Spectroscopy CLEA Lab Olszewski and Rigby
Astronomy 203, Fall 2003 Due: _____________

You may work on this lab alone, or with 1 partner. If you work as a pair, turn in <u>only</u> 1 writeup for your group.

Background:
We've talked about how stars have different colors, which means that they have different temperatures (the Wien law). In the spectroscopy lab, we looked at the "spectra" (light spread out into different colors/energies) of continuous spectrum sources, emission lines, and absorption lines. Now we'll apply what we learned by squinting through spectroscopes to the problems of what stars are made of and how stars work.

The spectrum of a star is basically a continuous spectrum (light of many colors) since the star's a hot, thick gas. Added to that spectrum are absoprtion lines (less light than usual) and in certain types of stars, emission lines (more light than usual.) The basic color of the star tells you how hot it is, and the spectral lines tell you what elements the star is made of, and how dense the star is.

In this lab, you'll use a computer simulation to find stars in the sky, steer a telescope toward them, and take spectra on the computer, in order to figure out what kinds of stars they are. Are they main sequence stars, giants, or supergiants, and how massive are they?

First, a bit of history.

In 1817, Fraunhofer discovered that if you spread sunlight out into a rainbow ("look at the sun's sectrum"), there are bands ("lines") of missing light. People had also noticed that if you threw elements like calcium, sodium, magnesium, and iron into a fire, and took a spectrum of the fire, you'd get the same bands of missing light. So the bands in stellar spectra were presumably related to these elements. But why were the strongest lines in the sun from calcium? Did this mean the sun was made of calcium? Why did other stars have extremely strong lines of hydrogen, and others of titanium oxide (fighter-jet material)?

To address these questions, in the 1890s Harvard astronomer Annie Jump Cannon analyzed the spectra of 200,000 stars (!), and sorted them by the strength of the hydrogen lines. Because she re-arranged an existing classification sequence, the order became (hot) O B A F G K M, (cool) (memorable as "Oh be a fine girl/guy kiss me").

It turns out that the Harvard classification scheme sorts stars by temperature. That's why we still use it. Hot stars are types O or B; cool stars are K or M. (The sun is G2 star.) But no one really understood the stars' spectra. What was different between an O star and a K star? Why does Vega have strong hydrogen lines and weak calcium lines, whereas the sun has just the opposite? Are the sun and Vega made of very different stuff, or do they just look different because they're at different temperatures, or is something else entirely going on?

Along came Cecelia Payne's 1925 Ph.D. thesis, widely considered the most brilliant ever in astronomy. She realized that stars have different spectral mostly because they're at different temperatures. Using the strength of the spectral lines in different types of stars (and lots of math), she calculated the abundances of 18 elements in stars. She was the first person to realize that stars are mostly made of hydrogen. She showed that though metals like iron and calcium have strong lines in stars at certain temperatures, they were minor ingredients. (Her thesis advisor thought this section was too bold, and made her tone it down.)

Another variable affecting the spectrum is the density of the star -- how puffy is the star? Is the star dense/small/dim like a main sequence star, or puffy/large/bright like a red giant? The width of the spectral lines helps diagnose this. The classification scheme is: V = dwarf; IV = subgiant; III = normal giant; II = bright giant; I = supergiant. (Stars on the main sequence are dwarfs = type V; red giants are type III.)

So astronomers use a star's spectrum to determine how hot and how dense it is, and call this a "spectral type." As we'll discuss in class, a star's spectral type tells you its history and its fate. Powerful tools, spectra!

ENOUGH BACKGROUND. ON TO THE LAB.

This is a computer-based lab. Try it out early to make sure you can complete it by the due date. If you have trouble, **come to office hours** or schedule an appointment. Earlier is better.

STARTING THE PROGRAM

Go to the Integrated Learning Center, and get on a Windows machine. Open the "**Courses**" folder, and select “**Stellar Spectra.**” Choose **File, Log In** to login to the program. File in your name(s).

There are two parts to the computer simulation. One is a spectrum-classification tool -- you'll use it to compare the spectrum of an unknown star with spectra of "standard stars" of known spectral type. The other tool simulates what it's like to take spectra at a telescope. You'll steer a simulated telescope to several stars, and aim the spectrometer (= device for collecting spectra, basically a prism and a camera) at the stars. You'll see the spectrum develop as the telescope collects photons from the star. You'll then use the spectrum-classification tool to figure out what kind of stars they are.

PART 1 OF THE LAB:

Now you'll take (and save!) spectra at the simulated telescope, which you'll classify in the next section.

From the **File** menu, choose **Run** and then **Take Spectra**. A telescope control panel will appear, and you'll also see an image from a TV camera mounted on the telescope, looking at the sky.

To begin the night's observing, click **Dome** to open the dome.

The stars are drifting across your view because the Earth is turning. Click **Tracking** to make the telescope compensate for this motion and track the stars.

From the **Field** menu, select “**Field 1**”. **IF YOU OMIT THIS, THE WHOLE LAB MAY BE WRONG!**

HERE ARE YOUR TARGETS:

	RA	**DEC**	**filename**	**Spectral Type**
STAR 1	06 12 19.5	33 58 03.0		
STAR 2	06 09 51.0	32 33 32.4		
STAR 3	06 02 34.2	32 24 16.5		
STAR 4	06 01 00.6	33 12 35.4		
STAR 5	06 10 17.5	32 31 40.0		
STAR 6	06 16 06.8	32 05 18.2		
STAR 7	06 15 18.2	34 49 21.1		

Use the **N, S, E**, and **W** buttons to center your star in the field.

Click **Change View** to see a magnified view. Use the **N,S,E,W** buttons to put the slit OVER your star. This way, the star is positioned so that light can travel down the telescope to the spectrograph and make a spectrum.

Click **Take Reading**. Click **Start/Resume** to start taking a spectrum. The spectrograph will start recording photons, and you'll see the spectrum forming. When the spectrum looks good (S/N > ~30) click **Stop Count**.

Save your spectrum! Click on **Save** in the file menu, give it a unique name. Then click okay. **WRITE DOWN that name** in the above table. You will need this spectrum later!

Click **RETURN** to return to the telescope. Repeat this proceedure to take spectra for all seven stars.

PART 2 OF THE LAB:

In this part, you'll use the Spectral-Classification tool to classify the stars you observed in Part 1. ("Classify"=figure out what kind ofstars they are.)

Select "**Classify Spectra**" from the **File, Run** menu.

You are now in the classification tool. The screen has 3 panels: the center panel will display the spectrum of an UNKNOWN star; the top and bottom panels will display the spectra of standard stars which you'll compare to the unknown spectrum.

To load the stars you took at the telescope, select **File, Unknown Spectra, Saved Spectra**. Load the first star you observed with the telescope simulation.

Select **File, Atlas of Standard Spectra**. A window with many options will appear. You will choose various atlasses and scroll through them, in order to find a good match to the stars of unknown type that you observed at the telescope.

The atlas spectra will come up in a separate window, but only 4 can be seen at any time. Use the scrollbar to see all the atlas spectra. 2 comparison spectra will also appear in the top and bottom panels of the main display (above and below the unknown spectrum.) Click the **UP** and **DOWN** buttons to scroll through the catalog and compare to the unknown star. You'll want to compare the general shape of the spectrum, as well as the width and depth of the absorption lines.

Once you're sure of the classification, **record your results** through the menu option **Results, Record**. Also write them down in the table from 2 pages previously in the lab.

When classifying, you may have to interpolate: if the spectrum looks partway between an A2 and an A6, you may decide it's an A4 (midway between the two), or an A5 (almost an A6, but a little like an A2), etc.

PART 3: Short writeup.

1. In one sentence per star, describe each star you examined. For example:

Star #0 is a G3V, so it is similar to the sun, on the main sequence, and has a lifetime several billion years.
Star #-1 is a K3 III, so it is a red giant, close to death.

2. In the spectra you took, you should have noticed that the absorption lines of hydrogen (at 6563 and 4861 Angstroms) varied in strength for stars of different types. In **one typed paragraph**, describe how the hydrogen-line strength changes with spectral type (O through M), and explain why. The table below (relating spectral type to surface temperature) may help.

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