Lab 06 CLEA The Classification of Stellar Spectra

Purpose

The purpose of this lab is to learn how to classify the spectra of main sequence stars.

Background: The History and Nature of Spectral Classification

Patterns of absorption lines were first observed in the spectrum of the sun by the German physicist Joseph von Fraunhofer early in the 1800's, but it was not until late in the century that astronomers were able to routinely examine the spectra of stars in large numbers. Astronomers Angelo Secchi and E.C. Pickering were among the first to note that the stellar spectra could be divided into groups by the general appearance of their spectra. In the various classification schemes they proposed, stars were grouped together by the prominence of certain spectral lines. In Secchi's scheme, for instance, stars with very strong hydrogen lines were called type I, stars with strong lines from metallic ions like iron and calcium were called type II, stars with wide bands of absorption that got darker toward the blue were called type III, and so on. Building upon this early work, astronomers at the Harvard Observatory refined the spectral types and renamed them with letters, A, B, C, etc. They also embarked on a massive project to classify spectra, carried out by a trio of astronomers, Williamina Fleming, Annie Jump Cannon, and Antonia Maury. The results of that work, the **Henry Draper Catalog** (named after the benefactor who financed the study), was published between 1918 and 1924, and provided classifications of 225, 300 stars. Even this study, however, represents only a tiny fraction of the stars in the sky.

In the course of the Harvard classification study, some of the old spectral types were consolidated together, and the types were rearranged to reflect a steady change in the strengths of representative spectral lines. The order of the spectral classes became O, B, A, F, G, K, and M, and though the letter designations have no meaning other than that imposed on them by history, the names have stuck to this day. Each spectral class is divided into tenths, so that a B0 star follows an O9, and an A0, a B9. In this scheme the sun is designated a type G2 (see Appendix I).

The early spectral classification system was based on the appearance of the spectra, but the physical reason for these differences in spectra was not understood until the 1930's and 1940's. Then it was realized that, while there were some chemical differences among stars, the main thing that determined the spectral type of a star was its surface temperature. Stars with strong lines of ionized helium (He II), which were called O stars in the Harvard system, were the hottest, around 40,000 K, because only at high temperatures would these ions be present in the atmosphere of the star in large enough numbers to produce absorption. The M stars with dark absorption bands, which were produced by molecules, were the coolest, around 3000 K, since molecules are broken apart (dissociated) at high temperatures. Stars with strong hydrogen lines, the A stars, had intermediate temperatures (around 10,000 K). The decimal divisions of spectral types followed the same pattern. Thus a B5 star is cooler than a B0 star but hotter than a B9 star.

The spectral classification system used today is a refinement called the **MK system**, introduced in the 1940's and 1950's by W. W. Morgan and P.C. Keenan at Yerkes Observatory to take account of the fact that stars at the same temperature can have different sizes. A star a hundred times larger than the sun, for instance, but with the same surface temperature, will show subtle differences in its spectrum, and will have a much higher luminosity. The MK system adds a Roman numeral to the end of the spectral type to indicate the so-called luminosity class: a I indicates a supergiant, a III a giant star, and a V a main sequence star. Our sun, a typical main-sequence star, would be designated a G2V, for instance. In this exercise, we will be confining ourselves to the classification of main sequence stars, but the software allows you to examine spectra of varying luminosity class, too, if you are curious.

The spectral type of a star is so fundamental that an astronomer beginning the study of any star will first try to find out its spectral type. If it hasn't already been catalogued (by the Harvard astronomers or the many who followed in their footsteps), or if there is some doubt about the listed classification, then the classification must be done by taking a spectrum of a star and comparing it with an **Atlas** of well-studied spectra of bright stars. Until recently, spectra were classified by taking photographs of the spectra of stars, but modern spectrographs produce digital traces of intensity versus wavelength which are often more convenient to study. FIGURE 1 shows some sample digital spectra from the principal MK spectral types; the range of wavelength (the x axis) is 3900 Å to 4500 Å. The intensity (the y axis) of each spectrum is normalized, which means that it has been multiplied by a constant so that the spectrum fits into the picture, with a value of 1.0 for the maximum intensity, and 0 for no light at all.

The spectral type of a star allows the astronomer to know not only the temperature of the star, but also its luminosity (expressed often as the absolute magnitude of the star) and its color. These properties, in turn, can help in determining the distance, mass, and many other physical quantities associated with the star, its surrounding environment, and its past history. Thus a knowledge of spectral classification is fundamental to understanding how we put together a description of the nature and evolution of the stars. Looked at on an even broader scale, the classification of stellar spectra is important, as is any classification system, because it enables us to reduce a large sample of diverse individuals to a manageable number of natural groups with similar characteristics. Thus spectral classification is, in many ways, as fundamental to astronomy as is the Linnean system of classifying plants and animals by genus and species. Since the group members presumably have similar physical characteristics, we can study them as groups, not isolated individuals. By the same token, unusual individuals may readily be identified because of their obvious differences from the natural groups. These peculiar objects can then be subjected to intensive study in order to attempt to understand the reason for their unusual nature. These *exceptions to the rule* often help us to understand broad features of the natural groups. They may even provide evolutionary links between the groups.

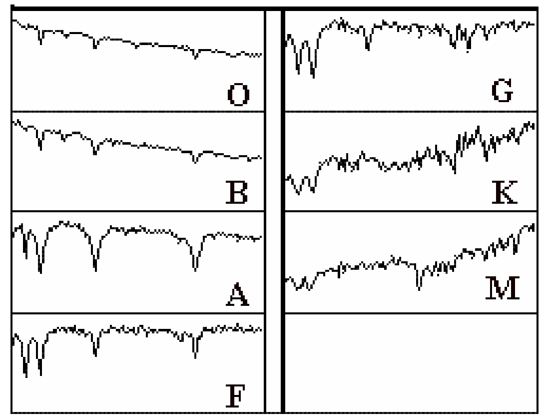

Figure 1
Digital Spectra of the Principal MK Types

The appendices to this manual give the basic characteristics of the spectral types and luminosity classes in the MK system. But the best way to learn about spectral classification is to do it, which is what this exercise is about.

<u>Part I: Spectral Classification of Main-Sequence Stars</u>

In this part of the lab you will become familiar with the appearance of main sequence stars and learn how to classify their spectra by comparing a spectrum with an atlas of spectra of selected standard stars.

Method

You will examine the digital spectra of 8 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 with a representative atlas of 13 standard spectra and by looking at the relative strengths of characteristic absorption lines.

Procedure

1. Position the cursor over the **File**…and then **LogIn...** on the menu bar at the top of the logo screen to activate the Student Accounting screen. You should enter your first and last name.
2. Select **File – Run - Classify Spectra** function from the menu. Answer **no** to any questions the computer may about stored spectra
3. Display the spectra of a practice *unknown* star by selecting **File - Unknown Spectrum - Program List**. A window will appear displaying a list of practice stars by name. Highlight the first star on the list — **HD124320** — by clicking the left mouse button (it will be highlighted already), and then click on the **OK** button.

4. Find the spectral type of HD 124320 by comparing its spectrum with spectra of a known type. Call up the comparison star atlas by selecting the **File…Atlas of Standard Spectra** option. A window will open up displaying numerous choices. Click on **Main Sequence**.

   a. **As you look through the stars in the Atlas, can you tell from the continuum which spectral type is hottest? Identify the hottest spectral type? ____________________.**

   b. **What would be the temperature range of this star? (See Appendix I) ____.**

5. Use the comparison spectra to classify the star. If neither of these looks quite like a match to your unknown star, you can move through the Atlas by clicking on the button labeled **down** located at the upper right of the spectrum display.
6. Because not all spectral types are represented in the Atlas, and because you want to get the classification precise (i.e. G2, not just G), you may have to do some interpolation. Look at the relative strengths of the absorption lines to do this. For your unknown star, for instance, you should note that it looks most like an A1 type star, but not quite. When the top panel shows an A1 comparison star, the bottom panel will show an A5 star. The strength of the absorption lines in HD124320 lies somewhere between these two. You can therefore make an educated guess that it is about A3.
7. If you want to do this in a more quantitative fashion, click on the button labeled **difference** to the right of the spectrum display.
8. 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 absorption line you are looking at. Select the **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 4341) and double click the left-hand mouse button. A double dashed red line on the spectral line list will identify the element at that wavelength.
9. You have now classified one spectrum. Call up the next unknown spectrum by pulling down the **File…Unknown Spectra…Next in List**. You do not have to reload the spectral atlas. Use the methods you have practiced above to classify the remaining 7 stars on the list. Use the data table to record your results and list the elements that create the three strongest absorption lines.

Data Table: Practice Spectral Classification

Star	Spectral Type	Absorption lines that match
HD124320		
HD 37767		
HD 35619		
HD 23733		
O1015		
HD 24189		
HD 107399		
HD 240344		

Part II: Taking Spectra Using A Simulated Telescope And Digital Spectrometer

In this part of the lab you will learn how to take spectra of stars and to use the spectra to classify the stars. You will then use the spectral classification of a main sequence star, along with its apparent magnitude, to determine its distance; this is called the *Spectroscopic Paralla*x method.

Method:

You will use a simulated telescope equipped with a photon-counting spectrograph, to obtain spectra of an unknown star. You will save the spectrum and, using the techniques learned in Part I, determine its spectral class. Then, using a table of the absolute magnitudes of stars versus spectral class (Appendix II), and a measure of the apparent magnitude, you will calculate the distance of the star in parsecs.

Procedure:

1. If you are in the Classification Tool, select **File — Return – Exit classification window** in the menu bar. Now choose **File – Run - Take Spectra**. In a few moments you will see a simulated telescope control panel with a dialog box telling you what type of telescope you have control of during your observing session. It is realistic in many of its fundamental functions and will give you a good feeling for how astronomers collect and analyze spectroscopic data. The following directions will familiarize you with the telescope and how it is used to take spectra.

2. The screen you see shows a control panel and a monitor window, which shows you the view through a TV camera attached to a telescope. Notice that the dome status is **closed** and the tracking status is **off**. The dome shutters, in the center of the screen, block out the light of the nighttime sky.

3. To begin our evening's observations, first open the dome by clicking on the **dome** button. If you look at the view in the monitor for a few moments, you will see that the stars are drifting to the right (westward) in the field. This is due to the rotation of the earth, and is very noticeable due to the high magnification of the telescope. It is even more noticeable in the spectrometer view, which has even higher magnification. In order to have the telescope keep an object centered and to collect data, we

need to turn on the drive control motors on the telescope. We do this by clicking on the **tracking** button. The telescope will now track the stars. You will note that they now appear to remain stationary in the field of view.

4. Move the telescope to position a star in the center of the viewing screen.

5. When the star is roughly centered in the view screen, you can center it more precisely by clicking on the **Change View** button to see a magnified view. The display will switch to the *instrument* view, which is 15 arc minutes on a side. It is harder to recognize objects in this view, since it is so magnified, and you will later want to go back to the wider *finder* view when you try to locate other objects. But all spectrum measurement must be taken when the telescope monitor is in this magnified *instrument* mode.

6. Now, before you have gone any further, record the coordinates of the star below so that you and your instructor can identify which one you are viewing. The coordinates appear on the telescope control panel to the left of the view monitor.

Star 1:

Right Ascension ___________________

Declination ___________________

7. If you have positioned the telescope, you are ready to take a spectrum. Click on the **Take Reading** button to the right of the view screen. The spectrometer window now opens. Click on **Start Count** and let ten seconds elapse. Click the **Stop Count** button. The computer will connect the dots representing the intensity at each wavelength to give you a trace of the spectrum. Record the apparent magnitude of the star.

Apparent Magnitude ___________________

8. You now want to save the spectrum so that you can classify it using the classification tool. Click on the **Save** option on the menu bar. A window will open asking you to assign a number to the star. Enter the object number located in the lower left hand corner of the spectrometer window, and click **OK**. The computer will now assign a name to the spectrum file based on the first letters of the name you logged in with and the number you just gave. Write the file name of the file below, just for your records, and click **OK** to save the file.

File name for first star spectrum: ___________________________

9. You can return to the telescope by choosing the **Return** option on the spectrometer menu bar. You now have seen how to take spectra and save them. Choose another bright star (you will have to return to the finder field to do so) and obtain and record its spectrum as star number 2.

Star 2:

Right Ascension ___________________

Declination ___________________

Apparent Magnitude ___________________

File name for second star spectrum: _____________________

10. When you are done taking and storing the spectra, you can call up the classification tool once again by selecting the **File – Run -Classify Spectra** option from the telescope menu bar.
11. To see the spectra you have just taken, choose the **File - Unknown Spectra - Saved Spectra** menu item. Classify both stars you observed.

Spectral Type of Two Unknown Stars

Star #	Name	Spectral Type
1		
2		

Appendix I

Distinguishing Features Of Main Sequence Spectra

SPECTRAL TYPE	SURFACE TEMP (° K)	**Distinguishing Features** (absorption lines unless noted otherwise)
O	28-40,000	He II lines
B	10-28,000	He I lines; H I Balmer lines in cooler types
A	8-10,000	Strongest H I Balmer at A0; CaII increasing at cooler types; some other ionized metals
F	6000-8000	Ca II stronger; H weaker; Ionized metal lines appearing
G	4900-6000	CaI II strong; Fe and other Metals strong, with neutral metal lines appearing; H weakening
K	3500-4900	Neutral metal lines strong; CH and CN bands developing
M	2000-3500	Very many lines; TiO and other molecular bands; Neutral Calcium prominent. S stars show ZrO and N stars C2 lines as well.
WR (Wolf-Rayet)	40,000+	Broad emission of He II; WC stars show CIII and CIV emission, while WN stars show NII prominently