TABLE 17.1 Pulsating Variable Stars Compared

Property	Cepheid	RR Lyrae
M_V (average)	−0.5–−6	0.5–1
Spectral Type	F, G, K	A, F
Pulsation Period	1–50 days	1.5–24 hours
Mass	3–18 $M_\odot$	0.5–0.7 $M_\odot$
Evolutionary Stage	supergiant	horizontal branch
Metallicity	high	low

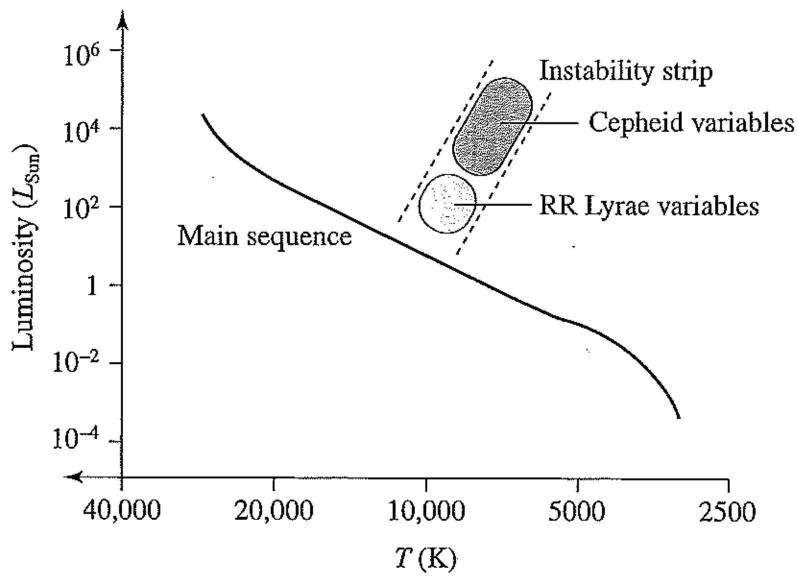

FIGURE 17.6 Location of Cepheids and RR Lyrae stars on a Hertzsprung–Russell diagram.

Table 17.1 shows the difference between Cepheids and RR Lyrae stars by comparing some of their properties.

Cepheid and RR Lyrae variables differ in many properties. However, if you plot their locations on an H–R diagram (Figure 17.6), you find they are adjacent to each other, on a diagonal stripe called the **instability strip**. Unlike the Sun and other stable main sequence stars, Cepheid and RR Lyrae stars pulsate in and out: they actually grow substantially larger and smaller in radius.

As an example of a pulsating variable star, consider δ Cephei. Over a period of $P =$ 5.366 days, its apparent magnitude varies by $\Delta m_V \approx 1$; this corresponds to $F_{max}/F_{min} \approx 10^{0.4} \approx 2.5$. A steep rise in flux (Figure 17.7) is followed by a slow decline. The radial velocity of the star δ Cephei, relative to the Sun, is approximately $-15\ \text{km s}^{-1}$. Because

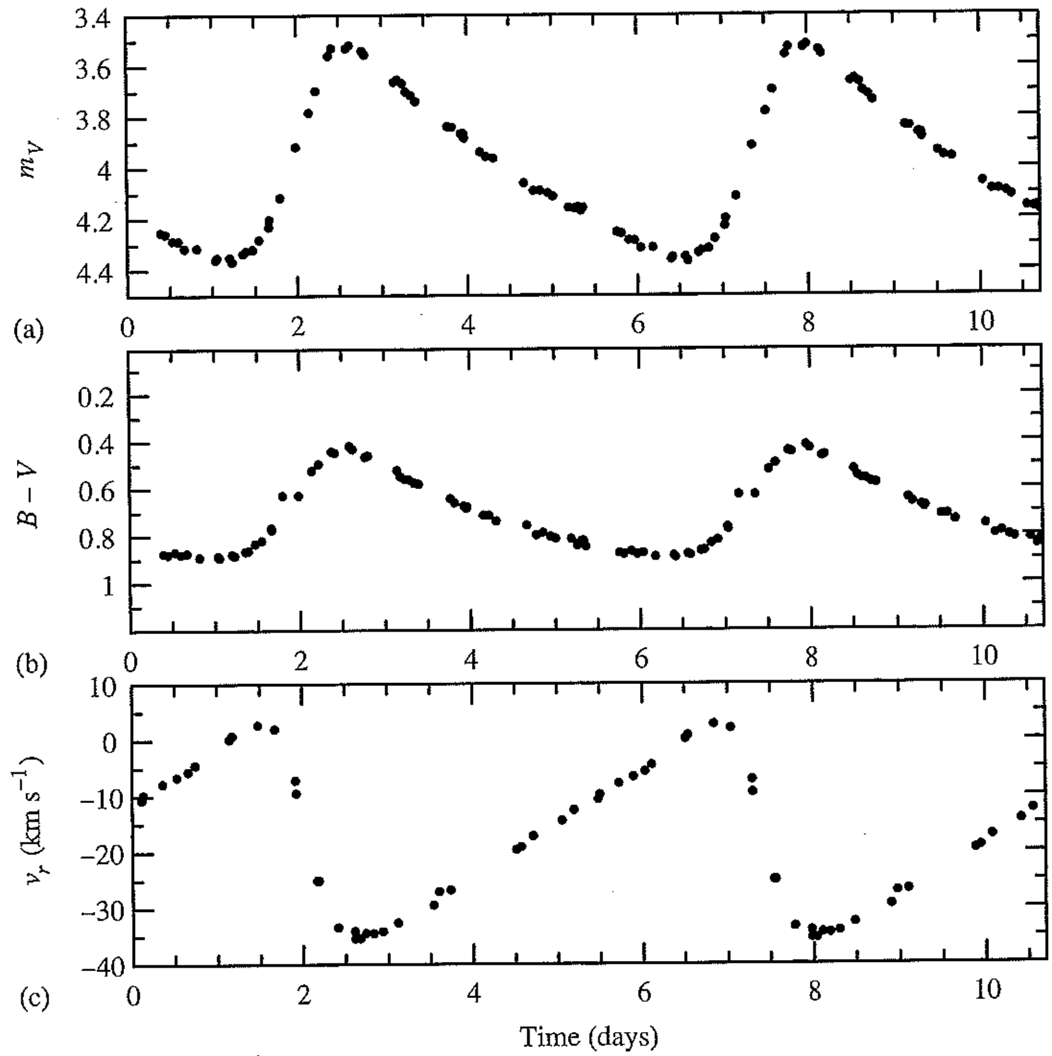

FIGURE 17.7 Time-variable properties of δ Cephei. (a) V-band apparent magnitude. (b) $B - V$ color index. (c) Radial velocity of photosphere.

of the expansion and contraction of the photosphere, the *observed* radial velocity varies from $v_r \approx -35\,\mathrm{km\,s^{-1}}$ when the photosphere is expanding to $v_r \approx +5\,\mathrm{km\,s^{-1}}$ when the photosphere is contracting. The effective temperature changes from $T_{\mathrm{eff}} \approx 5600\,\mathrm{K}$ when the star is near its minimum luminosity to $T_{\mathrm{eff}} \approx 6600\,\mathrm{K}$ when the star is near its maximum luminosity. The variations in radius can be deduced from the star's changes in luminosity and effective temperature: $R \propto L^{1/2}/T_{\mathrm{eff}}^2$. The radius of δ Cephei varies by nearly 15% over the course of one cycle; this means that the maximum volume is 50% greater than the minimum volume.

To see why pulsating variable stars pulsate, while the Sun is content to be stable, start by taking a star of radius R and squeezing slightly, so that its radius decreases to $R - dR$. As we saw in Section 17.1, squeezing a gas sphere makes a sound wave travel toward its center. Since a star in hydrostatic equilibrium is smaller than its Jeans length, the sound wave will reach the center in a time less than the collapse time. When the sound wave