Exercise 1: Emission Lines and Central Star Temperature in Planetary Nebulae

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Planetary nebulae are hot glowing gas clouds ejected by dying low- to intermediate-mass stars. They glow because they are heated by energetic ultraviolet photons from the exposed stellar core. According to Kirchhoff's laws, the light produced by a planetary nebula should be an emission spectrum, with spikes of emission at specific wavelengths corresponding to the elements in the gas. A spectrum can be displayed as a picture showing stripes of color at the wavelength of each emission line, or as a graph, plotting the amount of light at each wavelength.

In this exercise, you will learn how to

- use this database to plot a spectrum
- identify the elements in a planetary nebula's spectrum
- interpret the spectra of several planetary nebulae to rank the temperatures of their central stars.

Ionization in a Planetary Nebula

The central star in a planetary nebula is the exposed core of the original star. The temperature of the central star in a planetary nebula can be quite high, sometimes exceeding 200,000 K. (Eventually, all central stars will cool and become white dwarfs, and the planetary nebulae will expand and fade from view.) Typically, central star temperatures range from about 30,000 K to 100,000 K. At these high temperatures, a star will emit a great deal of radiation; the amount of radiation at each wavelength depends on the temperature, according to the Planck Law, otherwise known as "blackbody radiation," energetic enough to ionize the atoms in the nebula.

Of particular interest is the amount of ultraviolet radiation emitted; the energy of some ultraviolet photons is so high that they can ionize the atoms in the nebula, stripping off one or more electrons. The amount of energy required to produce the next higher level of ionization in an atom is called its ionization potential, usually expressed in electron volts. In general, heavier atoms are more easily ionized for the first time than lighter atoms. If an atom is already ionized, the remaining electrons are held more tightly, and it becomes even harder to remove the next electron to ionizing the atom more highly. The degree of ionization of atoms in a planetary nebula depends on the temperature of the central star. The hotter the star, the more photons of all energies it emits, **and** the greater the proportion higher-energy photons. Therefore a hotter star is capable of ionizing more atoms to higher ionization states than a cooler star. So, by examining the spectrum of a planetary nebula to see what ionization states of the various elements are present, you can get an idea of the temperature of the central star.

Plotting a Spectrum

All spectra in the database are listed on the Browse page. Clicking on the name of any planetary nebula takes you to the "Spectrum Display" page for that nebula. To expand any region of the graphed spectrum, hold the left mouse button down at one corner of the region you wish to enlarge, drag the mouse to the opposite corner of that region, and then release the mouse button. You can do this repeatedly to keep enlarging. To get back to the full plot, click on the "Zoom Out" radio button under the graph display. The horizontal axis of these graphs is the wavelength in Angstroms, and the vertical axis is the flux (in ergs cm^{-2} s^{-1}Angstrom^{-1}.