# Are There Groups of Stars With Similar Properties?

## Course Outcomes Met

1. Communicate scientific issues effectively in oral and written form;
2. Effectively collect, analyze and present data and correctly construct and interpret charts, graphs and tables to draw scientific conclusions;
3. Apply the fundamental concepts and methodologies of physics and/or chemistry to investigate a scientific theme.

Tools used in this activity:

1. Real stellar data from the Sloan Digital Sky Survey

We’re going to use actual data from the Sloan Digital Sky Survey to explore how astronomers classify stars according to similarity. The classification system was invented before anyone really knew what spectra even existed, let alone why they were varying between stars. Originally, the types were in alphabetical order. As spectra generally and stars particularly began to be better understood, some types were dropped as unnecessary and they were reordered according to a more physical understanding.

## A. Exploration

Open the file SDSS Stellar Spectrum Examples and familiarize yourself with the essential features of a spectrum. This is the same as the spectra we looked at in How to tell what stars are made of, but instead of a photograph they are graphs of brightness vs. wavelength. You also saw similar graphs in How Hot Are Stars, but now we know why they are not smooth. Some features are labeled. These correspond to specific elements such as hydrogen or oxygen. You’ve seen the hydrogen labels before in the “What are stars made of?” activity.

Now lets look at some real stars. Follow each of these links to a page that shows the star spectrum, an image of the star, and rather a lot of other information. Clicking on the spectrum will give you a larger version.

As you are looking at them, answer these questions:

1. What do you notice about the spectra? What are the most important features they all have in common?
2. What differences do you notice among the spectra? How do the continuum peak and the absorption lines change among the spectra?
3. Can you see a relationship between these star's color and their spectra?

1. <http://cas.sdss.org/dr7/en/tools/explore/obj.asp?plate=342&mjd=51691&fiber=586>

2. <http://cas.sdss.org/dr7/en/tools/explore/obj.asp?plate=363&mjd=51989&fiber=5>

3. <http://cas.sdss.org/dr7/en/tools/explore/obj.asp?plate=280&mjd=51612&fiber=202>

4. <http://cas.sdss.org/dr7/en/tools/explore/obj.asp?plate=283&mjd=51959&fiber=502>

5. <http://cas.sdss.org/dr7/en/tools/explore/obj.asp?plate=285&mjd=51930&fiber=242>

6. <http://cas.sdss.org/dr7/en/tools/explore/obj.asp?plate=342&mjd=51691&fiber=141>

7. <http://cas.sdss.org/dr7/en/tools/explore/obj.asp?plate=298&mjd=51955&fiber=400>

**Discuss your results with your instructor at this point**

## B. Closer Look

Open the file SDSS Stellar Spectra 1-7.docx.

1. From the previous activities, estimate the temperature of each star from its spectrum. What law must you use? Use the appropriate NAAP simulator to verify your estimate. (Note: to get wavelengths in nm from wavelengths in Angstroms, divide by 10. For example, 6000 Ǻ = 600 nm.)

2. The absorption line labeled Hα will turn out to be important. Each image has the full star spectrum and beneath it an enlarged version of the Hα absorption line. Estimate the wavelength at the bottom of this line. Use the NAAP hydrogen simulator to determine which two energy levels in the hydrogen atom it corresponds to. Which of the three series (Lyman, Paschen or Balmer) is it part of?

3. Find the lines labeled Hβ Hγ, and Hδ in the example spectrum (or any of the spectra). Do the wavelengths of these lines correspond to more or less energetic transitions than the Hα line?

4. Which pairs of energy levels do each of these absorption lines correspond to?

**Discuss your results with your instructor at this point**

## C. Stellar Classification

Open the file *SDSS Stellar Spectra 1-7.docx* and the file *Hα Absorption Lines Magnified.docx*

1. Observe the strength of the Hα absorption line in each of the seven star spectra. The strength of the line is literally how much light is absorbed. To measure the strength of a line, connect the centers of the two triangles with a straight line. This is approximately what the spectrum would have been had there been no absorption line. The area in between that straight line and the actual spectrum is the line strength. This is easiest to do and compare on the file *Hα Absorption Lines Magnified.docx* because you can use Word’s line tool on the Insert/Shapes menu to draw your lines.

2. Rank the stars by writing each star number in the appropriate place in the second column of the table below. Most of them you can eyeball but there are some where you will have to estimate the number of rectangles between the straight line and the absorption line.

|  |  |  |
| --- | --- | --- |
| **Line Strength** | **Star Number** | **Spectral Class** |
| Strongest line (greatest line area) | ? | A |
| ↓ | ? | B |
| ↓ | ? | F |
| ↓ | ? | G |
| ↓ | ? | K |
| ↓ | ? | M |
| Weakest line (least line area) | ? | O |

Originally, astronomers classified those stars with the strongest hydrogen lines as 'A' stars, stars with the next strongest lines as 'B' stars, the next strongest 'C' and so on. Eventually, they realized that some letters were unnecessary, and dropped them from the classification system. The letter assigned to a star is called its *Spectral Class*.

3. Which is hotter: a star whose continuum peaks at 5000 Ångstroms or a star whose continuum peaks at 6000 Ångstroms?

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4. Rank the stars according to peak wavelength of each star's thermal continuum, using the table below. Estimate where you think the star ranks if the peak is not shown on the graph.

|  |  |
| --- | --- |
| **Wavelength** | **Star Number** |
| Longest peak wavelength |  |
| ↓ |  |
| ↓ |  |
| ↓ |  |
| ↓ |  |
| ↓ |  |
| Shortest peak wavelength |  |

5. Rank the seven stars in order of temperature using the table below. Fill in both the star’s number and its spectral class.

|  |  |  |
| --- | --- | --- |
| **Temperature** | **Star Number** | **Spectral Class** |
| Hottest | ? | ? |
| ↓ | ? | ? |
| ↓ | ? | ? |
| ↓ | ? | ? |
| ↓ | ? | ? |
| ↓ | ? | ? |
| Coolest | ? | ? |

**Discuss your results with your instructor at this point**

6. Summarize your results in the table below: in the first row list the spectral types in order of decreasing Hα line strength, and in the second row in order of decreasing temperature.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Strongest Hα Line** | ? | ? | ? | ? | ? | ? | ? | **Weakest Hα Line** |
| **Hottest Temperature** | ? | ? | ? | ? | ? | ? | ? | **Coolest Temperature** |

7. Do the classification schemes in questions 5 and 6 give the same sequence?

8. Which class of stars is the hottest? Does this correspond to you answer in the How Hot Are Stars activity?

9. Which class of stars is the coolest? Does this correspond to you answer in the How Hot Are Stars activity?

10. Which class of stars has the strongest Hα line?

11. Which classes of stars have the weakest Hα lines?

12. The accepted ordering for spectral classes among astronomers is OBAFGKM. You may have learned the classes with the phrase "Only bad art features Godzilla killing Mothra." Why do the classes appear in this order?

**Discuss your results with your instructor at this point**

## D. Interpreting the Spectral Classes

You may have to remind yourself of what you did with the hydrogen simulator in the “What are stars made of?” activity to answer these questions.

1. For the stars with strong Hα lines, what energy state do Hydrogen’s electrons have to start in (before they absorb the Hα photon)?

2. What energy levels might you expect the electrons in the hydrogen of hotter stars to start in?

3. What energy level might you expect to see in the electrons of hydrogen in a colder star?

4. Why might these hot and cold stars both show very weak Hα lines?

5. Can you explain why the sequence of Hα line strength is not the same as the temperature sequence?

When scientists figured out why there are spectral lines in the first place, they realized that the classification sequence in alphabetical order was not in order of temperature. That’s why the remaining spectral classes were rearranged in order of temperature, giving that odd sequence of letters. They also divided the temperature between each class into ten equal parts so you get class O0 through O9, then B0 through B9 and so on.

5. Create a no more than 50-word summary, in your own words, that describes the meaning of the spectral classes, including both their original definition and the reason for their current ordering. Be sure to relate stellar temperature to atomic transitions to spectral features. Using data to discover relationships between seemingly different things is how science is done.

**Discuss your results with your instructor at this point**