CLEA/VIREO

CLASSIFICATION OF STELLAR SPECTRA

1. Starting up the program

The computer program you will use is a spectrum display and classification tool. This tool enables you to display a spectrum of a star and compare it with the spectra of standard stars of known spectral types. The tool makes it easy to measure the wavelengths and intensities of spectral lines and provides a list of the wavelengths of known spectral lines to help you identify spectral features and to associate them with particular chemical elements.

You will examine the digital spectra of 25 unknown stars, determine the spectral type of each star, and record your results along with the reason for making each classification. The spectra can be compared visually and digitally (point by point) with an representative atlas of 13 standard spectra, and by looking at the relative strengths of characteristic absorption lines, you will be able to estimate the spectral type of unknown stars to about a tenth of a spectral class, even if they lie between spectral types of these stars given in the atlas.

Double click on the "Vireo" icon on the start screen.
Go to File... Login and enter your names. You don't need to enter a table number.
Go to File... Run Exercise... Classification of Stellar Spectra
Go to Tools... Spectral Classification...

2. Understanding the Spectrum

Begin by loading the first unknown spectrum which you will identify:
Go to File... Unknown Spectra... Program List...
Select "HD 124320" from the Program List

Look at the spectrum carefully. Note that what you are seeing is a graph of relative intensity versus wavelength. The spectrum spans a range from 3700 Å to 4700 Å, and the intensity can range from 0 (no light) to 1.0 (maximum light). Remember that "Å" or Ångströms is a unit of length equal to 10^{-10} meters and is one of favored units of wavelength measurement in astronomy. Also, remember that "λ" or "lambda" is the greek letter which denotes wavelength.

You can change the wavelength range shown on the x-axis by the following:
Go to File... Display... Spectral Range

Try changing the minimum λ to 3900Å and the maximum λ to 4500Å.

The highest points in the spectrum, called the continuum, are the overall light from the incandescent surface of the star, while the dips are absorption lines produced by atoms and ions further out in the photosphere of the star. You can measure both the wavelength and the intensity of any point in the spectrum by pointing the cursor at it and clicking the left mouse button. At the bottom of the window displayed, two numbers will be listed as "Cursor@ : ____" and "Intensity: ____". These are the measurements of the wavelength and relative intensity at the location selected by the cursor.

Using the cursor, select any point on the continuum of HD 124320 and record the wavelength and intensity given onto your handout (*From page 8, part a*). Next, locate the deepest absorption line and, by using the cursor, select the deepest point of that absorption line. Record the wavelength and intensity (*From page 8, part b*).

Question: If you were to look at this range of wavelengths with your eyes, what color would they appear? In order to determine the color of a star by its spectrum, you need to determine the wavelength of peak intensity (λ_{peak}) across that spectrum. Change the range on the x-axis to λ = 3600Å-7400Å; the display now shows the full visual spectrum. At what wavelength is the continuum at a peak intensity? What color does this wavelength correspond to? Remember that the different wavelengths correspond to different colors, i.e. λ_{blue} = 4000Å and λ_{red} = 7000Å. Record your answer on the handout (*From page 8*).

3. Using Standard Spectral Types

Now you want to find the spectral type of HD 124320 by comparing its spectrum with spectra of known types. Call up the comparison star atlas by the following:
Go to File... Atlas of Standard Spectra...
Select "Main Sequence" from the list provided.

Note that the known spectral types are now plotted above and below the spectrum of HD 124320. The different types are also listed on the right hand side of the display window and can either be scolled through with the cursor or changed by using the up and down arrow keys. The names of the different spectral types shown are given as: O5V, B0V, B6V, A1V, A5V, F0V, F5V, G0V, K0V, M0V, M5V. This is only a small portion of the total range of spectral types ranging from hottest (O type) to coolest (M type). For each letter type, there is a range of numbers (0-9) which can be added to it so that the full list of spectral types looks like: O0V, O1V, O2V, O3V, O4V, O5V, O6V, O7V, O8V, O9V, B0V, B1V, etc. You can ignore the Roman numeral "V" at the end of the spectral type - this just indicates that the standard stars are main sequence stars.

Because the spectral types represent a sequence of stars of different surface temperatures two things are notable: the different spectral types show different absorption lines, and the overall shape of the continuum changes. The absorption lines are determined by the presence or absence of particular ions at different temperatures. The shape of the continuum is determined by the blackbody radiation laws. A blackbody is an idealized physical body that absorbs all electromagnetic radiation which hits it, regardless of frequency/wavelength or angle of incidence. One of these laws, Wien's Law, states that the wavelength of maximum intensity (λ_{peak}) is shorter (more blue) when the temperature of the object is hotter. This is described mathematically in the equation below, where λ_{peak} is in Ångströms and T is the temperature is Kelvin (K):

$$\lambda_{peak} = \frac{2.9 * 10^7}{T} \tag{1}$$

As you look through the different stars in the atlas, can you tell which spectral type is the hottest from the continuum and the location of λ_{peak}? Remember that the peak wavelength (color) and the temperature of a star are related to one another through Wien's Law. Record your answer and explain your reasoning on the handout (*From page 9, part a*).

If you scroll through the different spectral types, you should see that the peak of the spectrum shifts from around 3500Å for an O star to around 7000Å for an M star. This makes sense given that we know that O stars are blue and M stars are red. What spectral type shows a peak in the continuum intensity at $\lambda = 4200$Å? Record your answer (*From page 9, part b*).

Given that the peak wavelength of this star is $\lambda_{peak} = 4200$Å, what is the temperature of the star? Record your answer with appropriate units (*From page 9, part c*).

Now use the known spectral types to classify the star. When matching a spectral type to your unknown spectrum (HD 124320 in this case), you should compare the shapes and peaks of the continua to each other as well as the location and depths of the absorption lines. You can do this easily by changing the display of the spectra on your window:
Go to File... Display... Difference

The bottom panel graph will now change, showing the digital difference between the intensity of the comparison spectrum at the top and the unknown spectrum in the center, with zero difference being a straight horizontal line running across the middle of the lower panel. This will allow you to graphically compare the unknown spectrum to one of the known spectral types.

Look at the dips and valleys on this bottom panel and think about them for a minute. If an absorption line in the comparison star is shallower than the line at the same wavelength in the unknown star, then intensity at those wavelengths in the comparison star will be greater than those in the unknown. So the difference between the two intensities will be greater than zero, and the difference display will show an upward bump. If the top panel is showing an A0 spectra, for instance, and the middle panel HD124320, you should see a small bump at 3933Å, indicating that the absorption line in the unknown is deeper than that in the A0.

By the same reasoning, if an absorption line in the comparison spectrum is deeper than one in the unknown star, then the difference display will show a downward dip. Arrow down or scroll down to display an A5 comparison spectrum. Note that the 3933Å difference display now shows a dip, indicating that the absorption line in the unknown is shallower than that of an A5. So the correct spectral type of HD 124320 is somewhere in between A0 and A5.

To use the difference display, scroll through the comparison spectra until the difference between the comparison and unknown star is as close to zero at all wavelengths as possible. To estimate intermediate spectral types, watch to see when the display changes from bumps for some lines, to dips (Since some lines get stronger with temperature, and others get weaker, you will see some lines go from bumps to dips, and some from dips to bumps, as you change comparison spectra). Try to estimate whether the amount of change places the unknown halfway between those two comparison types, or if it seems closer in strength to one of the two comparison types that it lies between.

What is your estimate of the spectral type of HD 124320? Record your answer and explain your reasoning on the handout (*From page 10*).

4. Identifying Absorption Lines

You have used one or two spectral lines for making a refined classification. But what elements produced them? For reference, you will want to identify the source of the line you are looking at. You can do that by using the following table:
Go to File... Spectral Line Table

You will see a window containing a list of spectral lines. Using the mouse, point the cursor at the center of any absorption line in the spectrum (try the wavelength 4341Å) and click on it with the left hand mouse button. A red line should appear across the screen in the classification window and, if you've centered the crosshairs correctly, a double dashed line on the spectral line list will identify the absorption line at that wavelength. For instance, the line at 4341Å is a line from Hydrogen, "H I". Verify this.

Now identify the line at 3933Å and record your answer (*From page 11*).

Spectra are often displayed as black and white pictures showing the starlight spread out as a rainbow by a diffraction grating or prism. You can view spectra this way using the classification tool:
Go to File... Display... Grayscale Photo

You are now looking at a representation of what the spectrum might look like if you photographed it. To see the relation between the graphical trace and the photographic representation:
Go to File... Display... Comb. (Photo and Trace)

The center panel will show the photographic representation of HD124320, and the bottom panel a graph. Describe what the absorption lines look like in the photographic spectrum and in the graphical trace, record your answers (*From page 11*).

It is possible to classify stars by looking only at the photographs of the spectra (in fact that is the way it used to be done before computers and digital cameras came along). But you will want to use the trace display or the difference display for most of your work.

5. Classifying Unknown Spectra

You have now classified one spectrum. For the next, you do not have to reload the spectral atlas. To call up the next unknown spectrum:
Go to File... Unknown Spectrum... Next on List

Use the methods you have practiced above to classify the remaining 24 stars on the list. Remember that you can and should interpolate the spectral type of your unknown star when it does not completely match one of the types shown, i.e. choose A3 rather than A1 or A5. Under reasons, you should identify two or three of the prominent absorption lines which helped you identify the spectral type by using the Spectral Line Table. List only the element of the absorption lines (Ca II), not their wavelengths. If you choose to identify an unknown spectrum as a type not shown (like A3), you do *not* need to list the range of types (A0 to A5) along with the absorption line elements under the "Reasons" column.