Lab 2: Spectral Classification

Introduction

Classification lies at the foundation of nearly every science. Scientists develop classification systems based on perceived patterns and relationships. Biologists classify plants and animals into subgroups called genus and species. Geologists have an elaborate system of classification for rocks and minerals. Astronomers are no different. We classify planets according to their composition (terrestrial or Jovian), galaxies according to their shape (spiral, elliptical, or irregular), and stars according to their spectra.

In this exercise you will classify six types of stars by repeating the process that was developed by the women at Harvard around the turn of the 20th century. The resulting classification was a key step in elucidating the underlying physics that produces stellar spectra. Thus, in astronomy as well as biology, the relatively mundane step of classification eventually yields critical insights that allow us to understand our world.

Procedure

Part 1: Examine Stellar Spectra

Examine each of the panels in the handout provided.

1. Describe these spectra. Are there deep absorption lines? Broad absorption lines? Are all the lines in a panel about the same depth? Do the spectra all peak at the same wavelength in a given panel? In different panels? Describe the spectra in each panel, including any other features you might note.

2. The lines at about 4340 and 4860 angstroms are critical lines for classifying stars. These are two of the Balmer lines of hydrogen, in which the electron in a hydrogen atom is making a transition up from the second energy level to a higher level. Put the panels in order of strongest to weakest Balmer lines. Assign the strongest panel the letter A, next strongest B, next F, K, M, and the weakest O.

3. What is the peak wavelength (λ_{max}) of the continuum emission in each panel?

4. To find out what the actual temperature is, we need one more step. Using the peak wavelength (λ_{max}) of the spectral type from step 3, and the following formula (Wien's Law), find the temperature of the star with the strongest Balmer lines.

$$\lambda_{max} = (2.9\text{x}10^7\,\text{Å}\text{x}\text{K})/T$$

where λ_{max} is in angstroms, and T is in Kelvin. Calculate the stellar temperature for each panel of stars.

5. Which panel has the hottest stars? Which panel has the coolest stars? Put all the panels in order of hottest to coolest stars.

6. Are your lists from step 2 and step 4 the same? In what order should the letters go now? This is the famous M-K classification scheme. Originally, the spectra were ordered by the strength of the lines. Then it was discovered that the strength of the lines could also tell you something about the temperature of the star, and the classes were re-ordered.

7. What is the temperature at which the Balmer lines are the strongest? What happens to the Balmer lines at higher temperature? What happens to the Balmer lines at lower temperature?

8. But why do O stars and K stars BOTH have weak lines? To answer this, we need to know more about absorption lines. Absorption lines occur when an electron absorbs energy from the spectrum to move up the energy levels in the atom. Since hydrogen has only one electron, this electron is usually in the ground state. But as the temperature rises, the average electron gains more energy from collisions with other atoms, moving up to the second energy level, then the third, and so on. If the gas is hot enough, the electrons leave the atom entirely, so that it becomes ionized. There is a particular temperature at which the average electron will be in the second energy level. At this temperature, there are LOTS of atoms which can absorb Balmer line photons from the spectrum, and therefore stars of this temperature will have the strongest Balmer lines. Which spectral class corresponds to this temperature?

Part 2: Classify Spectra

Work with your group at one of the lab computers. The login password is: astroiscool

Go to http://cas.sdss.org/dr6/en/tools/getimg/plate.asp

SDSS is the Sloan Digital Sky Survey, a photographic survey of a quarter of the sky. It was intended for cosmological studies and so for as many galaxies as they could see (above a limiting magnitude) they took spectra of them. Additionally, in each plate, they took spectra of a few stars. We will be classifying these stellar spectra using everything we just learned!

Each plate is a different image of the sky that they took spectra for. Pick a plate at random, and at the bottom you will find the spectra for the stars. Find three stars with different colors, and record the following information in a table in your lab notebook: star color, RA, DEC, ObjID, peak wavelength, and a description of the Balmer lines.

Now calculate the temperature for each star, and assign a classification! Make a second table with each star's temperature, classification and a justification for the classification.

Part 3: H-R Diagram

Now we will explore the relationship between temperature and stellar luminosity, using what we have learned this lab and last lab. You will be given a table with information on twelve bright stars. Calculate the distance to each star. Then using the distance, calculate the absolute magnitude for each star using the distance modulus equation:

$$M - m = -5\mathrm{Log}(d/10pc)$$

A temperature is given for each star in the table. These temperatures were determined in the same way you determined temperature in Parts 1 and 2.

Plot temperature vs. absolute magnitude for each star. Describe your graph. Do you notice any patterns or features? This graph is called a H-R diagram and gives us a lot of information about the properties of stellar populations. We will explore this next lab.