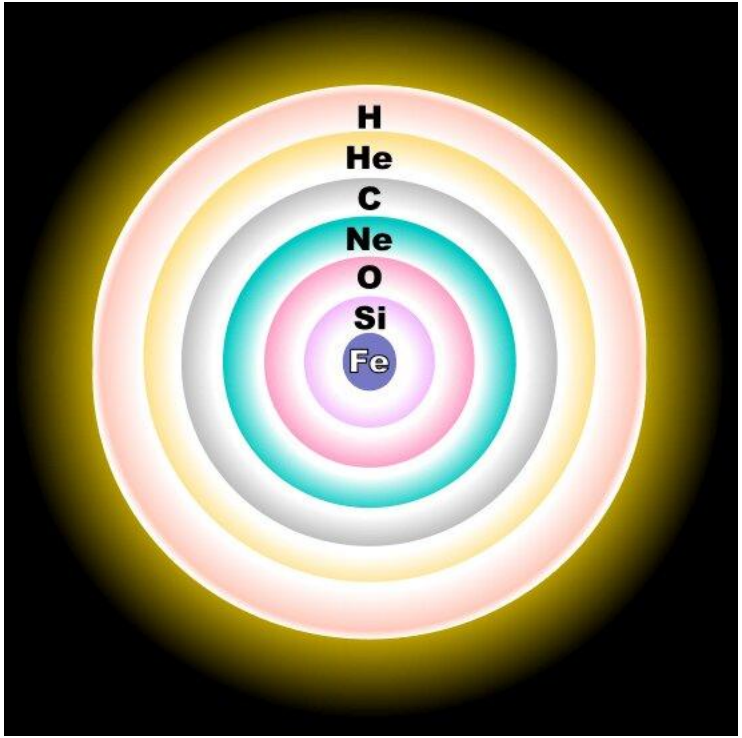
$$\frac{N_{element}}{N_H} = 12 + log_{10}\left(\frac{N_{element}}{N_H}\right)$$

N_H **Number density of hydrogen, here it can be column density**

6.6* 10^23

$N_{element}$ **Number density of Sodium, here it can be column density**

2.137 * 10^18



Number density ratio (N_Na / N_H) = 3.24 * 10^-06

Relative log abundance ([Na/H]) = 6.51

Results

Ground Sodium Density

8.24×10^14 atoms/cm**2

Ionized state number density (N_aii)

2.136 *10^18 atoms/cm**2

Number Density of Excited State

2.432 × 10^13 atoms/cm**2

Column density of Sodium

2.137 * 10^18

Number density ratio (N_Na / N_H)

3.24 * 10^-06

Relative log abundance ([Na/H])

6.51

Comments?