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ASTRONOMY

Chapter 17 ANALYZING STARLIGHT

PowerPoint Image Slideshow

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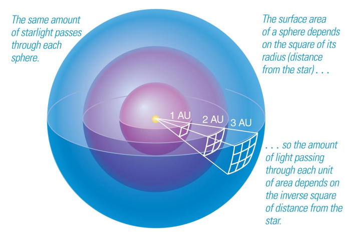
17.1 THE BRIGHTNESS OF STARS

- **Star Colors.** This long time exposure shows the colors of the stars. The circular motion of the stars across the image is provided by Earth's rotation. The various colors of the stars are caused by their different temperatures.

Luminosity



Luminosity passing through each sphere is the same.

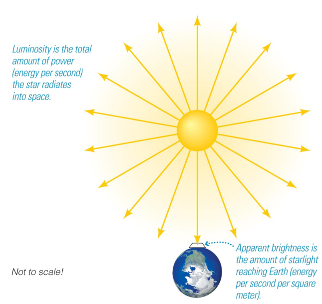
Area of sphere:
4π (radius)^2

Divide luminosity by area to get brightness.

Brightness of a star depends on both distance and luminosity.

$$\text{Brightness} = \frac{\text{Luminosity}}{4\pi\,(\text{distance})^2}$$

Apparent Brightness



Luminosity:
Amount of power a star radiates
(energy per second = watts)

Apparent brightness:
Amount of starlight that reaches Earth (energy per second per square meter)

Magnitude Scale

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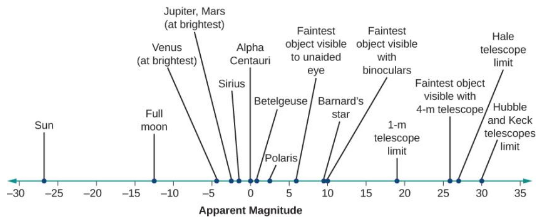

- **Apparent Magnitudes of Well-Known Objects.** The faintest magnitudes that can be detected by the unaided eye, binoculars, and large telescopes are also shown.

Magnitudes

m = apparent magnitude　　*M* = absolute magnitude

b = apparent brightness　　$m_1 - m_2 = 2.5\log(b_2/b_1)$

$$\frac{\text{apparent brightness of Star 1}}{\text{apparent brightness of Star 2}} = (100^{1/5})^{m_1 - m_2}$$

$$\frac{\text{luminosity of Star 1}}{\text{luminosity of Star 2}} = (100^{1/5})^{M_1 - M_2}$$

Figure 17.3

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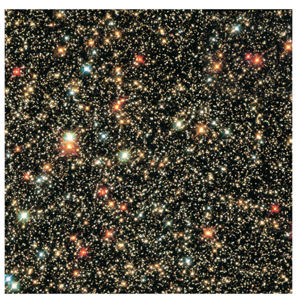
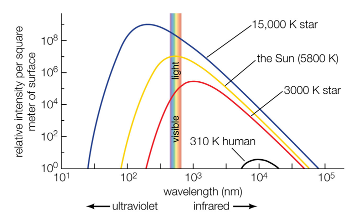


- **Sagittarius Star Cloud.** This image, which was taken by the Hubble Space Telescope, shows stars in the direction toward the center of the Milky Way Galaxy. The bright stars glitter like colored jewels on a black velvet background. The color of a star indicates its temperature. Blue-white stars are much hotter than the Sun, whereas red stars are cooler. On average, the stars in this field are at a distance of about 25,000 light-years (which means it takes light 25,000 years to traverse the distance from them to us) and the width of the field is about 13.3 light-years.

17.2 COLORS OF STARS

1. Hotter objects emit more light per unit area at all frequencies.
2. Hotter objects emit photons with a higher average energy.



Hottest stars:

50,000 K

Coolest stars:

3000 K

(Sun's surface is 5800 K)

10^6 K

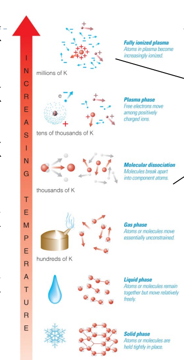
10^5 K

10^4 K

10^3 K

10^2 K

10 K



Ionized Gas (Plasma)

Neutral Gas

Molecules

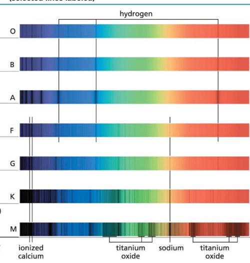
Solid

Level of ionization also reveals a star's temperature.

17.3 THE SPECTRA OF STARS

TABLE 12.1 The Spectral Sequence

Spectral Type	Example(s)	Tempera-ture Range	Key Absorption Line Features	Brightest Wavelength (color)	Typical Spectrum (selected lines labeled)
O	Stars of Orion's Belt	>33,000 K	Lines of ionized helium, weak hydrogen lines	< 89 nm (ultraviolet)*	O
B	Rigel	33,000 K–10,000 K	Lines of neutral helium, moderate hydrogen lines	89–290 nm (ultraviolet)*	B
A	Sirius	10,000 K–7500 K	Very strong hydrogen lines	290–390 nm (violet)*	A
F	Polaris	7500 K–6000 K	Moderate hydrogen lines, moderate lines of ionized calcium	390–480 nm (blue)*	F
G	Sun, Alpha Centauri A	6000 K–5200 K	Weak hydrogen lines, strong lines of ionized calcium	480–560 nm (yellow)	G
K	Arcturus	5200 K–3700 K	Lines of neutral and singly ionized metals, some molecules	560–780 nm (red)	K
M	Betelgeuse, Proxima Centauri	<3700 K	Strong molecular lines	>780 nm (infrared)	M



*All stars above 6000 K look more or less white to the human eye because they emit plenty of radiation at all visible wavelengths.

Figure 17.4

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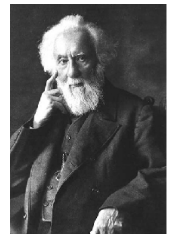
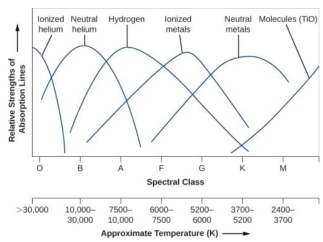


- **William Huggins (1824–1910) and Margaret Huggins (1848–1915).** William and Margaret Huggins were the first to identify the lines in the spectrum of a star other than the Sun; they also took the first spectrogram, or photograph of a stellar spectrum.

Figure 17.5

openstax



- **Absorption Lines in Stars of Different Temperatures.** This graph shows the strengths of absorption lines of different chemical species (atoms, ions, molecules) as we move from hot (left) to cool (right) stars. The sequence of spectral types is also shown.

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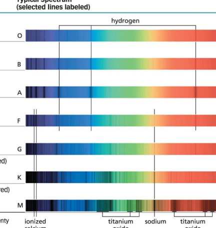

*All stars above 6000 K look more or less white to the human eye because they emit plenty of radiation at all visible wavelengths.

Lines in a star's spectrum correspond to a ***spectral type*** that reveals its temperature:

(Hottest) O B A F G K M (Coolest)

Remembering Spectral Types

(Hottest) O B A F G K M (Coolest)

6000K 0123456789 5200K

The Sun is a G2 star 5800K

- Oh, Be A Fine Girl/Guy, Kiss Me

Figure 17.6

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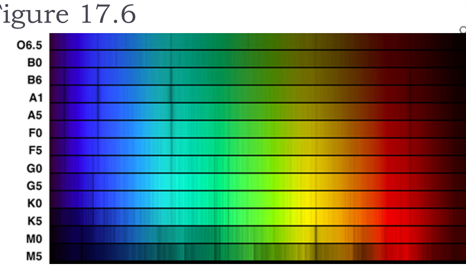


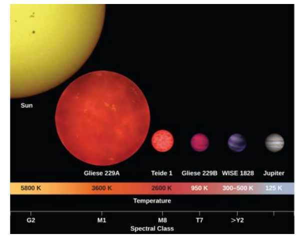
- **Spectra of Stars with Different Spectral Classes.** This image compares the spectra of the different spectral classes. The spectral class assigned to each of these stellar spectra is listed at the left of the picture. The strongest four lines seen at spectral type A1 (one in the red, one in the blue-green, and two in the blue) are Balmer lines of hydrogen. Note how these lines weaken at both higher and lower temperatures, as Figure 17.5 also indicates. The strong pair of closely spaced lines in the yellow in the cool stars is due to neutral sodium (one of the neutral metals in Figure 17.5).

Pioneers of Stellar Classification

- **Annie Jump Cannon (1863–1941).** Cannon is well-known for her classifications of stellar spectra.

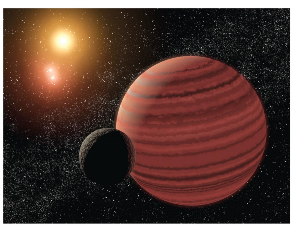
- Annie Jump Cannon and the "calculators" at Harvard laid the foundation of modern stellar classification.

O B A F G K M L T Y



- **Brown Dwarfs.** This illustration shows the sizes and surface temperatures of brown dwarfs Teide 1, Gliese 229B, and WISE1828 in relation to the Sun, a red dwarf star (Gliese 229A), and Jupiter.

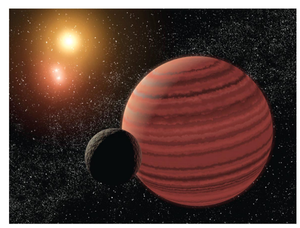
Brown Dwarfs



a Artist's conception of a brown dwarf, orbited by a planet (to its left) in a system with multiple stars. The reddish color approximates how a brown dwarf would appear to human eyes. The bands are shown because we expect brown dwarfs to look more like giant jovian planets than stars.

- Degeneracy pressure halts the contraction of objects with $<0.08M_{Sun}$ before the core temperature becomes hot enough for fusion.
- Starlike objects not massive enough to start fusion are **brown dwarfs**.

Brown Dwarfs



a Artist's conception of a brown dwarf, orbited by a planet (to its left) in a system with multiple stars. The reddish color approximates how a brown dwarf would appear to human eyes. The bands are shown because we expect brown dwarfs to look more like giant jovian planets than stars.

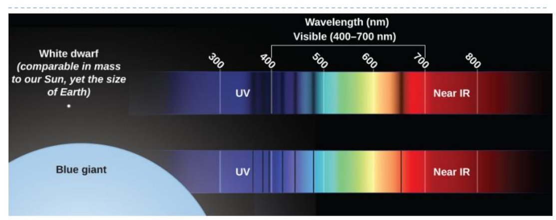
- A brown dwarf emits infrared light because of heat left over from contraction.
- Its luminosity gradually declines with time as it loses thermal energy.

Brown Dwarfs in Orion

b An infrared image showing brown dwarfs (circled) in the constellation Orion. They are easier to spot in star-forming regions like this one than elsewhere in our galaxy, because young brown dwarfs still have much of the thermal energy left by the process of gravitational contraction. They therefore emit measurable amounts of infrared light.

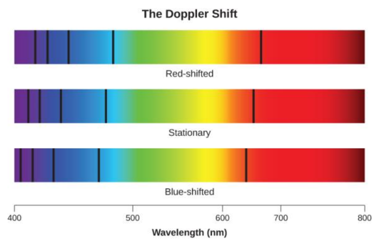
- Infrared observations can reveal recently formed brown dwarfs because they are still relatively warm and luminous.

17.4 USING SPECTRA TO MEASURE STELLAR CHARACTERISTICS



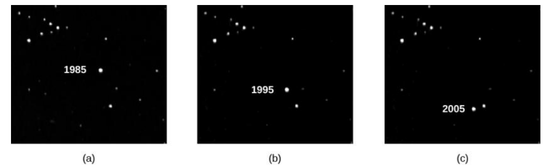
- **Spectral Lines.** This figure illustrates one difference in the spectral lines from stars of the same temperature but different pressures. A giant star with a very-low-pressure photosphere shows very narrow spectral lines (bottom), whereas a smaller star with a higher-pressure photosphere shows much broader spectral lines (top).

Radial Velocity



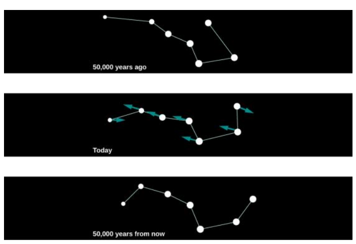
- **Doppler-Shifted Stars.** When the spectral lines of a moving star shift toward the red end of the spectrum, we know that the star is moving away from us. If they shift toward the blue end, the star is moving toward us.

Figure 17.11



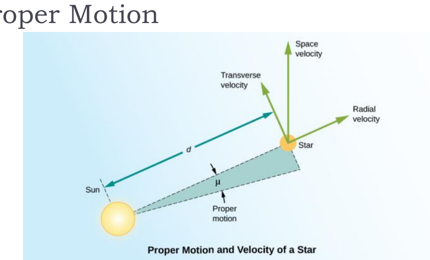
- **Large Proper Motion.** Three photographs of Barnard's star, the star with the largest known proper motion, show how this faint star has moved over a period of 20 years. (modification of work by Steve Quirk)

Figure 17.12



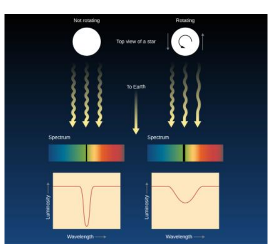
- **Changes in the Big Dipper.** This figure shows changes in the appearance of the Big Dipper due to proper motion of the stars over 100,000 years.

Proper Motion



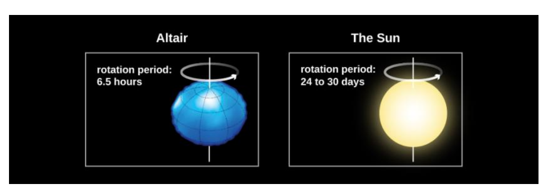
- **Space Velocity and Proper Motion.** This figure shows the true space velocity of a star. The radial velocity is the component of the space velocity projected along the line of sight from the Sun to a star. The transverse velocity is a component of the space velocity projected on the sky. What astronomers measure is proper motion (μ), which is the change in the apparent direction on the sky measured in fractions of a degree. To convert this change in direction to a speed in, say, kilometers per second, it is necessary to also know the distance (*d*) from the Sun to the star.

Rotation



- **Using a Spectrum to Determine Stellar Rotation.** A rotating star will show broader spectral lines than a nonrotating star.

Figure 17.15



- **Comparison of Rotating Stars.** This illustration compares the more rapidly rotating star Altair to the slower rotating Sun.

Exercise 27 (Figure 17.16)

Homework activity

- ***Why are the color temperatures wrong?***

Videos

Reading

- 17.1
- 17.2
- 17.3