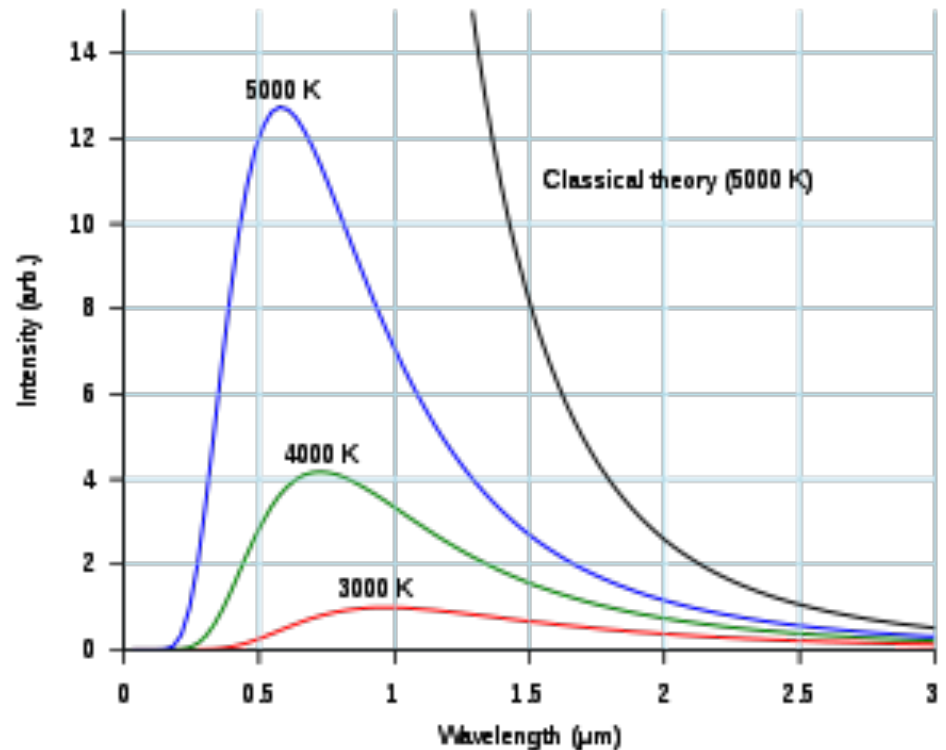# BLACK BODY RADIATION

In theory, it is possible to envision an object that absorbs all frequencies of electromagnetic radiation that falls on it. That means it wouldn't transmit or reflect any frequencies, looking black at low temperatures. Such a body would, though, produce emitted radiation due to thermal agitation within the body. This temperature-dependent spectrum is called "black body radiation."

No object is a true black body radiator as there are no physical object that absorb all frequencies of electromagnetic radiation. On the other hand, all objects do produce a thermal, black body radiation curve (this is the radiation curve produced by the object if it didn't additionally produce radiation at other frequencies due to absorption and emission).

1.)

What's interesting is that with the exception of intensity and peak frequency, the black body radiation curve for one object at one temperature will look just like the black body radiation curve for another object at another temperature. The only two differences will be that higher temperature objects will have black body curves whose *intensity* is higher, and higher temperature objects will have black body curves whose peak frequency has shifted toward the higher frequency end (the high energy end) of the overall E/M spectrum (note that this is the *lower end* of the wavelength scale). From Wikipedia, the graphic to the right shows these characteristics:
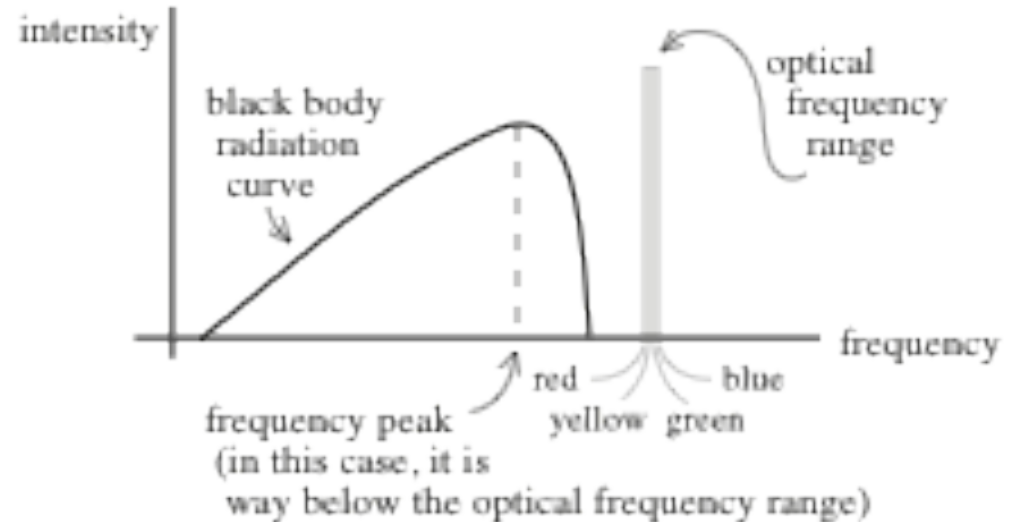

2.)

For the amusement of it, the frequency blackbody radiation curve for a rock is shown to the right, and the wavelength version of that same situation is shown below:

Note 1: It has been experimentally determined that the peak wavelength of an object's blackbody curve is related to its temperature as:
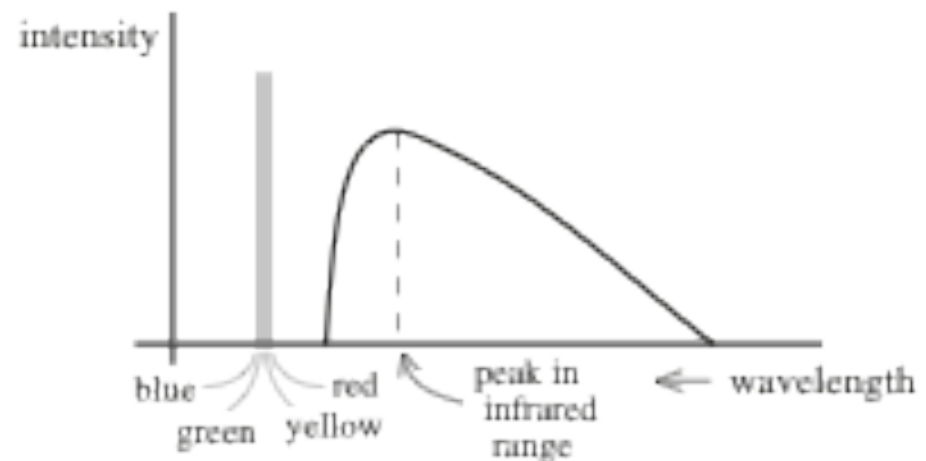
$$\lambda_{peak} = .0029 / T,$$

where T is temperature in kelvin.

black body frequency spectrum for a rock

intensity

black body radiation curve

optical frequency range

frequency

red   blue
yellow green

frequency peak
(in this case, it is
way below the optical frequency range)

black body wavelength spectrum for a rock

intensity

blue   red
green yellow

peak in infrared range

wavelength

(Note: It has also been experimentally determined that the energy flux in *joules per unit area per second* from a radiating object is proportional to the fourth power of the object's surface temperature. The proportionality constant is called the Stefan-Boltzman constant. The symbol used to denote it is a baby sigma, or σ. With it we can write the flux relationship as:

$$F = \sigma T^4$$

(This is not important when it comes to the absorption spectrum of a star but will be useful later.)

BLACKBODY RADIATION CURVES
AND ABSORPTION SPECTRA

Consider the blackbody radiation curve of two sources, one hot and one relatively cool.
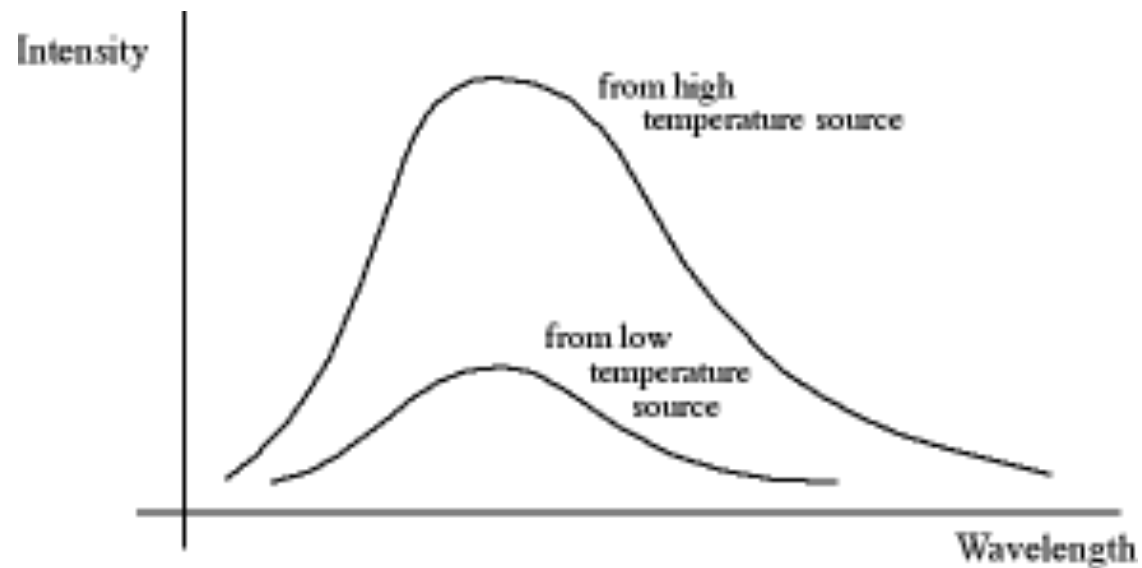
Again, the intensity of the high temperature source is greater than the intensity of the low temperature source.

(Yes, the wavelengths aren't shifted. Don't worry about that here.)

5.)

Consider now the thermal cross section of a star.

Close to the surface, the temperature is relatively low.

In deeper toward the core, the star's temperature is higher.

As temperature governs the intensity of blackbody radiation, the blackbody radiation being emitted from the deeper regions will be more intense than the blackbody radiation being emitted close to the surface where the temperature is lower.

If this was all that was going on, the intense blackbody radiation from the inner portion of the star would overwhelm all other radiation and that would be what we would see. This *isn't* all that is happening, though.

As photons move from the hot, central section of the star outward, most of them will make it out of the star without incident.

… But, photons whose energies happen to match up with the energy jumps found in the atoms closer to the surface will be absorbed, then reemitted.

The reemitted radiation, coming from a cooler part of the star, will have a less intense blackbody radiation signature.

What this means is that most of the energy we see coming out is high intensity, whereas the frequencies that have been absorbed and then reemitted will be of considerable less intensity.

This discrepancy of intensity is what shows itself as an absorption spectrum.

Looking at a *Very Small Section* of a Star's Black Body Radiation Curve
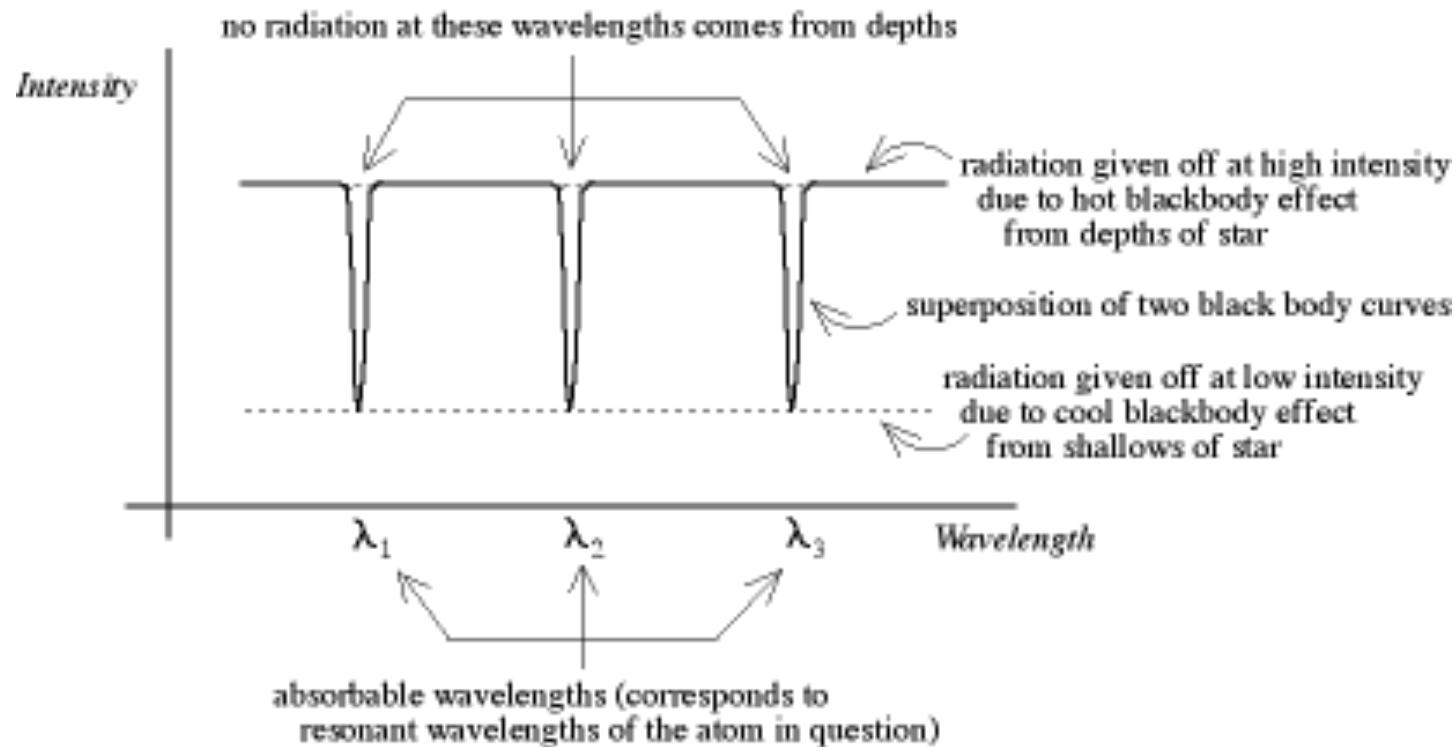
Spectral lines differ depending upon the temperature of the star's surface. How so?

For stars in the 3000 degree Kelvin range, thermal activity hasn't torn apart their molecular compounds. They produce spectral lines that correspond to molecules like carbon monoxide and titanium oxide.

For stars in the 6000 degree Kelvin range, they have no molecular compounds left to produce lines, so those lines are not found in those stars. Instead, we find hydrogen lines because those temperatures are not hot enough to ionize hydrogen atoms.

In fact, type A stars at 8000 to 10,000 degrees Kelvin are famous for their Balmer series hydrogen lines (these lines originate due to electron jumps to hydrogen's second excited state--they correspond to light in the optical range). (The Lyman electron jumps to hydrogen's ground state are in the u.v. range. These are not viewable on earth because the earth's atmosphere doesn't not pass u.v. radiation.)
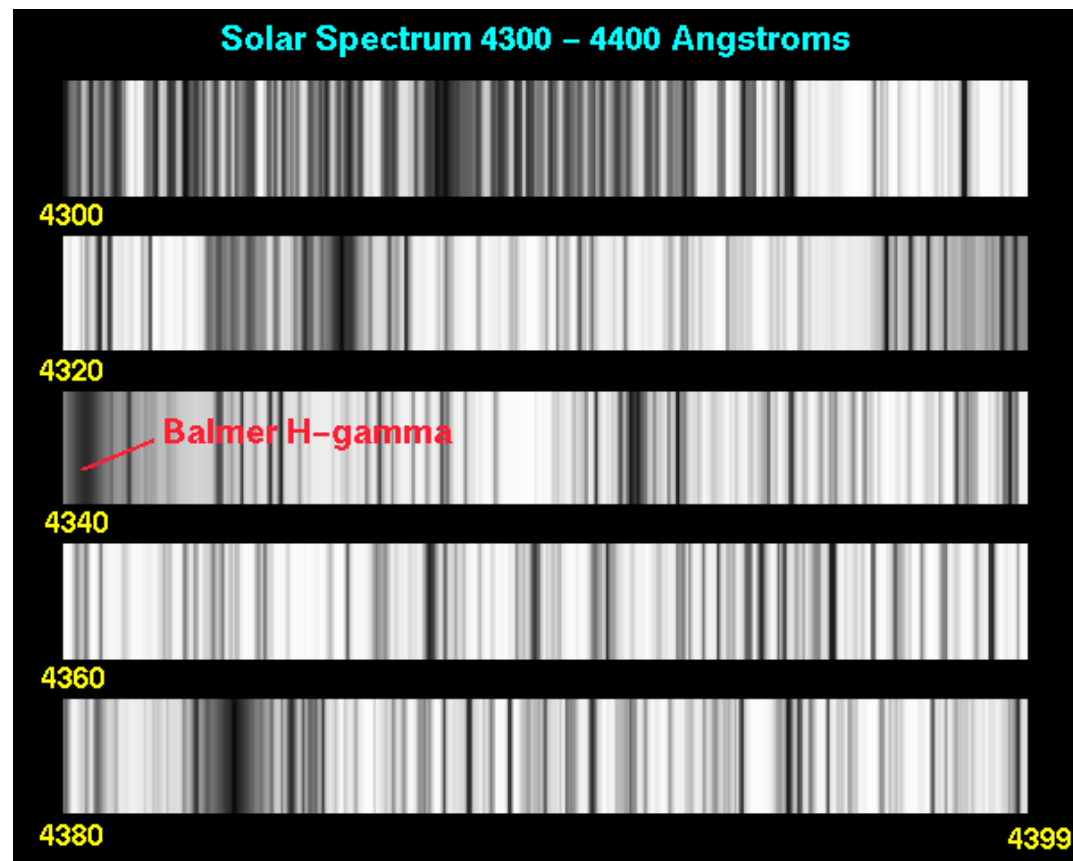
"A" type stars do NOT put out helium lines, though, because their temperatures are not high enough to excite helium atoms out of their ground state.

For stars in the 30,000 degree Kelvin range, they have completely stripped their hydrogen atoms of electrons. These stars have absolutely NO hydrogen lines present at all. Instead, we find singly ionized helium lines.
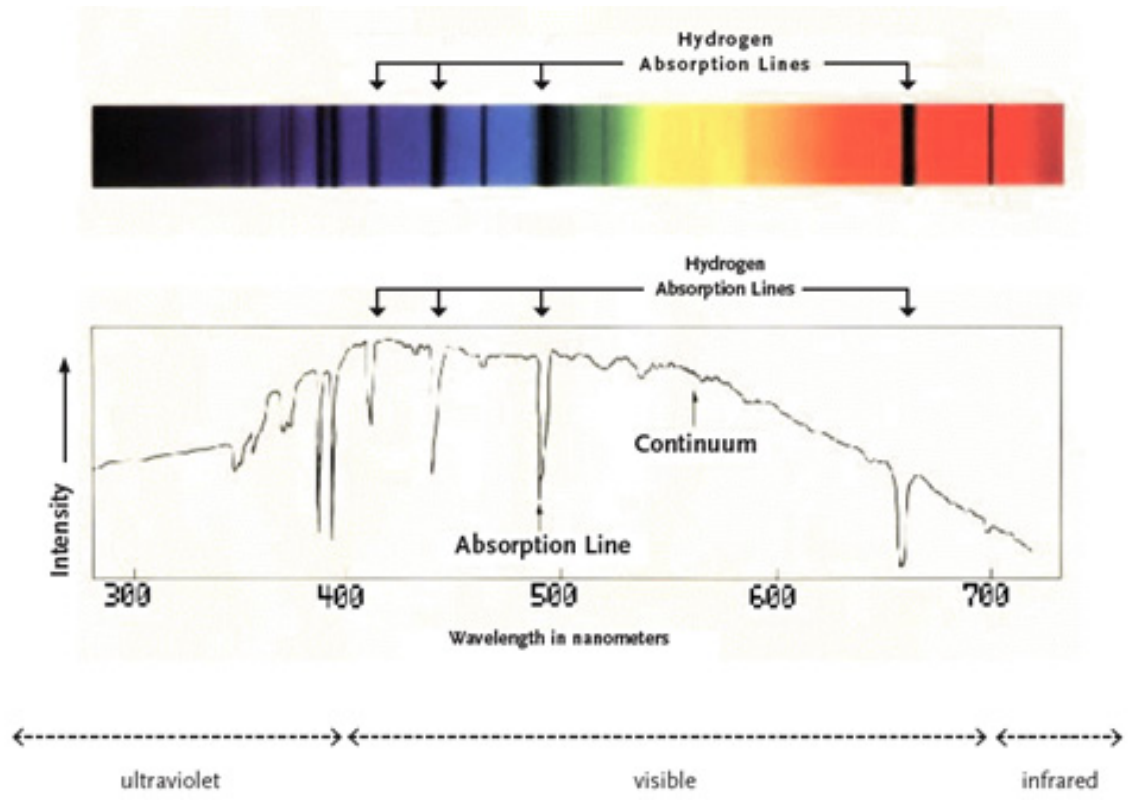
In short, by looking at the absorption spectral lines from a star, we can determine the star's spectral class AND TEMPERATURE.

Lastly, for the amusement of it, several stellar absorption spectra are shown below:

From our star, the Sun, between $4300\overset{o}{A}$ and $4380\overset{o}{A}$.

Solar Spectrum 4300 – 4400 Angstroms

And:

And:

The Sun displays an enormous number of spectrum lines, over three dozen appearing here in a 20 A-wide stretch in the yellow part of the spectrum. Roman numeral "I" stands for the neutral ion of an element, "II" for the once-ionized version. Different lines have different strengths. The ionized iron lines are nearly black, whereas those produced by the much rarer elements yttrium (Y), neodymium (Nd), and lanthanum (La) are very weak. E. C. Olson, Mt. Wilson Observatory.