Celestial Census

Distances

d = 1 / p" (pc)

d = 206,265 / p" (AU)

1 pc = 3.26 LY
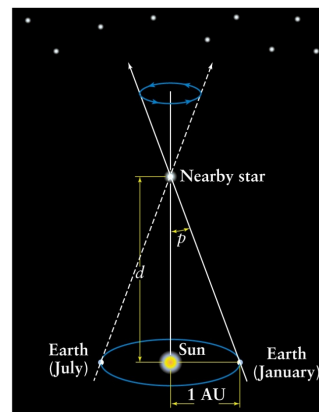
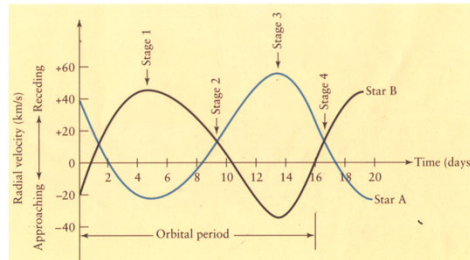

Universe by Freedman, Geller, and Kaufmann
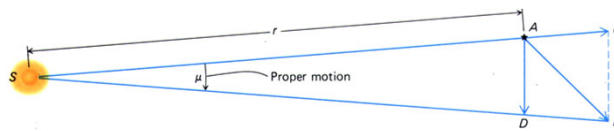
Radial Velocity

$$\Delta\lambda / \lambda = v / c = (\lambda_{obs} - \lambda) / \lambda$$

$$\Delta v = c\, \Delta\lambda / \lambda$$

Universe by Freedman, Geller, and Kaufmann

Proper Motion & Tangential Velocity
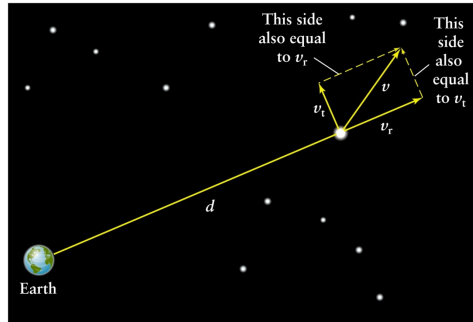

Universe by Freedman, Geller, and Kaufmann

$$T = 4.74\, \mu\, d = 4.74\, \mu / p'' \quad (km/s)$$

where μ is in arcsec/year, d is in parsecs, and p'' is in arcsec.

Space Velocity

The total space velocity is

$$V^2 = V_R^2 + V_T^2$$

Universe by Freedman, Geller, and Kaufmann

Flux-Distance-Luminosity

Brightness = Flux = Luminosity / $4 \pi d^2$

$$b = F = L / d^2$$

$$\frac{F_1 \, d_1^2}{F_2 \, d_2^2} = \frac{L_1}{L_2}$$

Apparent Magnitudes

$$F_2 / F_1 = 100^{(m_1 - m_2)/5}$$

$$\log (x^n) = n \log (x)$$

$$\log (F_2 / F_1) = (m_1 - m_2) / 5 \; \log (100) = 2 (m_1 - m_2) / 5$$

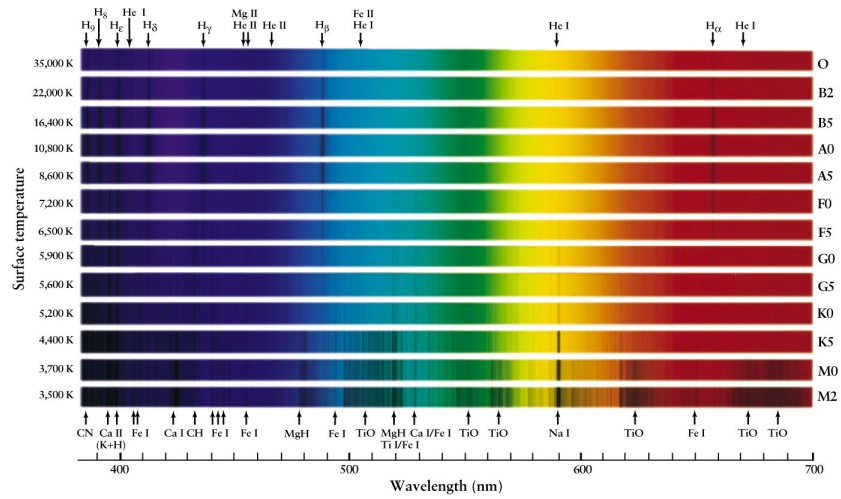$$m_1 - m_2 = 2.5 \log (F_2 / F_1)$$

Absolute Magnitudes

$$m_1 - m_2 = 2.5 \log (F_2 / F_1)$$
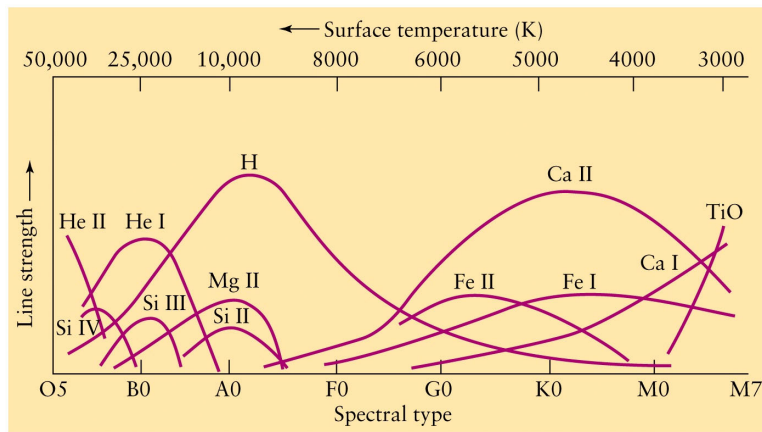
$$F = L / 4 \pi d^2$$

$$F(10) / F(d) = (d / 10)^2$$

$$m - M = 5 \log (d / 10)$$

Spectral Types

Universe by Freedman, Geller, and Kaufmann
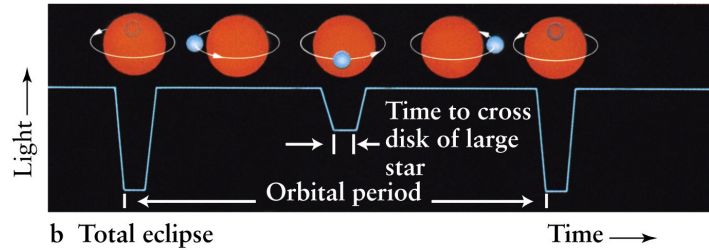
Ionization via Temperature

Universe by Freedman, Geller, and Kaufmann

Diameters of Stars

$$L = 4 \pi R^2 \sigma T^4$$

$$L \propto R^2 T^4$$

Universe by Freedman, Geller, and Kaufmann

Masses of Stars

Kepler's 3rd Law

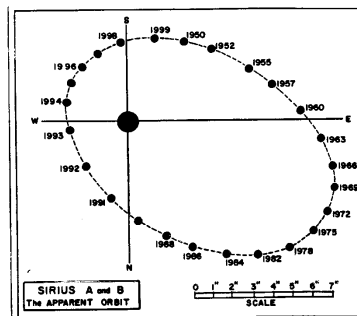$$(\mathcal{M}_1 + \mathcal{M}_2) P^2 = a^3$$

$\mathcal{M}$ is in solar masses

P is in years, and

a is in Astronomical Units

(1 AU = mean Earth-Sun distance)

Spectroscopic Binaries

Conservation of Angular Momentum

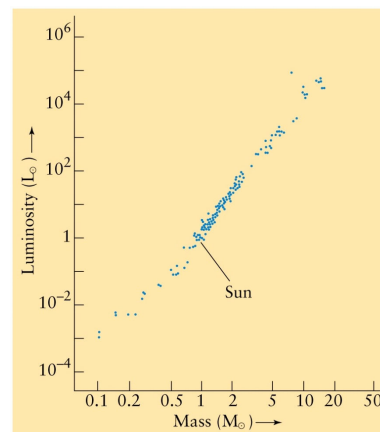$$\mathcal{M}_1 / \mathcal{M}_2 = v_2 / v_1$$

$$v_2 / v_1 = r_1 / r_2$$

Doppler Shift

$$\Delta\lambda / \lambda = v / c$$

Mass-Luminosity Relationship

$$L \propto \mathcal{M}^{4.0}$$

$$0.08 \text{ solar} < \mathcal{M} < 50 \text{ solar}$$

Universe by Freedman, Geller, and Kaufmann

How Can We Visualize It All?

E. Hertzsprung (1911) and Norris Russell (1913) independently produced plots to investigate stellar properties.
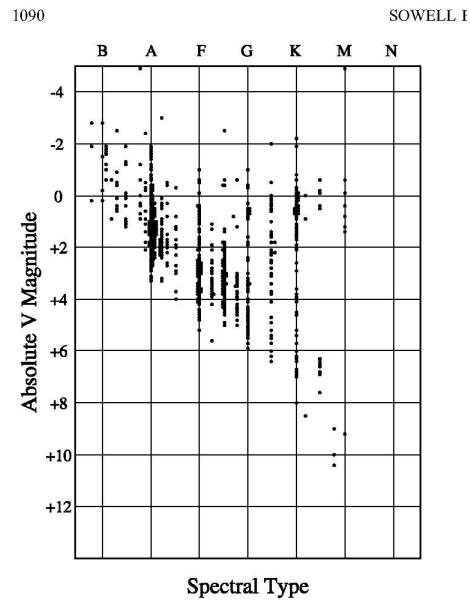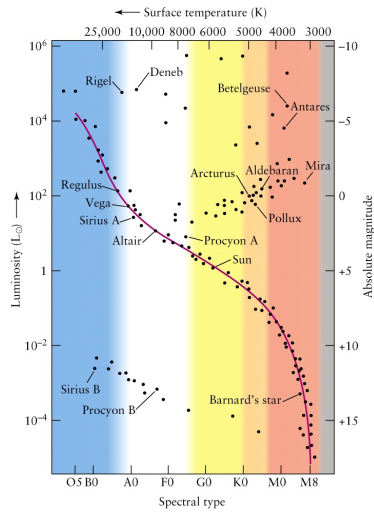
Today, those graphs are called **H-R Diagrams**.

Fig. 1.—Russell's diagram. The original does not reproduce well, but this is a faithful reproduction showing the data points and style used.
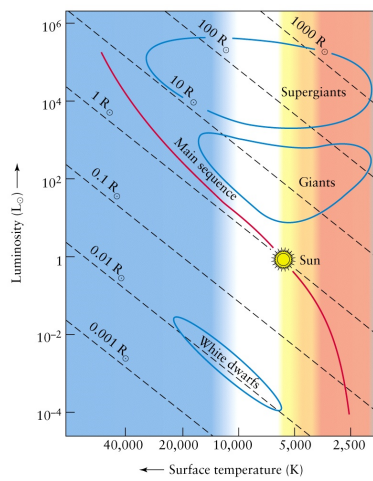
Hertzsprung-Russell Diagram

Universe by Freedman, Geller, and Kaufmann

Radii Relationships

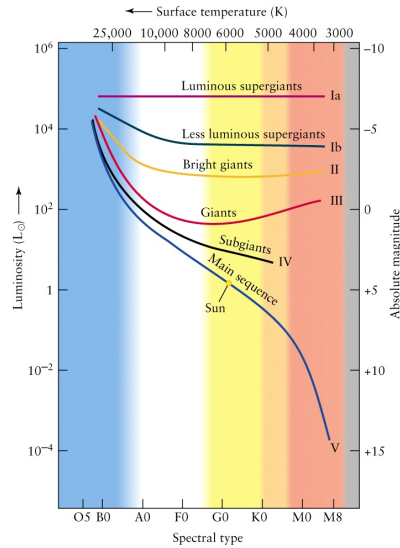*Universe* by Freedman, Geller, and Kaufmann

Hertzsprung-Russell Diagram

The most significant feature of the HR diagram is that the stars are not distributed over it at random. Rather they cluster into certain parts of the diagram.

Main Sequence
Red Giants
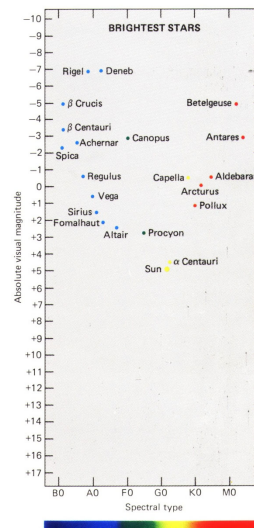**Supergiants**
White Dwarfs

$L \propto R^2 T^4$

Universe by Freedman, Geller, and Kaufmann

The Brightest Stars

Of the 20 brightest stars, only 6 are within 10 pc of the Sun.

The vast majority of nearby stars, those less luminous than the Sun, do not send enough light across interstellar distances to be seen without optical aid.

The Nearest Stars

Only 3 of the 44 nearest stars are among the 20 brightest stars: Sirius, Alpha Centauri, and Procyon.

The nearby stars also tend to have large proper motions. Interestingly, 13 of the 44 stars are really binary- or multiple-star systems. Total of 59 stars are within 5 pc.
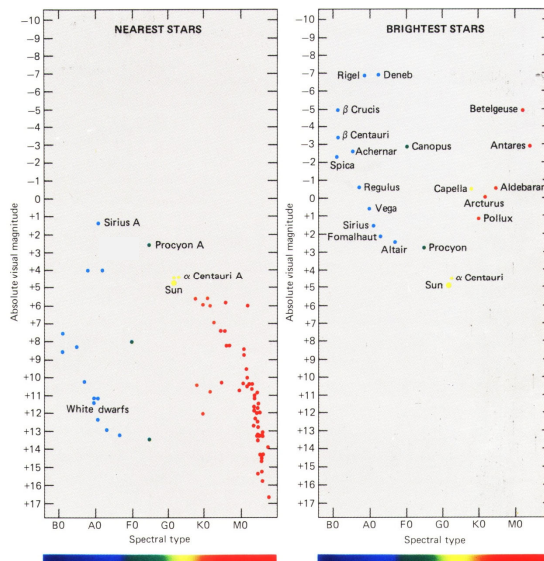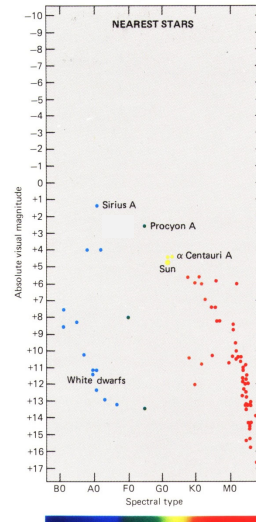
The Nearest Stars

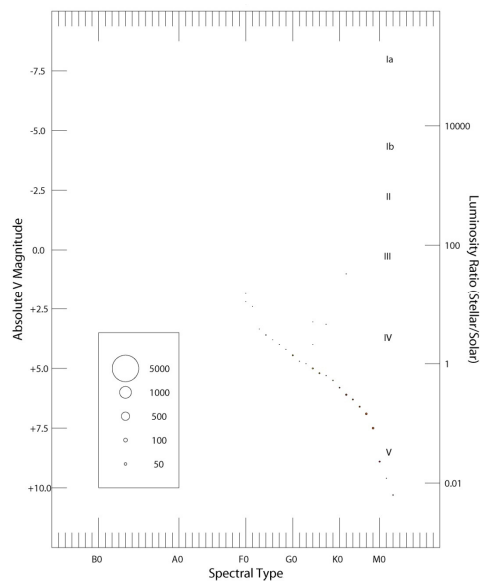The most important datum is that **most nearby stars are intrinsically faint**.

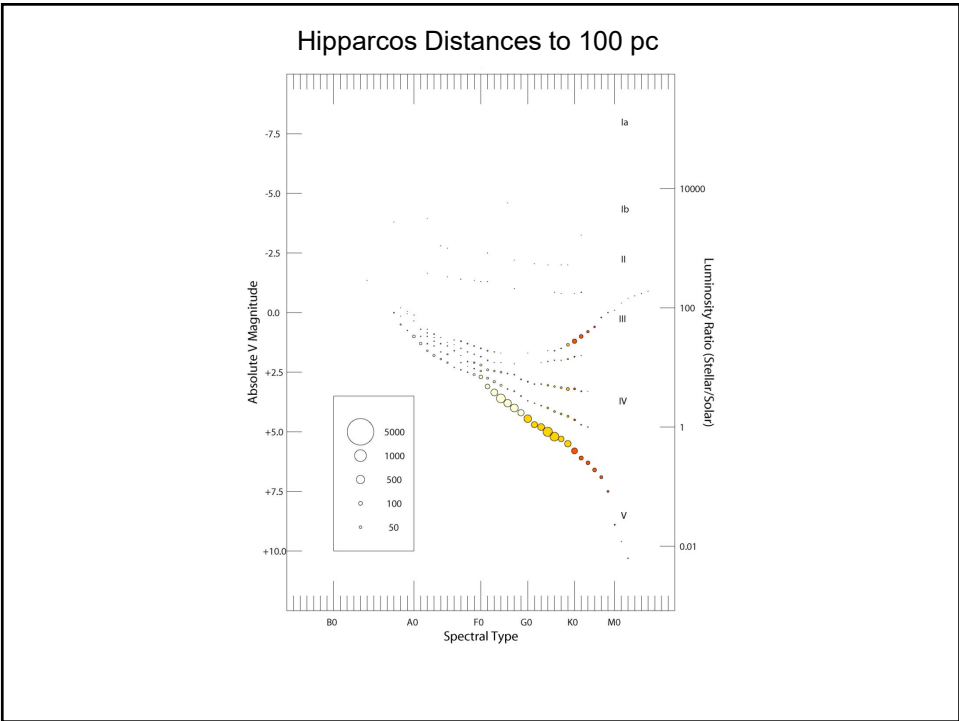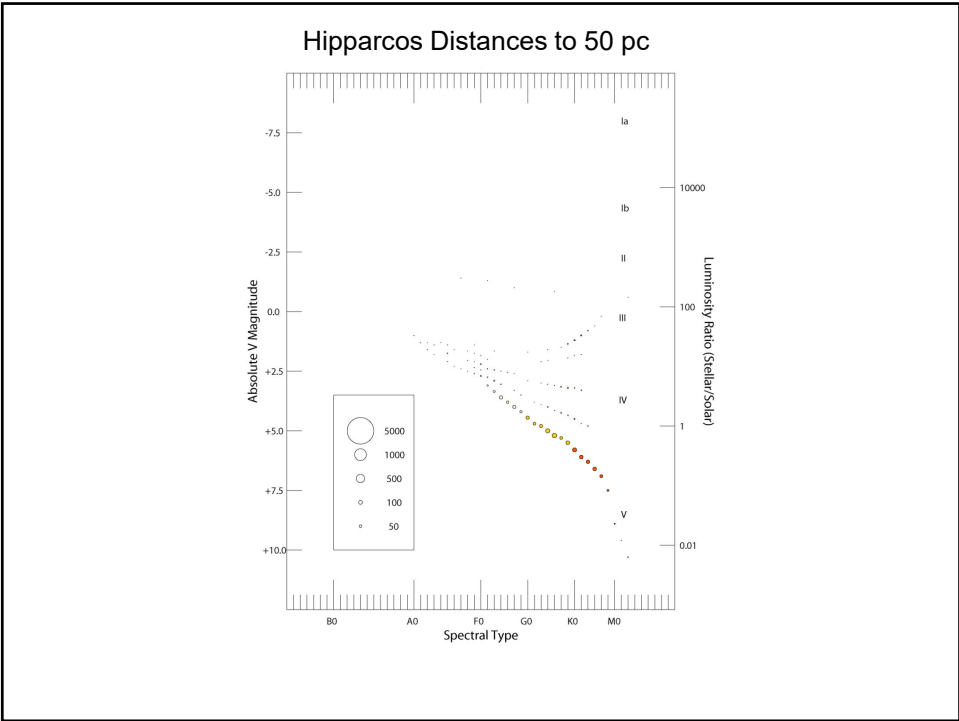Only 10 of the 50 nearest stars are visible to the unaided eye.

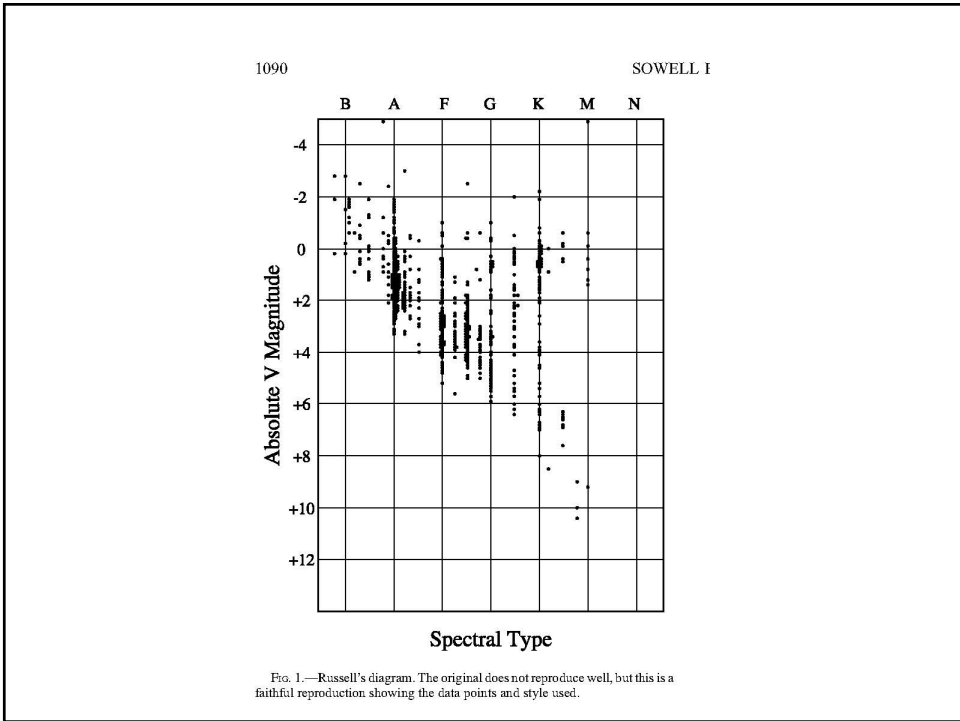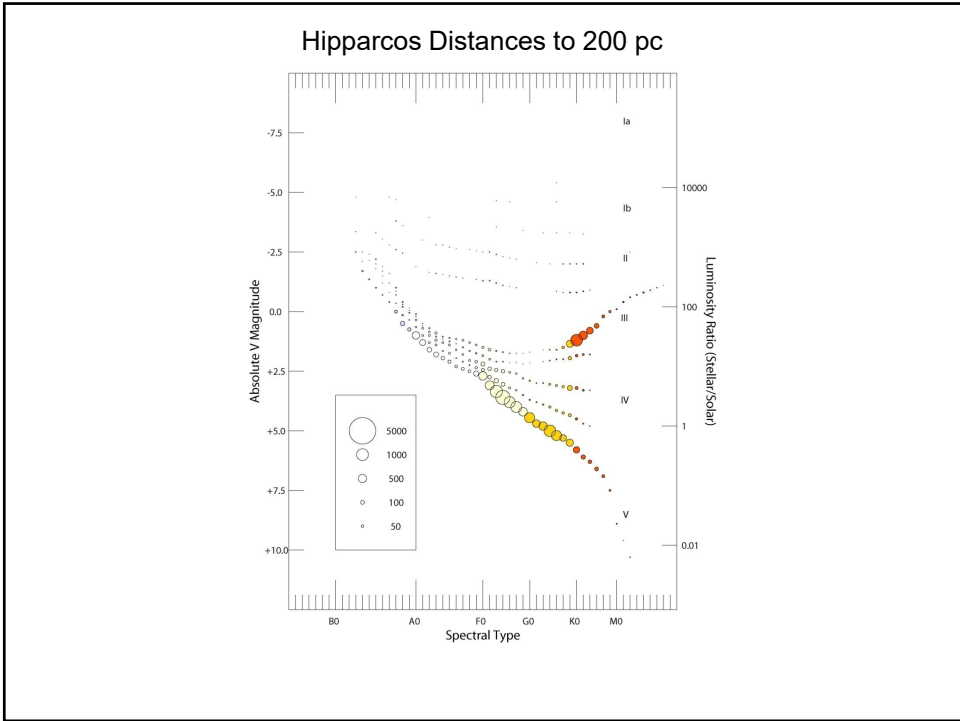Only 3 are as intrinsically luminous as the Sun.

43 have luminosities less than 0.01 solar.
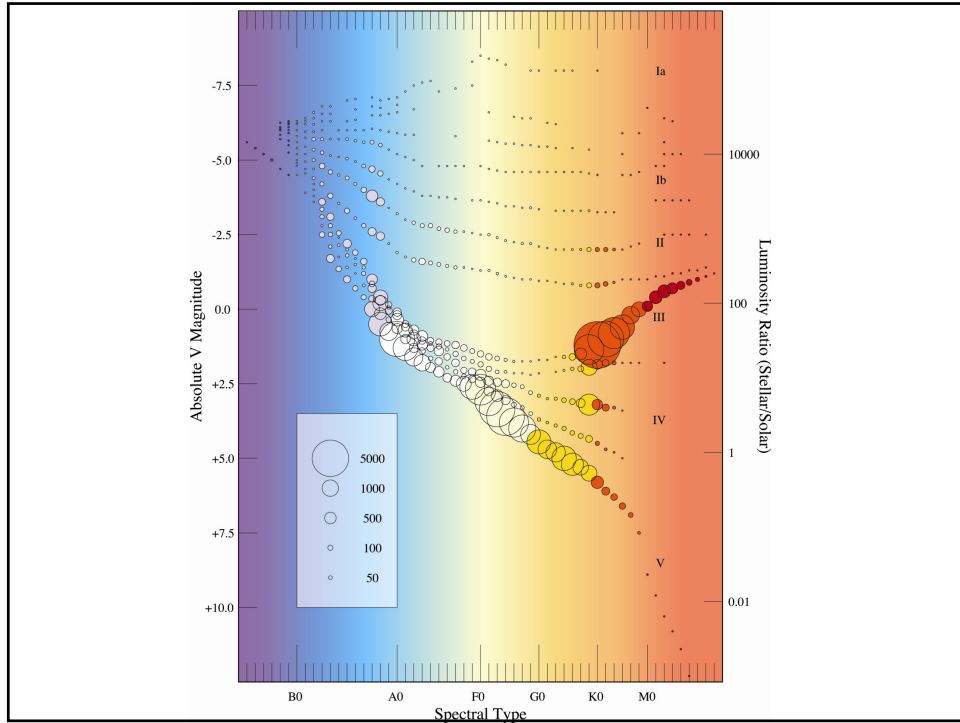
If the stars in our immediate stellar neighborhood are representative of the stellar population in general, we must conclude that the most numerous stars are those of low luminosity. In this sample, only about 1 star in 20 is as luminous as the Sun. (90% are main sequence; 10% are white dwarfs)

Hipparcos Distances to 20 pc

Hipparcos Distances to 50 pc

Hipparcos Distances to 100 pc

Hipparcos Distances to 200 pc

Fig. 1.—Russell's diagram. The original does not reproduce well, but this is a faithful reproduction showing the data points and style used.
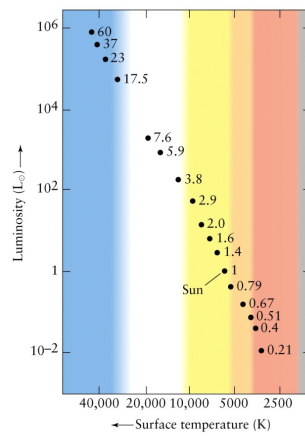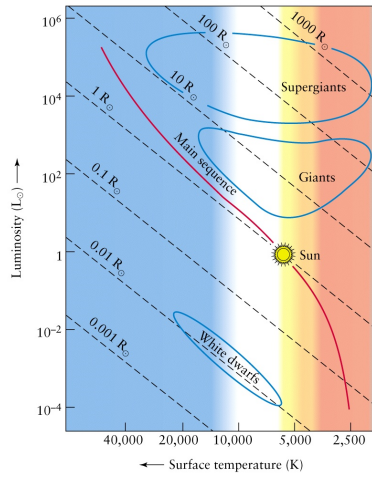
Main Sequence Masses

Universe by Freedman, Geller, and Kaufmann

Luminosity, Temp, Radius, & Mass

Universe by Freedman, Geller, and Kaufmann

Example 1

Star A is classified as K5 V and Star B is classified as K5 II.

What do you know for certain when comparing these two stars?

Example 2

Star A is classified as A0 Ib and Star B is classified as M0 Ib.

What do you know for certain when comparing these two stars?

Example 3

Star A is classified as A5 V and Star B is classified as G0 V.

What do you know for certain when comparing these two stars?

Main Sequence Extremes

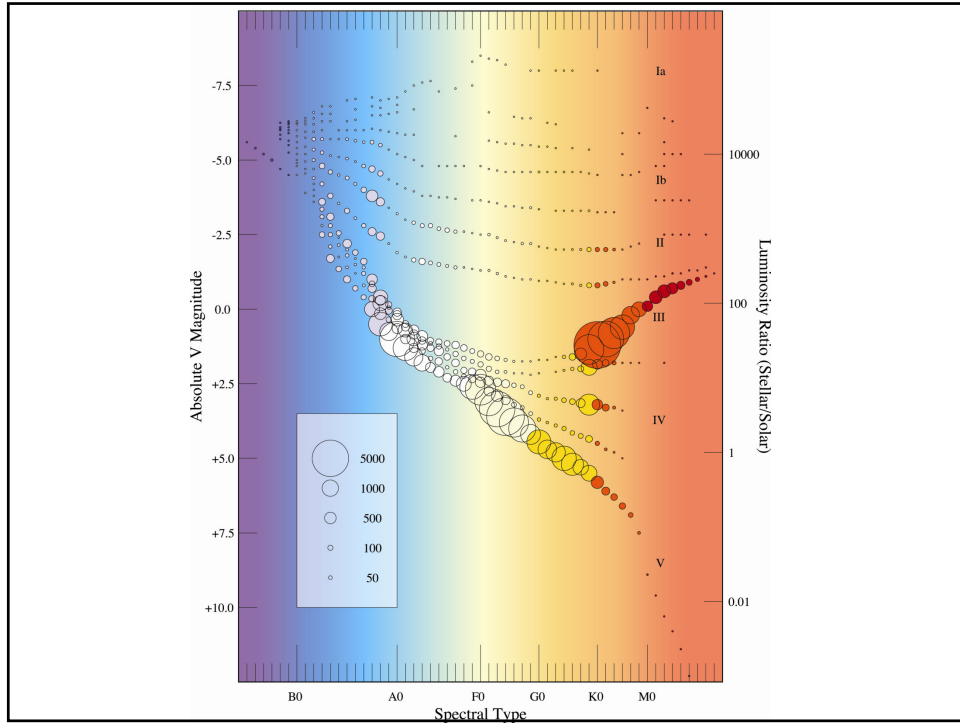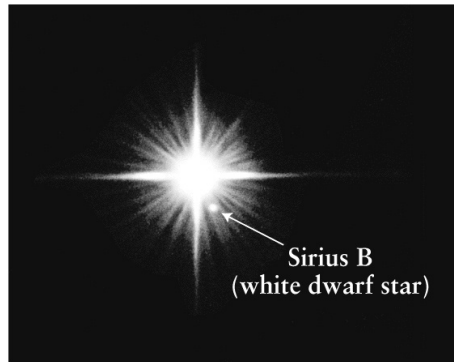| Most Luminous	Least Luminous
L = 50,000 solar	L = 0.005 solar
$\mathcal{M}$ = 60 solar	$\mathcal{M}$ = 0.08 solar
R = 40 solar	R = 0.1 solar
T = 45,000 K	T = 3000 K
O5	M5

Further Distances

1. Take the Spectrum of the star.
2. Classify the Spectrum.
3. Use the HR Diagram to assign an Absolute Magnitude (M).
4. Measure the Apparent Magnitude (m).

$$m - M = 5 \log (d / 10)$$

Spectroscopic Parallax

The White Dwarfs

Sirius B
(white dwarf star)

Mass of the Sun but the Size of the Earth

$\rho = 1.6 \times 10^5$ g/cm^3 (one spoonful = 50 tons)