Your Name: AST1002

Analyzing Spectra[1]

Types of Spectra (/8):
Finding Thermal Spectra (/5):
Analyzing Spectra (/7):
Total (/20):

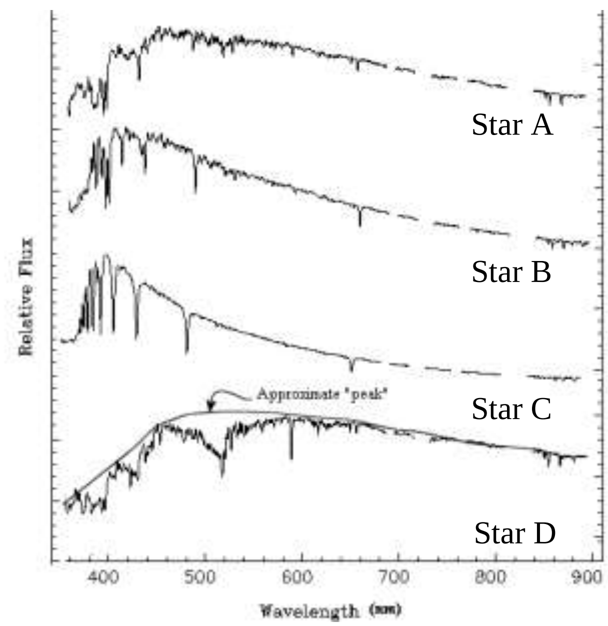
Introduction

Since astronomy is almost entirely dependent on light, we will spend some time working with spectra. In this lab you will:

- Work to understand the three main types of spectra, and
- Predict the composition of gasses based on their spectra.

The Three Main Types of Spectra

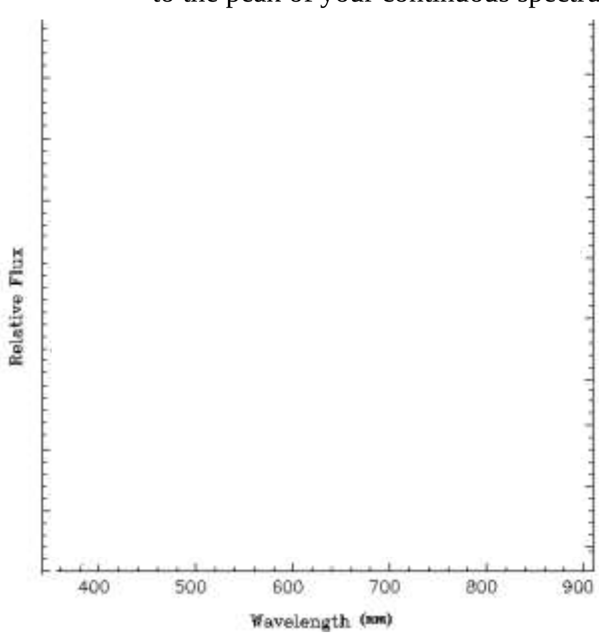
Shown here are spectra from four different stars. Each spectrum is shifted vertically so they don't overlap. Stellar spectra, like these, are almost always absorption spectra. This is because the hot interior of the star produces a continuous spectrum, but that light has passed through the (relatively) cool atmosphere of the star, where atoms can absorb light at certain wavelengths.



1. Circle a single spectral line in Star C's spectrum. *(1 point)*

2. Use the blank spectrum below to draw an example continuous spectrum, and an example emission spectra. *(2 points--we aren't grading on realism, intead we want to see the relevant features)*

3. Continuous spectra are characterized by their peak wavelength. Draw an arrow pointing to the peak of your continuous spectrum. *(1 point)*

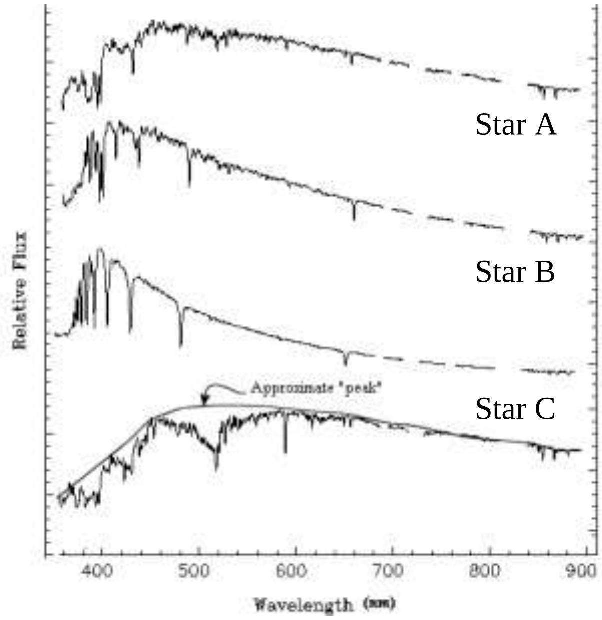


4. Circle a single emission line in your example emission spectrum. *(1 point)*

5. Is that emission line caused by electrons gaining or losing energy? *(1 point)*

6. In the next step, you will trace the shape of the continuous spectrum for each of the stars above. Why does the trace of the star's continuous spectrum go over the top of the absorption spectrum, and not through any lines? *(2 points)*

7. Trace a curve over the spectra of these stars to approximate the underlying continuous spectra. I've drawn the curve for Star D already. *(1 point)*



Finding Thermal Spectra

8. Use Wein's Law to estimate the temperature of each star. First measure the peak of the smooth curve you drew and write it in the table below. Then use Wien's Law:

$$\lambda_{\text{peak}} = \frac{2.9\times10^{6}\ nm{\cdot}K}{T},$$

Star D

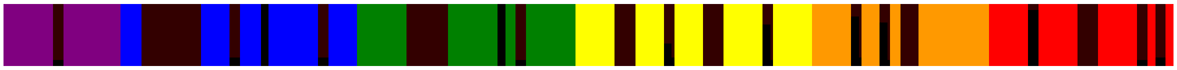
to calculate the temperature that produced the underlying continuous spectrum. *(4 points)*

Star	Peak Wavelength (nm)	Temperature (K)
A		
B		
C		
D		

Analyzing Spectra

9. Examine the following spectra. One of which represents the Sun’s spectrum, and the other represents the emission line spectrum of vaporized iron. Explain if this provides evidence for the presence of iron in the atmosphere of the Sun. *(1 point)*

Solar Spectrum



Emission Spectrum of Iron

Star Abba

Star Babba

Star Cabba

Carbon (laboratory emission spectrum)

Nitrogen (laboratory emission spectrum)

Oxygen (laboratory emission spectrum)

Xenon (laboratory emission spectrum)

Hydrogen (laboratory emission spectrum)

Helium (laboratory emission spectrum)

All three stars—Abba, Babba, and Cabba—are made primarily of hydrogen and helium (just like all of the other stars in the sky) but in this imaginary case one star has a high percentage of carbon in its atmosphere, another has a high percentage of nitrogen, and the third has a high percentage of oxygen

10. Which star has a high abundance of nitrogen in addition to hydrogen and helium? *(1 point)*

11. Which star has a high abundance of oxygen in addition to hydrogen and helium? *(1 point)*

12. Which star has a high abundance of carbon in addition to H and He? *(1 point)*

13. Do any of these three stars show evidence of having xenon in their atmospheres? *(1 point)*

14. Explain why it's possible to identify which atoms exist in stars and nebulae; relate your explanation to the "fingerprint" analogy for spectral lines. *(2 points)*

Identifying Lines in the Solar Spectrum

Adapted from *Learning Astronomy by Doing Astronomy* by Ana Larson

Summary

The student will identifies lines of the solar spectrum, using interpolation from "known" Fraunhofer lines.

Background and Theory

The brightest star in our sky is the Sun. Absorption lines in the solar spectrum were first noticed by an English astronomer in 1802, but it was a German physicist, Joseph von Fraunhofer, who first measured and cataloged over 600 of them about 10 years later. These lines are now known collectively as the "Fraunhofer lines." In the 1800's, scientists did not know that these lines were chemical in origin. Thus, the letters used by Fraunhofer to identify the lines have no relation to chemical symbols nor to the symbols used to designate the spectral types of stars. Today's astronomers use some of the designations simply for convenience and ease in identifying lines.

Now we know that each absorption line is caused by a transition of an electron between energy levels in an atom. Each element has a distinct pattern of absorption lines. Once the pattern of the lines of a particular element has been observed in the laboratory, it is possible to determine whether those elements exist elsewhere in the universe simply by pattern matching the absorption lines.

The strongest Fraunhofer lines of the Sun can easily be seen with even the most primitive spectroscope. By viewing a bright sky (of course, never look directly at the Sun -- the lines you see will be those of your retina burning), or the full Moon with a spectroscope or diffraction grating, you should be able to see at least a few absorption lines. In this exercise, we work with the solar spectrum between approximately 390 and 660 nm (3900 - 6600 Angstroms) and identify some of the strongest Fraunhofer lines.

Procedure

Print out the worksheet (at the end of this document).

Table 1 -- "Known" Lines

Part A: Determine the Scaling factor (completing Table 2 on worksheet)

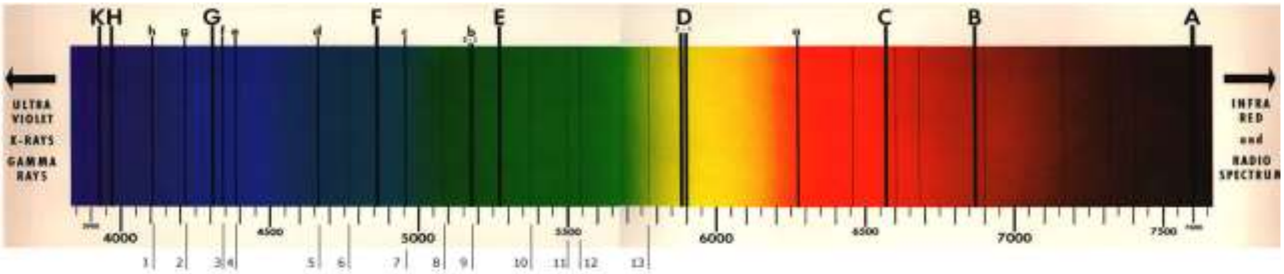
Designation	Wavelength (nm)	Origin
A	759.4	terrestrial oxygen
B	686.7	terrestrial oxygen
C	656.3	hydrogen (Hα)
D_1	589.6	neutral sodium (Na I)
D_2	589.0	neutral sodium (Na I)
E	527.0	neutral iron (Fe I)
F	486.1	hydrogen (Hβ)
H	396.8	ionized calcium (Ca II)
K	393.4	ionized calcium (Ca II)

1. On the solar spectrum, measure the distance (in pixels) between two widely spaced, "known" lines (See Table 2 on worksheet, one pair has been completed as an example).
   Note: Pixels are the small dots that make up images on computer screens
2. Find the distance between these lines in nanometers using Table 1.
3. Divide the distance in nanometers (step 2) by the distance in pixels (step 1) to get the number of nanometers per pixel.
4. Average the results of the four measurements to get the scaling factor.

Part B: Calculate the wavelengths of the "unknown" lines (completing Table 3 on worksheet)

1. Pick **one** of the lines from table 1 to serve as your reference; for example, the **K** line of **Ca II** at **393.4** nm. Fill in your reference line's designation, location (in pixels), and wavelength on the worksheet.
2. Measure the location of each of the unknown lines (numbered 1-13) in pixels on the website.
3. Subtract the location of the reference line in pixels to find the distance in pixels from each unknown line to your reference line.
4. Use the scaling factor to find the distance in nanometers.
5. Add (or subtract) the distance in nm to the wavelength of your reference line to get the wavelength of the "unknown" lines.
6. Compare these wavelengths to the list of lines in Table 4 on the worksheet and identify the "unknown" lines. Your values may not exactly match those given in the table.
   Note: If you find that some of your calculated wavelengths do not seem to match any of those in the table, find the closest match and the corresponding element.

Part C: Answer the Questions on Worksheet



No coordinates specified.

This is a printed version of the solar spectrum. Either use a ruler (and report the distance between lines in cm on the page) or use [this link] to see the image on your screen and report the difference in pixels.

Identifying Lines in the Solar Spectrum: Worksheet

Table 2 -- Determining the Scale Factor

Lines	Location of first line	Location of second line	Distance between lines (pixels)	Distance between lines (nm)	Scale Factor (nm/pixel)
K, F	106	414	308	92.7	0.30
H, E					
F, C					
K, D_2					
					Average: ____ nm/pixel

Table 3 -- Identification of "Unknown" Lines

Reference Line Name	Location (pixels)	Wavelength (nm)

Line #	Location (pixels)	Distance from ref. line (pixels)	Distance (nm)	Wavelength (nm)	Element Name
1					
2					
3					
4					
5					
6					
7					

8					
9					
10					
11					
12					
13					

Questions

1. To find the wavelength of each unknown line we asked you to measure from a reference line. Why didn't we just convert the location (in pixels) to the line's wavelength?

2. Stars are made up of approximately 90% Hydrogen, 9% Helium, and 1% heavier elements. Based on this, is the strength of the lines you've observed dependent on composition?

3. Two of the known lines ('A' and 'B') are actually caused by terrestial oxygen, in other words our own atmosphere on Earth. If you were in charge of the telescope during these observations what simple extra observation could you make to verify this is true?

4. What does the "line width" tell you about the "strength" of the line? Is a line having a width of 1.5467 nm more evident than a line having a line width of 0.0083 nm? The strength of a line in a stellar spectrum depends upon the temperature of the star as well as the abundance of the element in the atmosphere of the star, and the ease with which electrons can move between levels in a particular atom.

5. Did you have discrepancies between your calculated wavelengths and those given in the table of wavelengths? Describe.

6. If so, why do you think this happened? In answering this question, consider your accuracy in determining the scaling factor and measuring the distance to each "unknown" line. How much of an effect did these errors have on the calculated wavelengths?

7. Suggest a better method that students might use to extract more accurate wavelengths and line identifications.

8. How do astronomers use similar processes to identify absorption lines in other stars?