Spectral Analysis: Measuring Abundance

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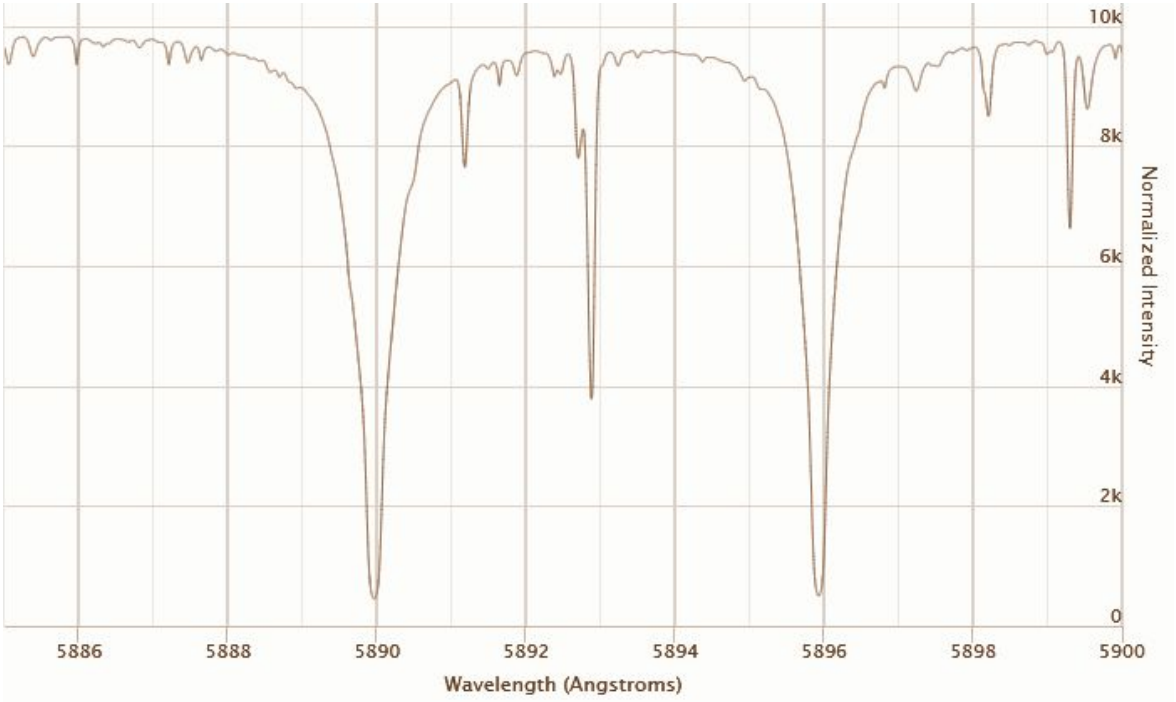
Introduction - Spectroscopy

- Every element has a unique “fingerprint”
- We can match these fingerprints to the measured spectra of a star to determine its composition
- Exoplanet composition closely relates to stellar composition
  - Measuring the chemical abundances of exoplanet host stars gives researchers an idea of their exoplanets’ compositions

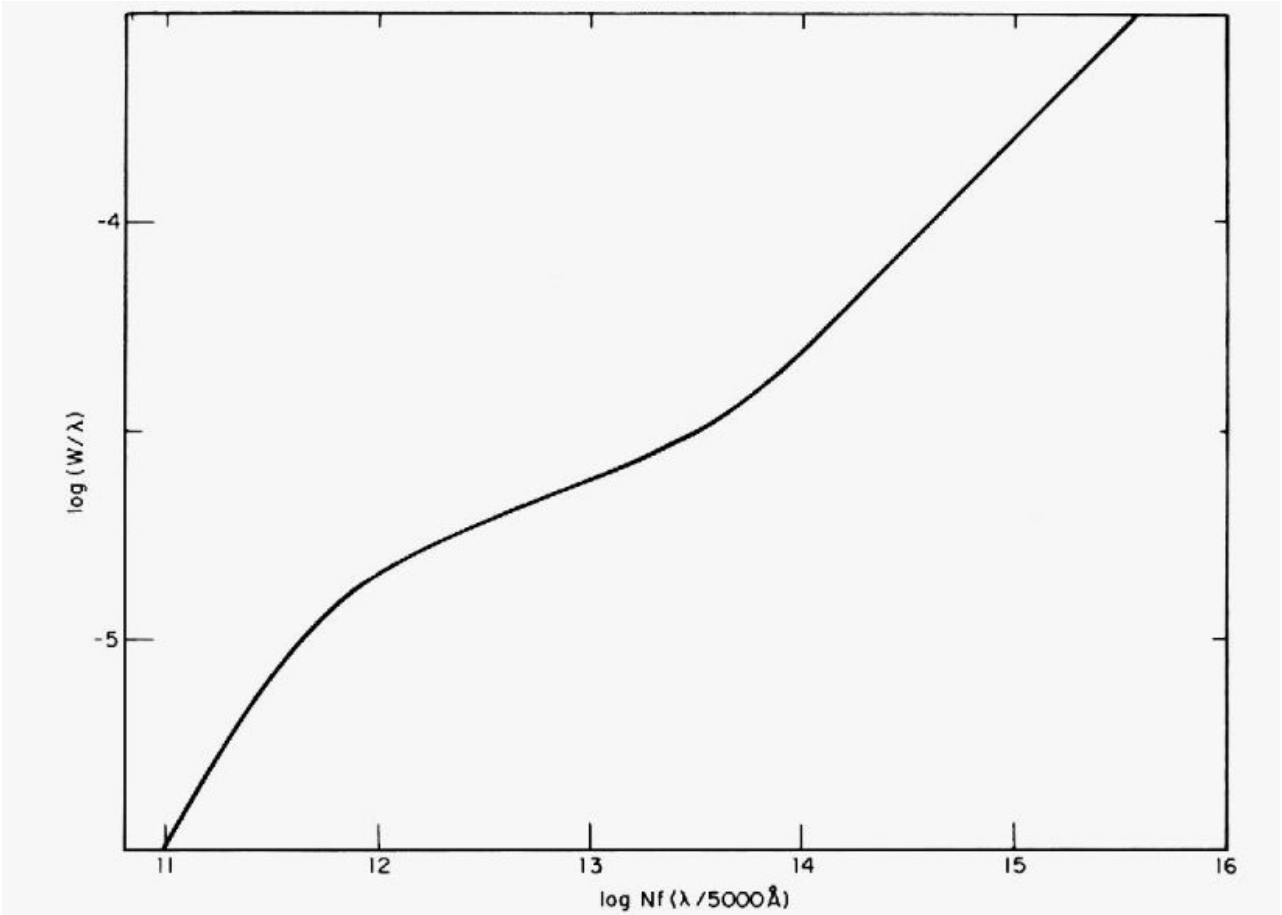
Method

- Sodium Doublet
  - Absorption lines at 5890 Å and 5896 Å



Curve of Growth

- Relationship between intensity of absorption line and number of atoms



Method - Calculations

- Boltzmann Equation
  - N_a is the result from the Curve of Growth
  - N_b Is the number of excited atoms

$$\frac{N_b}{N_a} = \left(\frac{g_b}{g_a}\right)\left(e^{-(E_b - E_a)/kT}\right)$$

- Total number of Neutral Atoms
  - $N_I = N_a + N_b$

- Saha Equation
  - N_{II} Is the number of ionized atoms

$$\frac{N_{II}}{N_I} = \frac{2Z_{II}}{n_e Z_I}\left(\frac{2\pi m_e kT}{h^2}\right)^{3/2} e^{-\chi/kT}$$

- Total Atoms
  - $N_{Total} = N_I + N_{II}$

Results

- Total column density of sodium atoms
  - Na = 2.143×10^{18} atoms/cm^2
- Chemical Abundances
  - Given number density of hydrogen
    - H = 6.6×10^{23} atoms/cm^2
  - Solar sodium log abundance: 6.30
  - Solar helium log abundance: 12

Galactic Astronomer	Physicist: Mole Ratio	Stellar Astronomer
$12 + log_{10}\left(\frac{Na}{H}\right)$	$\frac{Na}{H}$	$\left[\frac{Na}{H}\right] = \log\left(\frac{Na/H}{Na_{sun}/H_{sun}}\right)$
6.51	3.24×10^{-6}	0.21

Results

- Total column density of Iron atoms
  - Fe = 9.87×10^{18} atoms/cm^2
- Chemical Abundances
  - Given number density of hydrogen
    - H = 6.6×10^{23} atoms/cm^2
  - Solar Iron log abundance: 7.48
  - Solar helium log abundance: = 12

Galactic Astronomer	Physicist: Mole Ratio	Stellar Astronomer
$12 + log_{10}\left(\frac{Fe}{H}\right)$	$\frac{Fe}{H}$	$\left[\frac{Fe}{H}\right] = \log\left(\frac{Fe/H}{Fe_{sun}/H_{sun}}\right)$
7.17	1.50×10^{-5}	-0.31

Conclusion

Calculated log sodium abundance:
6.51

Solar log sodium abundance
6.30

Calculated log iron abundance:
7.17

Solar log iron abundance
7.48