Measuring Sodium and Iron Abundance in the Sun

Group 3: Avidaan Srivastava, Joshua Kingsbury, Kevin Hoy, Logan Steele

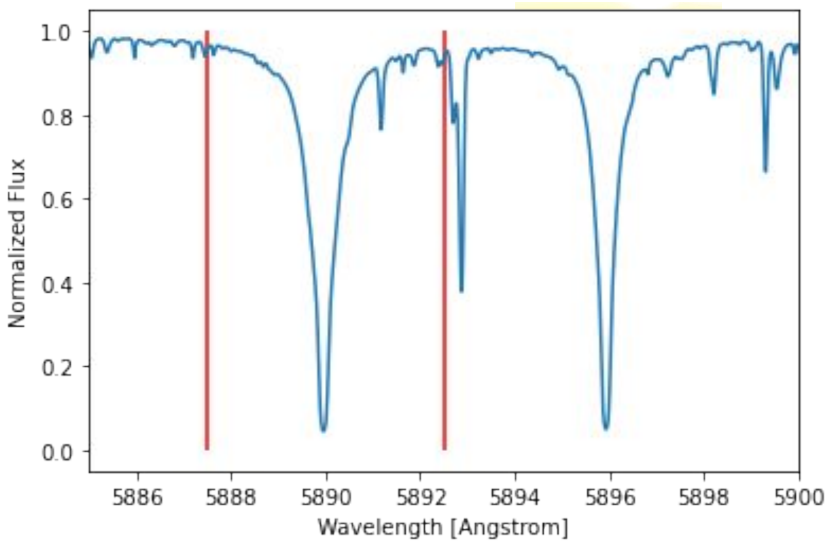
Motivation

- We want to learn about planet composition, but it’s difficult to observe directly
- Stars and their planets come from the same cloud of gas and dust
- Stars and their planets are formed from the same base materials
- Star composition gives insight into planet composition
- Star composition can be observed via spectra

Look at stellar spectra → Learn something about a planet

Equivalent Width

- Raw spectra are messy
- Rectangles are not
- Equivalent Width: Width of a rectangle that has the same height and area as observed absorption line



Curve of Growth

- Total column density of ground-state Na
- Assuming oscillator strength f = 0.65
- Equivalent Width 0.83 Å
- Solve this for N:

$$log(Nf\frac{\lambda}{5000A^o}) \sim 14.8$$

- We get $N_1 = 8.24*10^{14}$ atoms/cm^2

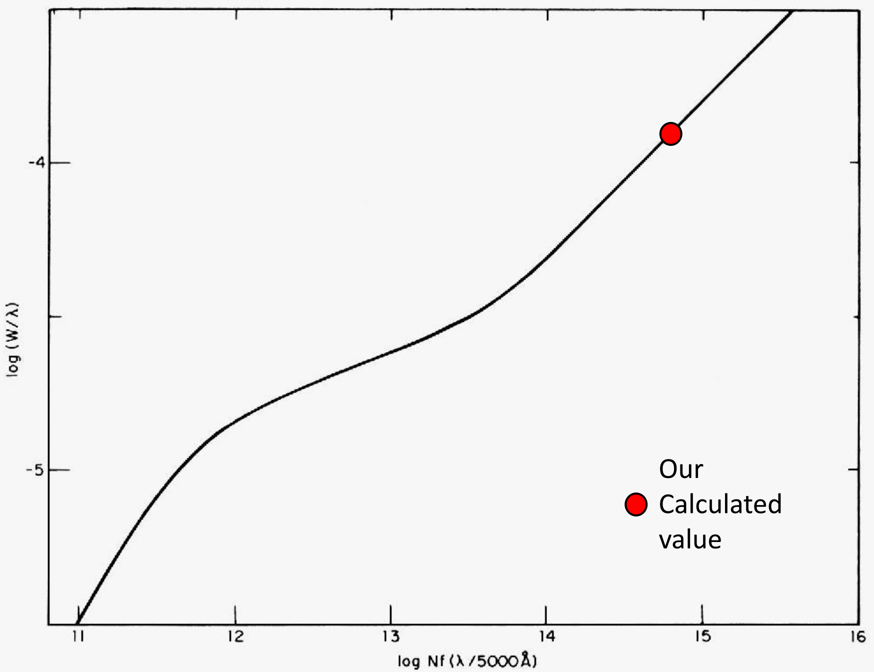


Figure 9.22 A general curve of growth for the Sun. (Figure from Aller, *Atoms, Stars, and Nebulae*, Revised Edition, Harvard University Press, Cambridge, MA, 1971.)

Excitation & Ionization

Boltzmann Equation

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

Saha Equation

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

g_i -> # of Degenerate States

E_i -> Energy Level

k -> Boltzmann Constant

T-> Temperature

P_e -> Electron Pressure

Z_i -> Partition Function

m_e -> Electron Mass

h -> Planck Constant

χ -> Ionization Energy

Calculations

Using:

$Z_I = 2.4$

$Z_{II} = 1.0$

$P_e = 1.0$ N/m

$T = 5770$ K

□ = 5.1 eV

$$\frac{N_2}{N_1} = 0.043$$

$$\frac{Na_{II}}{Na_I} = 2482.7$$

Relative to Hydrogen

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

Using previous results and $N_H = 6.6 * 10^{23}$ atoms/cm^2

Astronomer Molar Ratio = **6.51 Calculated** / **6.30 ± 0.03 Literature**

$N_{Na} / N_H = 3.2 * 10^{-6}$

[Na / H] = 0.21

Iron

Oscillator Strength: $7.1 * 10^{-6}$

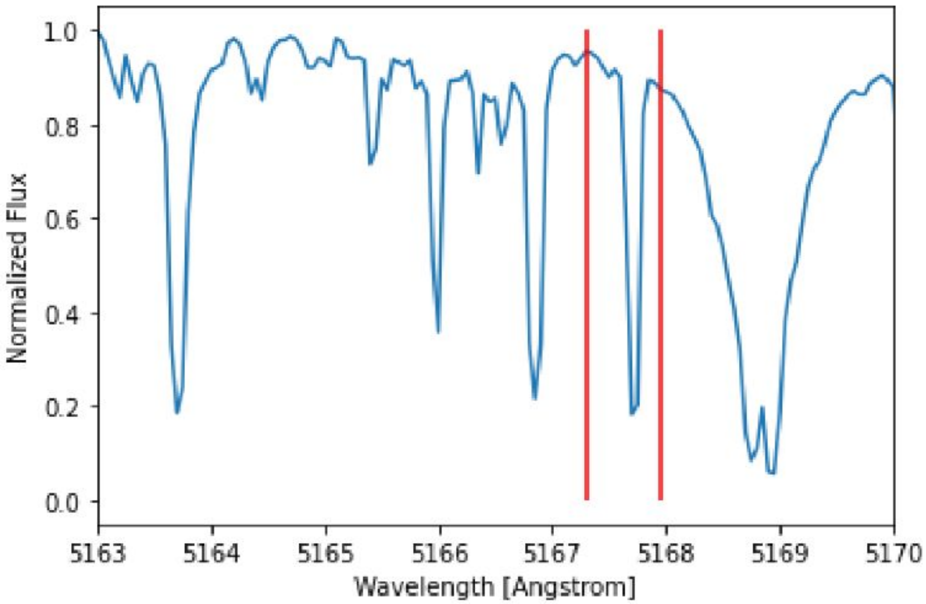
Equivalent Width: 0.15 Å

χ = 7.9 eV

Astronomer Molar Ratio = 7.72 Calculated / 7.48 ± 0.06 Literature

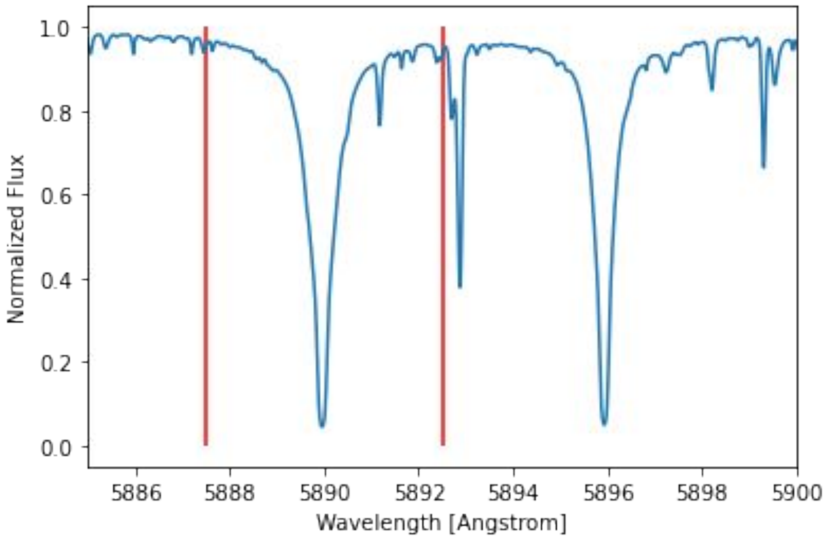
$N_{Fe} / N_H = 5.27 * 10^{-5}$

[Fe / H] = 0.22



Conclusion

Using Sodium and Iron Spectra, we have successfully reproduced the Sodium and Iron abundances observed in the Sun.



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Contributions

Kevin - Presentation

Avidaan - Sodium Calculations

Logan - Iron Calculations

Josh - Report

Citation

Palme, H., Lodders, K., & Jones, A. 2014, in Planets, Asteriods, Comets and The Solar System, ed. A. M. Davis, Vol. 2, 15–36