Name: ______________________________

Partner(s): ___________________________

Why is Classification Important?

Classification lies at the foundation of nearly every science. In many natural sciences, one is faced with a bewildering degree of complexity in the subjects of one's study. However, by sorting objects into distinct classes, patterns and relationships can be revealed, suggesting an underlying order. For example, biologists have classified plants and animals into genus and species and through these classifications have discovered evolutionary connections among different life forms. Geologists likewise have an elaborate system of classification for rocks and minerals, which helps them to constrain the formation mechanisms for various materials. Astronomers are no exception. They classify planets as terrestrial or Jovian, galaxies as spiral, elliptical or irregular, and stars according to the appearance of their spectra.

In this exercise, you will study the method that astronomers use to classify stars by their spectra. The resulting classification was a key step in elucidating the underlying physics that produced stellar spectra. Thus, in astronomy as well as biology, the relatively mundane step of classification eventually yields the critical insights which lead to breakthroughs in understanding.

The Spectra of Stars

A spectrum of a star is produced by photons emitted from its very outermost layers. Photons emitted from further within the star interact frequently with the dense stellar material, and can not "escape" before being absorbed or redirected. Thus, we never see these inner photons, and *only* observe photons emitted from the star's more tenuous "atmosphere". This is similar to what would happen to someone trying to observe the Earth from outer space. They could never "see" below the ground, because the Earth was too dense, and could only observe light emitted in the atmosphere[1]. Technically, we say that the inner parts of a star (or the Earth) are "opaque", or "optically thick", and that only the atmophere is "transparent" or "optically thin".

Almost all stellar spectra consist of a broad, smooth distribution of photons of different wavelengths, known as "continuum emission", with many absorption lines superimposed, changing the featureless smooth continuum spectrum into a much more complex one. The continuum emission is dominated by thermal radiation, which you have studied in a previous lab. Thermal radiation is produced by the interactions between the moving particles in a star's atmosphere and photons. The exact shape and amplitude of the thermal spectrum

[1]Note that this is not an exact analogy, since the Earth is solid, and stars remain gaseous all the way to the center.

depends on the temperature of the star's atmosphere (i.e. how fast the particles in the atmosphere are moving).

While the spectrum of black body radiation is smooth, the actual spectrum of a star is much more complicated. Many absorption lines remove light from the underlying black body spectrum at specific wavelengths. These wavelengths depend on the exact ions, atoms, and molecules that exist in a star's atmophere, and thus the pattern of absorption lines reveals the chemical content and physical state of the star's atmosphere (e.g. are there many heavy elements in the star? is the atmosphere hot and mostly ionized, or cool and mostly molecular?). The absorption lines are produced when electrons in atoms and/or ions absorb individual photons from the smooth continuum that happen to have exactly the energy needed to boost a bound electron to a higher energy level. This removes light from the continuum, and leaves behind a dark region in the spectrum. These absorption lines are very narrow in wavelength, meaning they only remove photons at very specific wavelengths. However, sometimes there are so many absorption lines in a spectrum that it is difficult to see individual lines, and instead the spectrum has large jagged dark regions made from the superposition of many many different absorption lines from many different elements and ions. In some very cool stars (cooler than 3,000 K), the absorption lines are produced by entire molecules absorbing photons, rather than electrons in atoms.

Why do Spectra of Stars Vary?

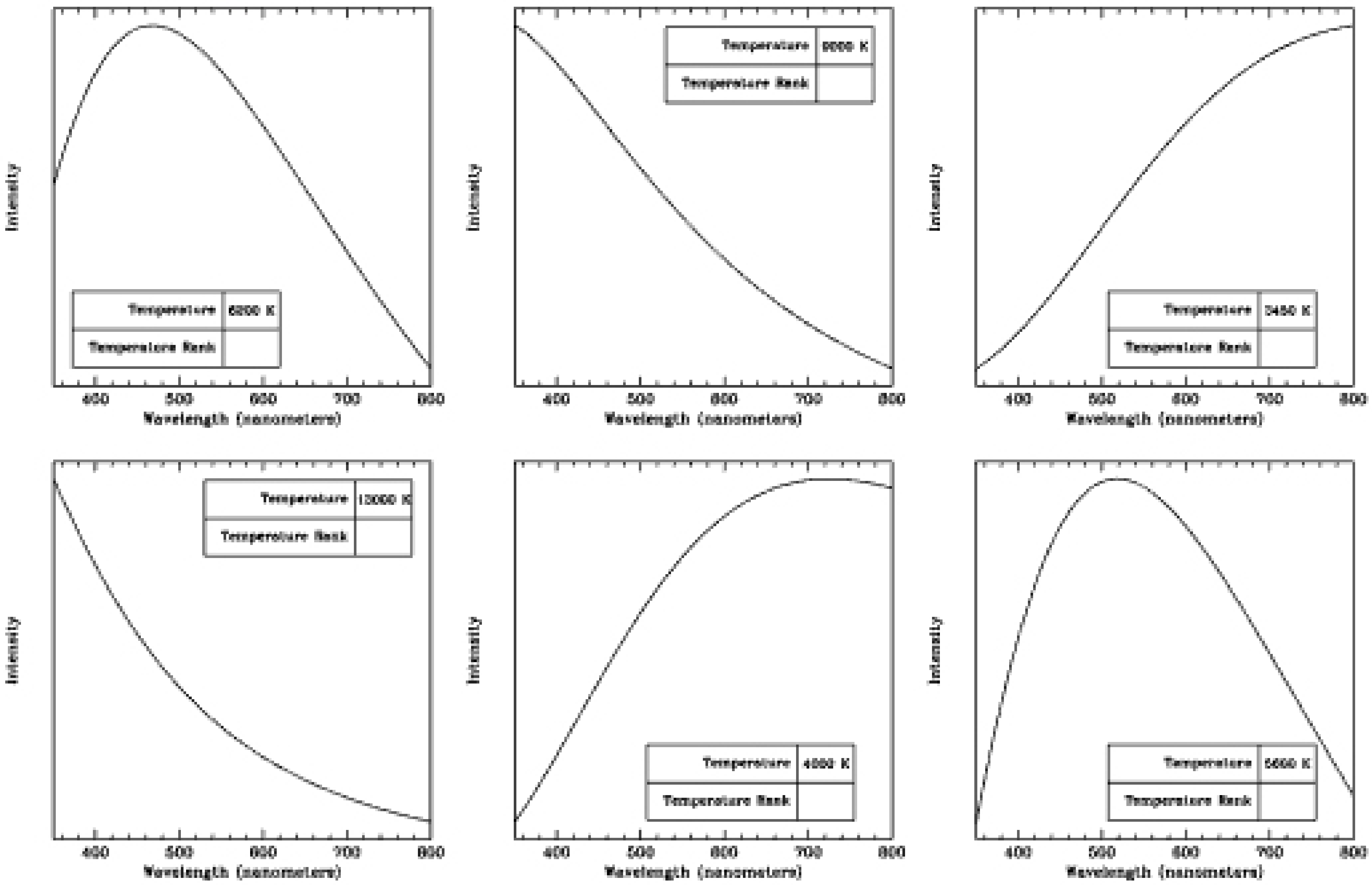
Stars come in a wide range of sizes and temperatures. The hottest stars in the sky have temperatures in excess of 40,000 K, whereas the coolest stars that we can detect optically have temperatures of only 1,000-1,500 K. The appearance of the spectrum of a star is very strongly dependent on its temperature. The temperature changes the shape of the underlying thermal continuum as well as the kinds of ions, atoms, and molecules which can exist in a star's atmosphore. For example, the very hottest stars (called O-type stars) show absorption lines due to ionized helium (He II) and doubly or even triply ionized carbon, oxygen or silicon. On the other hand, the coolest stars (M-, L-, and T-type) show lines produced by molecules like Titanium Oxide (TiO).

Procedure

This lab teaches the basic techniques and criteria of the Morgan-Keenan system of spectral classification. You will put several stars in a temperature sequence, first using the shape of the continuum, and then using the strength of the absorption lines. You will then use these observations to classify the stars.

Estimating Temperature from the Shape of the Thermal Radiation Spectrum

The plots below show how the spectra of objects of different temperatures would appear at optical wavelengths. Each curve shows a "thermal" or "black-body" radiation spectrum, for different temperatures.



1 (1pt). A thermal spectrum should always have a peak. Why don't you see a peak in all of these plots?

2 (2 pts). Rank these spectra from hottest to coolest. Label the spectrum with the highest temperature with a "1", the next hottest with a "2", etc.