Lab #9:
Project CLEA's Classifying Stellar Spectra

April 25, 2011

Objectives:

To acquire good signal-to-noise data.
To determine the spectral type of stars from their spectra.
To determine distances using spectroscopic parallax.

Equipment:

Project CLEA's "Classification of Stellar Spectra" program
Calculator

Introduction: 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 1800s, 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 Secchis 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.

The early spectral classification system was based on the appearance of the spectra, but the physical reason for these differences in spectra were not understood until the 1930s and 1940s. 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 (HeII), which were called O stars in the Harvard system, were the hottest, around 40,000K, 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 3000K, since molecules are broken apart (dissociated) at high temperatures. Stars with strong hydrogen lines had intermediate temperatures (around 10,000K). 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 1940s and 1950s 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: an I indicates a supergiant, an 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 hasnt 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. 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.

Procedure

Part I

1) In the Astr 101 folder on the desktop, click on “CLEA_SPE - shortcut”.

2) In the program that pops up, click on “Log In...”, enter your names (ignore table number), and click “OK”.

3) Click on “Run” and select “Take Spectra”.

4) On the left side, there are controls for the “telescope.” You’ll notice that the dome is closed, so go ahead and click “Dome” to open it.

5) Next, you’ll notice that the stars are slowly panning across your field of view. This is due to the Earth’s rotation, so you’ll need to select “Tracking” to toggle it on.

6) Now you want to find a star. First, click on “Field” and then select “Field 1” in the pop-up window, and click “OK”. The “Monitor” button has two settings: “Finder”, which will show you a large view of the sky, and “Instrument”, which will show you the slit of your spectrometer. Toggle this button a few times to see what it does.

7) Use the “Set Coordinates” button to enter the coordinates of a star from the list in the appendix. The telescope will then slew to the right coordinates. If you are in “Finder” mode, you can then use the “NSEW” buttons to center up the star in the slit. MAKE SURE IT IS CENTERED WELL! This will make your exposure times much shorter. You can change the speed at which the telescope moves by toggling the “Slew Rate” button, where 1 is very slow, and 16 is very fast.

8) Once you have the object lined up, click on "Take Reading" on the right side of the window. This brings up a window with Relative Intensity on the y-axis, and Angstroms on the x-axis.

9) Click on "Start/Resume Count" to begin acquiring your spectrum. Watch the "Signal/Noise:" ratio in the the bottom right of the window. You want a signal to noise (S/N) of AT LEAST 25, otherwise the spectral features will be difficult to see. Higher signal to noise is always better, but some of the objects are dim enough that it might take a very long exposure to even get the S/N of 25. When you have reached S/N of 25+, click on "Stop Count" to stop the exposure. **MAKE SURE THE OBJECT ID MATCHES WHAT'S GIVEN IN THE TABLE!** (You may want to stop the count to check the Object ID, and then resume the count to get the desired S/N.) Then click on "Save" to save your spectrum. Give the ID number in the star list in the appendix as the **Spectrum ID**, then click "OK". Click on "OK" when it tells you what the spectrum will be saved as and note the name of the file. **RECORD THE APPARENT MAGNITUDE** (listed on the lower left) in your chart in the appendix. You will need this for part III of the lab. Then click on "Return" to return to the data acquisition window. ("Return" may be greyed out, but if you click it, it should still work.)

10) Repeat steps (7) through (9) for all 8 stars on the list in the appendix. Remember to record your apparent magnitudes! NOTE: Do not rely on previously saved data. I have scrambled the object list for each lab section!!

Part II 1) The next step is to classify your spectra. To do this, select "Run" from the menu, then "Classify Spectra".

2) Then select "Load", "Unknown Spectra", "Saved Spectra", and your objects should show up as ".CSP" files. Select a saved file. Next, from the "Load" menu, select "Atlas of Standard Spectra" to load the list of stars with known spectral types. You want to load the "Main Sequence" spectral atlas. Also load the "Spectral Line Table". If you then zoom in on some of the features and click on the very minimum intensity, this will tell you what ion is causing the feature.

3) In the "Classify Spectra" window, click on the "Up" and "Down" buttons to scroll through the standards. The display shows your unknown object in the middle, with a known standard above and below. See that button labeled "Difference"? This will be a good friend to you. Click on it to toggle the bottom spectrum between a standard spectrum ("Difference" is off) and the difference between the standard shown above your unknown spectrum and your unknown ("Difference" is on). Use "Difference" off to try to find a couple spectra that look similar to your unknown, and then switch to "Difference" on to see how well the spectrum you chose fits the unknown. Clearly, you want "Difference" to look as flat as possible. If you're having trouble deciding, don't forget to go back to the "Difference" off option, which might help you decide.

4) When you have decided on a spectral type, RECORD YOUR SPECTRAL TYPE in the chart in the appendix.

5) Repeat steps (2) through (4) for all 8 stars on your list.

6) Now, open the spectrum again for one of your stars that you identified as an A1 or A5 star. Scroll through the standards until you are comparing your A star with an O5 star. Note which of the two has a stronger (i.e. deeper relative to the continuum) line at 4340.48 Angstroms (due to HI). Also note any other obvious differences you see between the general shapes of the two spectra and roughly where the continuum of each spectrum peaks. You will use your notes to answer questions in Part III.

7) Now scroll down through the standards to compare your A star to an M0 star. Again, note which of the two spectra have the stronger line at 4340.48 Angstroms, as well as the continuum peaks and any obvious differences between general shapes of the two spectra, for the questions in Part III. Once you have made your notes, you are finished with the program. Please remember to quit from the program once you are finished!

Part III

1) Use the distance modulus to find the distances to your 8 stars, using the absolute magnitudes given in the chart in the appendix and the apparent magnitudes you recorded from your spectra.

Questions

1) What differences did you notice between the A star spectrum, the M star spectrum, and the O star spectrum? Which of the three spectra had the strongest HI line at 4340.48 Angstroms?

2) Rank the three stars mentioned in Q1 in order of temperature, hottest to coolest, and **support your answer based on the appearance of the spectra** (NOT using what you know about the order of the spectral type sequence).

Write-up

Your write-up should include:
1) Your completed chart from the appendix
2) Your distance calculations
3) Your answers to the Questions section

Appendix: Data Chart							
Spectrum ID	Object ID	RA (h:m:s)	Dec (d:am:as)	Spectral Type	m (mag)	M (mag)	Distance (pc)
001	379	6:18:40	31:56:17			1.5	
002	220	6:23:11	34:54:35			7.8	
003	363	6:10:58	34:44:04			-2.5	
004	462	6:17:59	31:22:38			5.2	
005	39	6:14:23	32:41:14			5.8	
006	494	6:14:26	32:29:20			6.8	
007	72	6:14:41	33:20:46			3.8	
008	52	6:21:03	32:03:54			1.5	

Appendix: Data Chart							
Spectrum ID	Object ID	RA (h:m:s)	Dec (d:am:as)	Spectral Type	m (mag)	M (mag)	Distance (pc)
001	462	6:17:59	31:22:38			5.2	
002	363	6:10:58	34:44:04			-2.5	
003	494	6:14:26	32:29:20			6.8	
004	52	6:21:03	32:03:54			1.5	
005	379	6:18:40	31:56:17			1.5	
006	39	6:14:23	32:41:14			5.8	
007	220	6:23:11	34:54:35			7.8	
008	72	6:14:41	33:20:46			3.8	