19-1 Looking Deeper into Astronomy

Equivalent Widths and Line Strengths

Most astronomers today use a light-sensitive CCD to record the spectra of stars because it is much more sensitive than photographic film. The large graph shows 14 stellar spectra obtained with such a device, which generates a plot of intensity versus wavelength. Each spectrum is a continuous curve, very much like the blackbody curve for the star's surface temperature. The dips in each curve represent absorption lines in the star's spectrum (compare Figure 6-24 on page 134 of *Universe*).

Astronomers designate an un-ionized atom with a roman numeral I; thus, H I is neutral hydrogen. A roman numeral II is used to identify an atom with one electron missing; thus, He II is singly ionized helium (He^+). This notation is used in the graph to label some of the prominent spectral lines on the 14 spectra, which cover spectral types from O5 to M5.

Using a plot of the intensity in a spectrum versus wavelength, an astronomer can study the shapes of individual spectral lines. The small graph shows a typical spectral line consisting of a "core" flanked by "wings." The detailed shape of a spectral line, called the *line profile*, contains important information about a star. For example, if a star is rotating, light from the approaching side is slightly blueshifted, while light from the receding side is comparably redshifted. As a result, the star's spectral lines are broadened in a characteristic fashion. By measuring the shape of the spectral lines, astronomers can deduce how fast the star is rotating.

The true shape of a spectral line reflects the properties of a star's atmosphere. However, the observed line profile is also broadened somewhat by the astronomer's measuring instruments. Instrumental effects do not significantly alter the *total* absorption of the line, which is a measure of the energy deleted from the star's blackbody radiation, or *continuum*, across the entire spectral line. Thus, the total absorption does not depend on the line's shape. Astronomers express the total absorption of a spectral line—that is, the *line strength*—in terms of its *equivalent width*, which is the width of a completely dark rectangular line with the same total absorption as the observed line. For example, the equivalent width of an iron line in the Sun's spectrum is about 0.01 nm.

The darkest absorption lines in Figure 19-11 on page 423 of *Universe* are those with the greatest equivalent widths; the faintest absorption lines have the smallest equivalent widths. Figure 19-12 on page 424 of *Universe*, which shows how the line strengths of different chemicals depend on a star's surface temperature, is actually a graph of relative equivalent widths versus temperature.

The equivalent width of a spectral line depends on how many atoms in the star's atmosphere are in a state in which they can absorb the wavelength in question. For a given temperature, the more atoms there are, the stronger and broader the line is. Hence, by analyzing a star's spectrum, an astronomer can determine the star's chemical composition.