



## Lab 09: Stellar Spectroscopy and Classification

### Introduction

Once upon a time, astronomers had to perform their observations in cold, open-air observatories, using telescopes which had to be positioned by hand. Over the past thirty years, telescopes have become increasingly automated. The observatory dome can be opened at the touch of a button. The telescope can be positioned on the desired object as quickly as the astronomer can type the coordinates into the computer. Data collection can be performed at precise and regular intervals, with the information stored on computers, either local or remote. It is now possible for an astronomer in Arkansas (or wherever) to perform observations using a telescope in Arizona (or anywhere), without ever leaving home.

What that means to us is that we can simulate the observing experience with astonishing realism. We will not be able to get observing time on a real telescope, but the VIREO (The VIRTUAL Education Observatory) program we will use has been designed by astrophysicists to reproduce an accurate observing experience. The Student Manual for this exercise is freely available online at:

[ftp://io.cc.gettysburg.edu/pub/clea\\_products/manuals/SpecL\\_sm.pdf](ftp://io.cc.gettysburg.edu/pub/clea_products/manuals/SpecL_sm.pdf)

A clickable link is provided on the course web, and remember that you can run these programs any time the lab LSC 174 is open.

We will start by examining stellar spectra. Similar to the spectroscopy we performed in lab previously, astronomers look to stellar spectra to determine many things about a star. By determining the spectral type of a star, we can find its temperature, luminosity, and color. From these fundamental facts, many more properties of the star can be extrapolated: its mass, its distance, its life history...the list goes on and on.

### Objectives

You have been granted unlimited observing time on a 0.4 meter optical telescope and permission to request time on a 1.0 meter and/or 4.0 meter optical telescopes. The telescopes will be equipped spectrographs. Your project mission is to:

- Obtain spectra of a sample of 10 stars
- Determine the spectral and luminosity types for each
- Calculate the distances of main-sequence stars

### Start up Procedures

1. **Start VIREO:** Double click on the icon for the VIREO program found on the desktop.
2. **File → Login:** Enter your name and the number of the computer and click OK.
3. **File → Run Exercise → Classification of Stellar Spectra:** Choose the appropriate exercise.
4. **Telescopes → Access 0.4 Meter:** Choose a telescope, or *Request Time* → on either the *1.0 Meter* or *4.0 Meter*. If you are granted time on either of the larger telescopes, then you will have to access them from the menu in order to use them. (Hint: Bigger telescope means more light-gathering power means shorter exposures required!)

5. **Control the scope:** Once you have selected one of the telescopes you will need to open the dome, and once the dome is open you will need to turn on the *Telescope Control Panel*.
6. **Tracking:** Turn on the telescope *Tracking* on from the control panel.
7. **Field of view:** Toggle from *Finder* view to *Telescope* view. This switch occasionally sticks, and you might have to toggle a second time to change to the *Telescope* view.

### Targeting Stars

8. **Slew → Set Coordinates:** Enter the coordinates for the target star. Coordinates are listed on the table below.
9. **Double check:** Once the telescope has slewed, there should be a star centered on the spectrograph aperture.

NAME	I.D.	RA (H, M, S)	DEC (°, ', ")
EPSILON ERIDANI	S0730-01533	03 32 55.8	-09 27 29.7
SIRIUS	S1500-02767	06 45 08.9	-16 42 58.0
TAU CETI	S1500-02288	01 44 04.1	-15 56 14.9
PHI ORIONIS	N0730-02401	05 34 49.2	09 29 22.0
MU DRACONIS	N5230-01396	17 05 19.7	54 28 13.0
MINTAKA	S0000-02445	05 32 00.4	-00 17 57.0
PROCYON	N0000-02180	07 39 18.1	05 13 29.0
ARCTURUS	N1500-01426	14 15 39.7	19 10 56.0
BETELGEUSE	N0000-01873	05 55 10.3	07 24 25.4
BARNARD'S STAR	N0000-02498	17 57 54.1	04 33 04.0

### Acquiring Spectra

10. **Open the spectrometer:** Choose *Spectrometer* using the *Instrument* slider, and click *Access* to bring up the *Reticon Spectrometer Reading* control panel.
11. **Double check:** Verify that you are on the correct star by comparing the I.D. listed on the table above with the Object displayed on the Spectrometer control panel.
12. **Collect the data:** Click on *Go* to start an exposure and *Stop* once the Signal-to-Noise Ratio is sufficiently high (S/N should be greater than about 500 for best results). A dimmer star (greater V means dimmer star) will require a longer exposure time.
13. **Record the apparent magnitude (V) of the star.**
14. **Save the spectrum:** *File* → *Save Spectrum*.
15. **Target the next star:** Repeat the above steps until you have saved a spectrum for each star.

### Spectral Classification

16. **Tools → Spectral Classification :** Go to the VIREO Exercise-The Classification of Stellar Spectra Window and *Tools*→*Spectral Classification* to bring up the *Classify Spectra* tool.
17. **File → Display → Show Difference:** This displays the comparison of the *Standard* spectra and the *Unknown* spectrum. When the spectra match, the difference will literally be zero.
18. **File → Unknown Spectra → Saved Spectra:** Choose a saved spectrum for one of the stars you observed.
19. **File → Atlas of Standard Spectra:** Select the *Main Sequence Atlas*. Now you can compare the spectrum of the target star “Unknown” to a sample of main-sequence star spectra by choosing them from the Standards list. The *Difference* will give a quantitative look at how close the Standard and the Unknown match. If you find an exact match, then you can identify the spectral and luminosity type. If you cannot find an exact match, then there are two possibilities:
  - A) **The star might be a giant star.** To check, return to the *Atlas* and chose “Luminosity at \_\_\_\_\_”, where \_\_\_\_\_ is the spectral type that fits the closest when comparing to main-sequence stars. You will be given a sample spectra of different luminosity classes at that spectral type. If you find an exact match, or a better match, then you can conclude it is one of these spectral and luminosity types.
  - B) **The star really is a main sequence star.** If you have ruled out that the star is some sort of giant star then the star is a main-sequence star (luminosity class V) but a spectral sub-class not part of the example standards given. If that is the case, you will need to estimate the sub-type.
20. **Repeat:** Classify all of the stars for which you have collected spectral data.
21. **Organize:** Construct a table in your notebook to summarize your classification results.

STAR	SPECTRAL TYPE	NOTES
EPSILON ERIDANI		
SIRIUS		
TAU CETI		
PHI ORIONIS		
MU DRACONIS		
MINTAKA		
PROCYON		
ARCTURUS		
BETELGEUSE		
BARNARD’S STAR		

In the column labeled “Notes,” you might simply cite that the overall match is very exact, or that you saw two possibilities and had to check/compare the luminosity classes, or that you have estimated a spectral sub-type. Just include a brief note for your own reference to remind you how you came to a specific conclusion.

### Spectroscopic Parallax

For the stars you identified as being main-sequence stars (luminosity class V), determine their distances.

1. **Absolute Magnitude:** Use Appendix II from the Student Manual and the spectral type of each main-sequence star to determine the Absolute Visual Magnitude (M) for each. If it is more convenient, you may look these stars up using Wikipedia. The data for these particular stars is accurately reported.
2. **Calculate (V-M) for each star.** Remember that you only need to do this for the main sequence stars!
3. **Calculate the distance:** Use the equation below to calculate the distance to each star in parsecs (pc).

$$d = 10^{\left(\frac{(V-M)+5}{5}\right)} \text{ pc}$$

Note that the equation reads “ten raised to the power of.” *You are not multiplying ten by the value in parentheses.*

4. **Summarize:** Construct a table in your lab notebook to summarize your findings. Note that you may not fill in the values for every star you observed! *Only calculate distance for the stars you have identified as main sequence.*

STAR	ABSOLUTE MAGNITUDE (M)	APPARENT MAGNITUDE (V)	V – M	DISTANCE IN PC
EPSILON ERIDANI				
SIRIUS				
TAU CETI				
PHI ORIONIS				
MU DRACONIS				
MINTAKA				
PROCYON				
ARCTURUS				
BETELGEUSE				
BARNARD’S STAR				

Make sure that you are recording all your answers in your lab notebook. Include any sketches or additional explanations that you think may help you answer quiz questions!