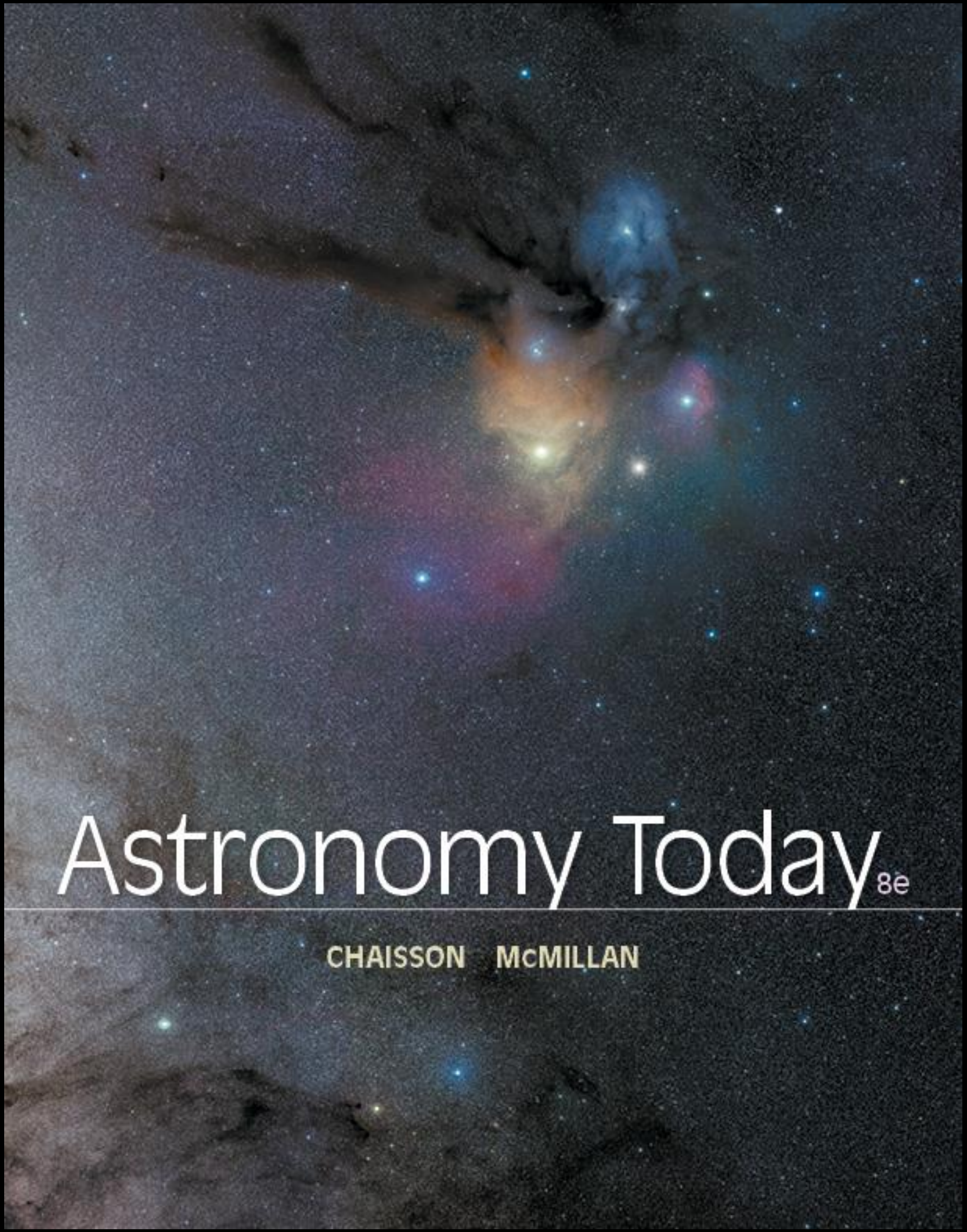


Lecture Outlines

Chapter 3

Astronomy Today

8th Edition

Chaisson/McMillan

Chapter 3

Radiation

Units of Chapter 3

3.1 Information from the Skies

3.2 Waves in What?

3.3 The Electromagnetic Spectrum

Discovery 3-1: The Wave Nature of Radiation

3.4 Thermal Radiation

More Precisely 3-1: The Kelvin Temperature Scale

More Precisely 3-2: More About the Radiation Laws

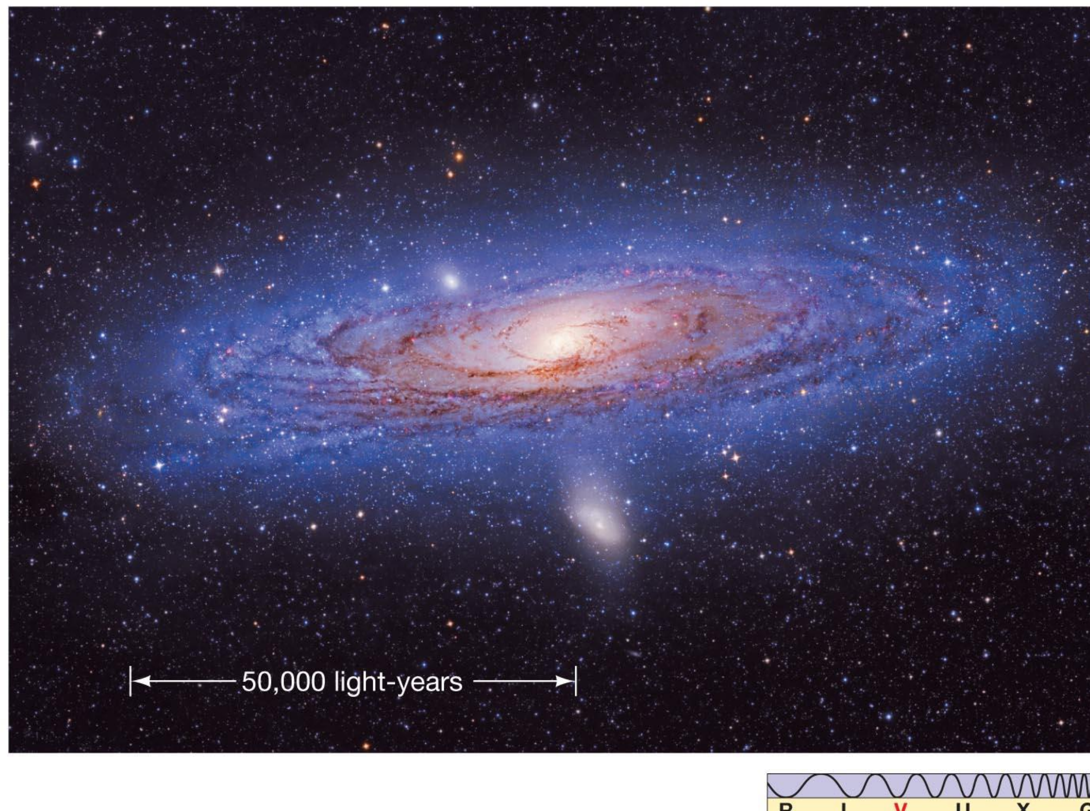
3.5 The Doppler Effect

More Precisely 3-3: Measuring Velocities with the Doppler Effect

3.1 Information from the Skies

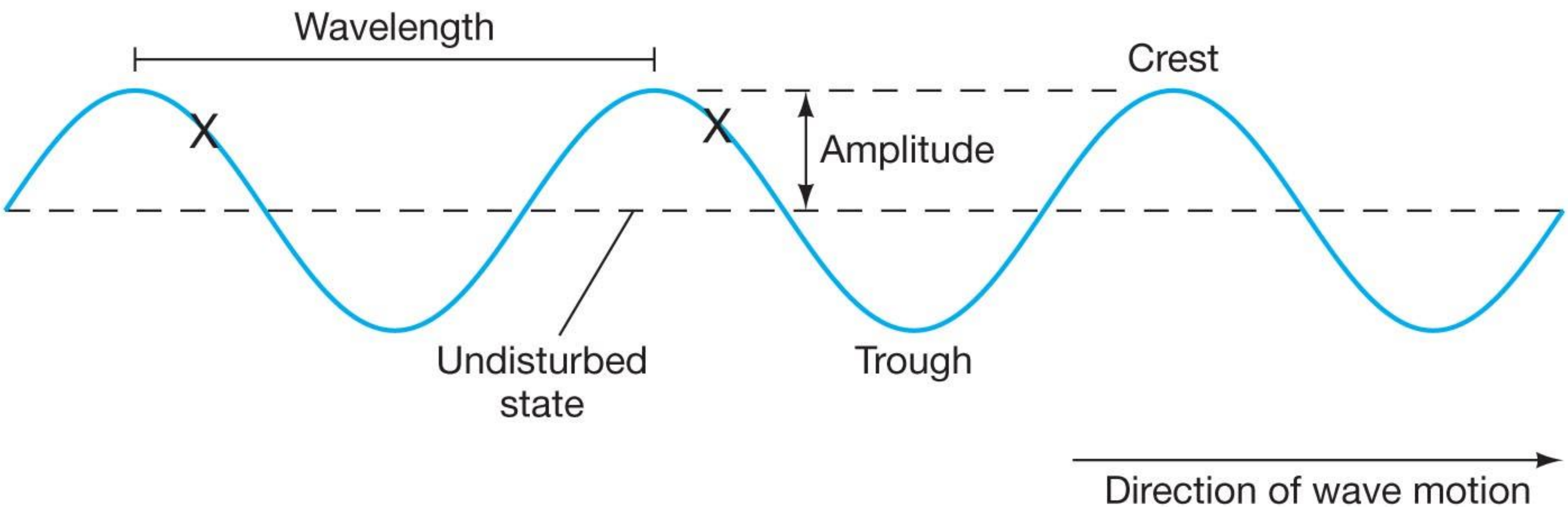
Electromagnetic radiation: Transmission of energy through space without physical connection through varying electric and magnetic fields

Example: **Light**



3.1 Information from the Skies

Wave motion: **Transmits energy without the physical transport of material**

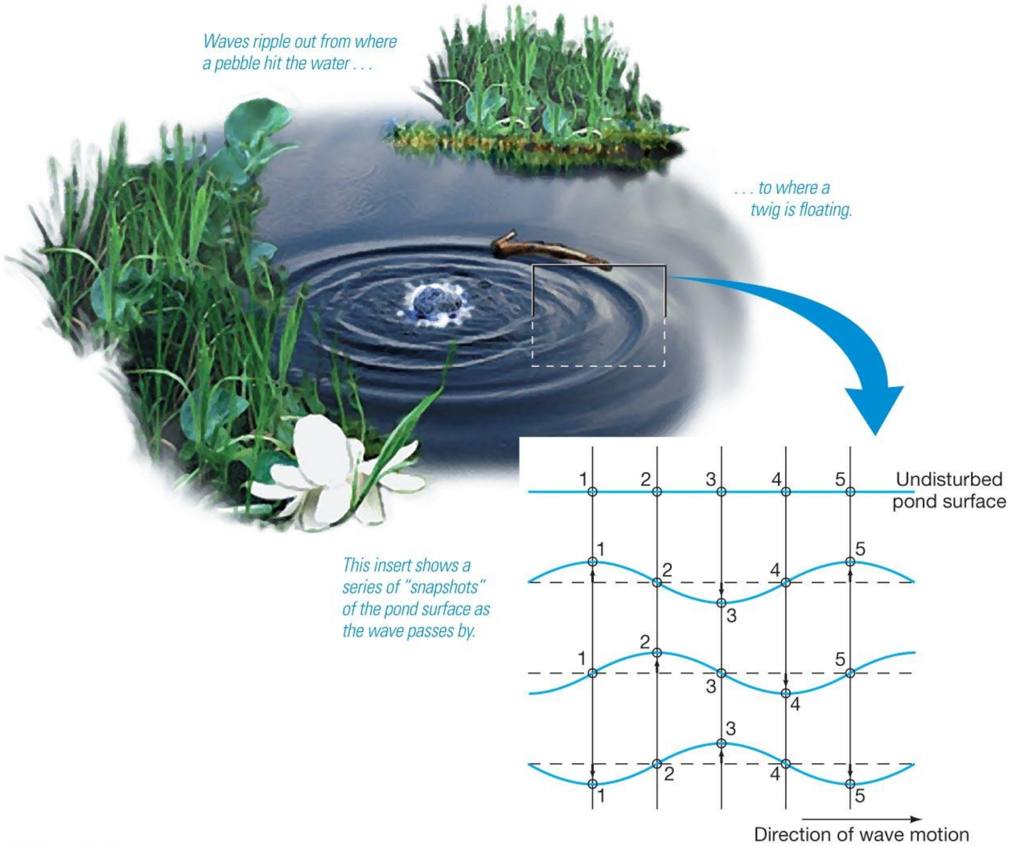


3.1 Information from the Skies

Example: Water wave

Water just moves up and down

Wave travels and can transmit energy



3.1 Information from the Skies

Frequency: Number of wave crests that pass a given point per second

Period: Time between passage of successive crests

Relationship:

$$\text{Period} = 1 / \text{Frequency}$$

3.1 Information from the Skies

Wavelength: Distance between successive crests

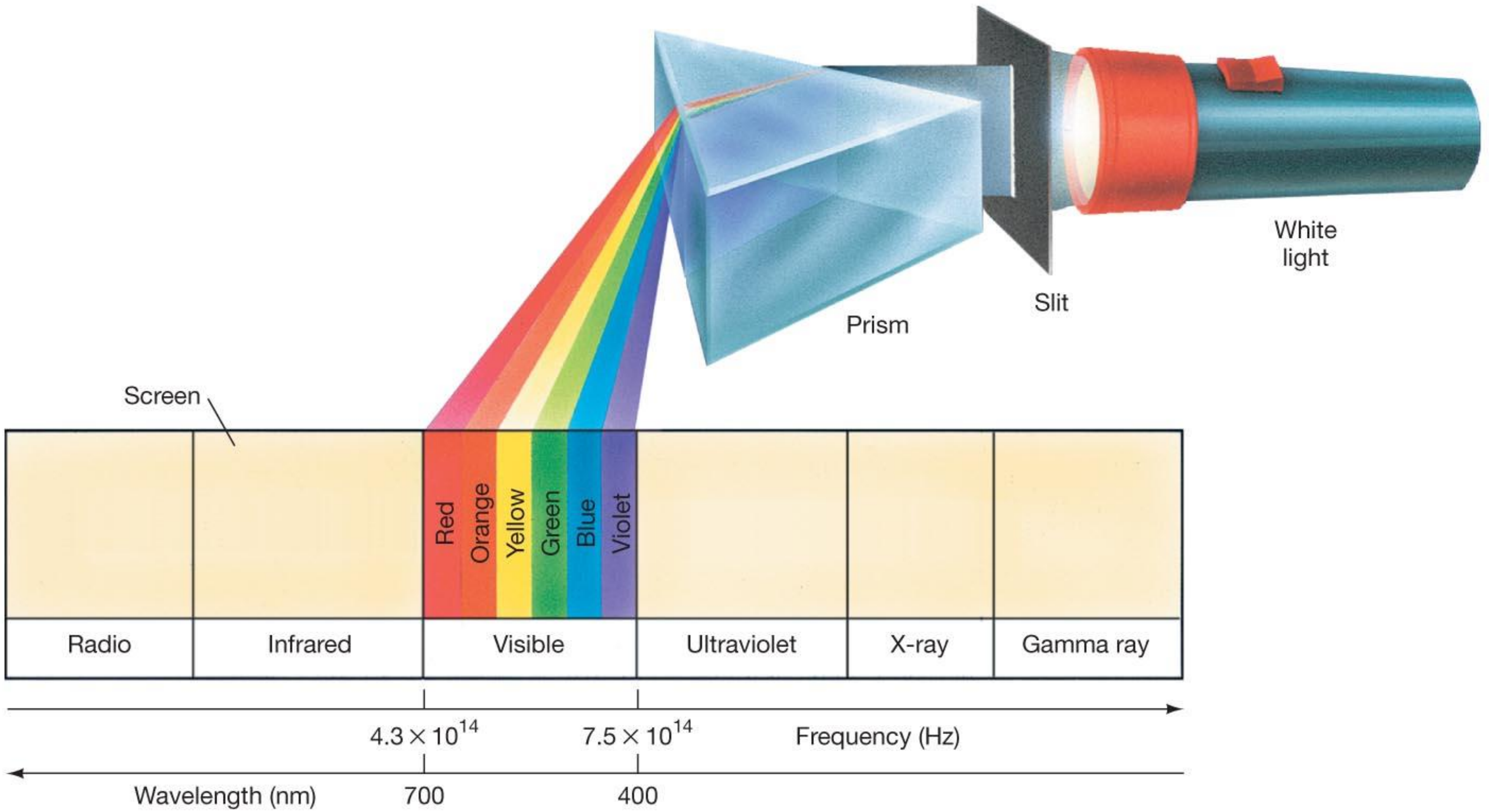
Velocity: Speed at which crests move

Relationship:

Velocity = Wavelength / Period

3.1 Information from the Skies

Visible spectrum:

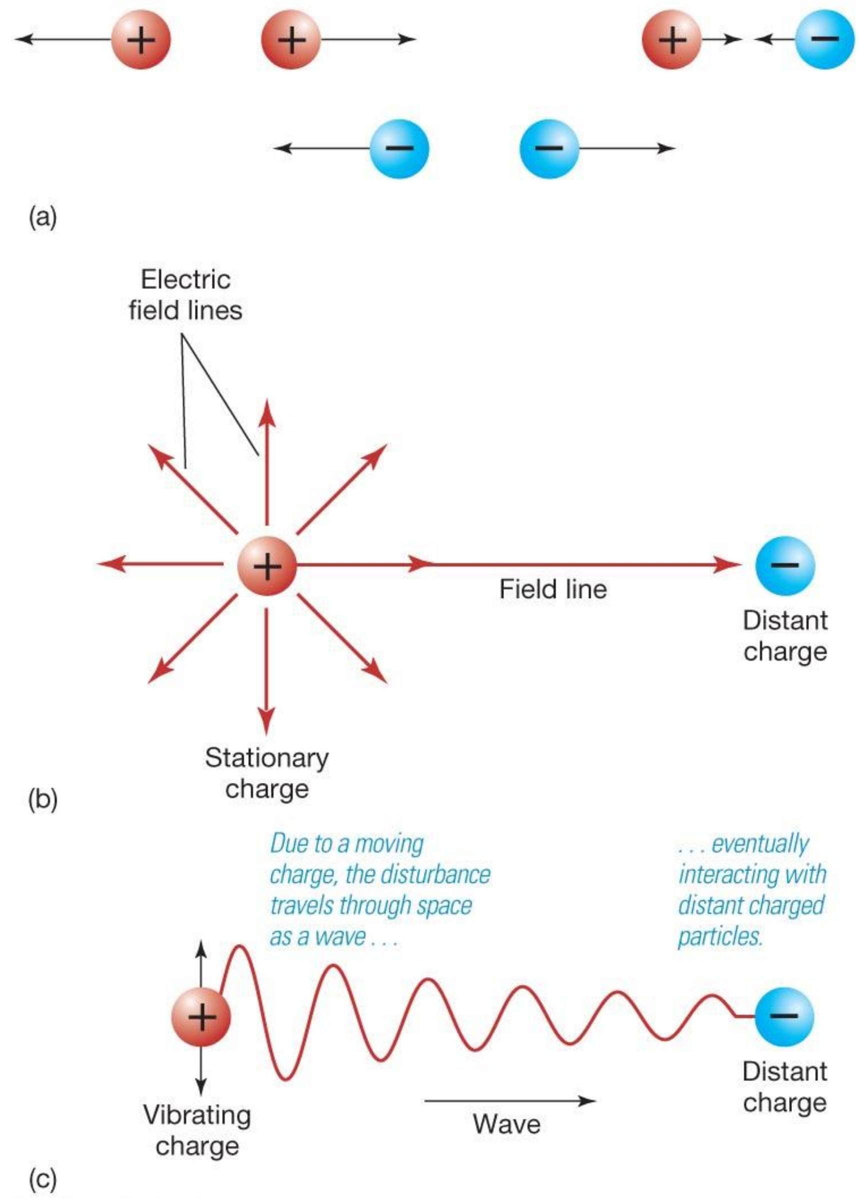


3.2 Waves in What?

Water waves, sound waves, and so on, travel in a medium (water, air, …)

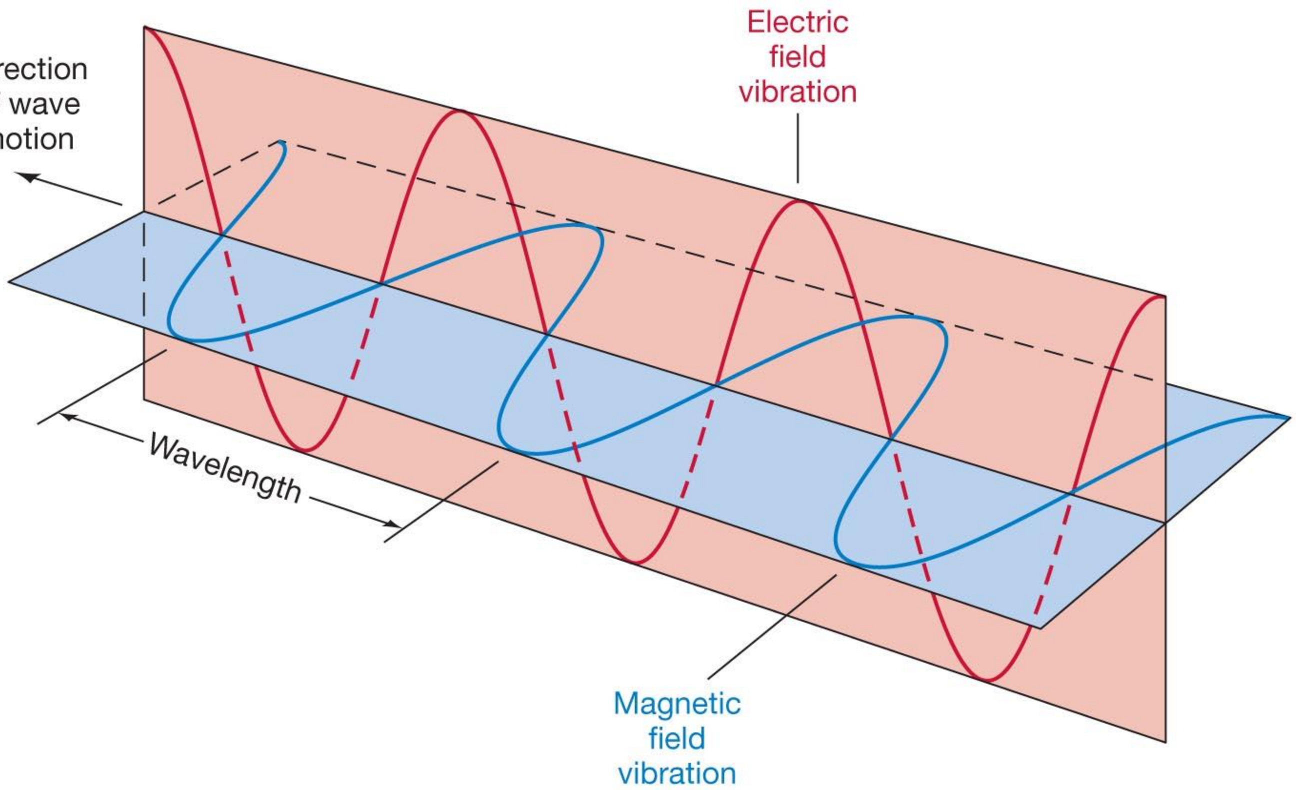
Electromagnetic waves need no medium

Created by accelerating charged particles



3.2 Waves in What?

Electromagnetic waves: Oscillating electric and magnetic fields. Changing electric field creates magnetic field, and vice versa.



3.2 Waves in What?

What is the **wave speed** of electromagnetic waves?

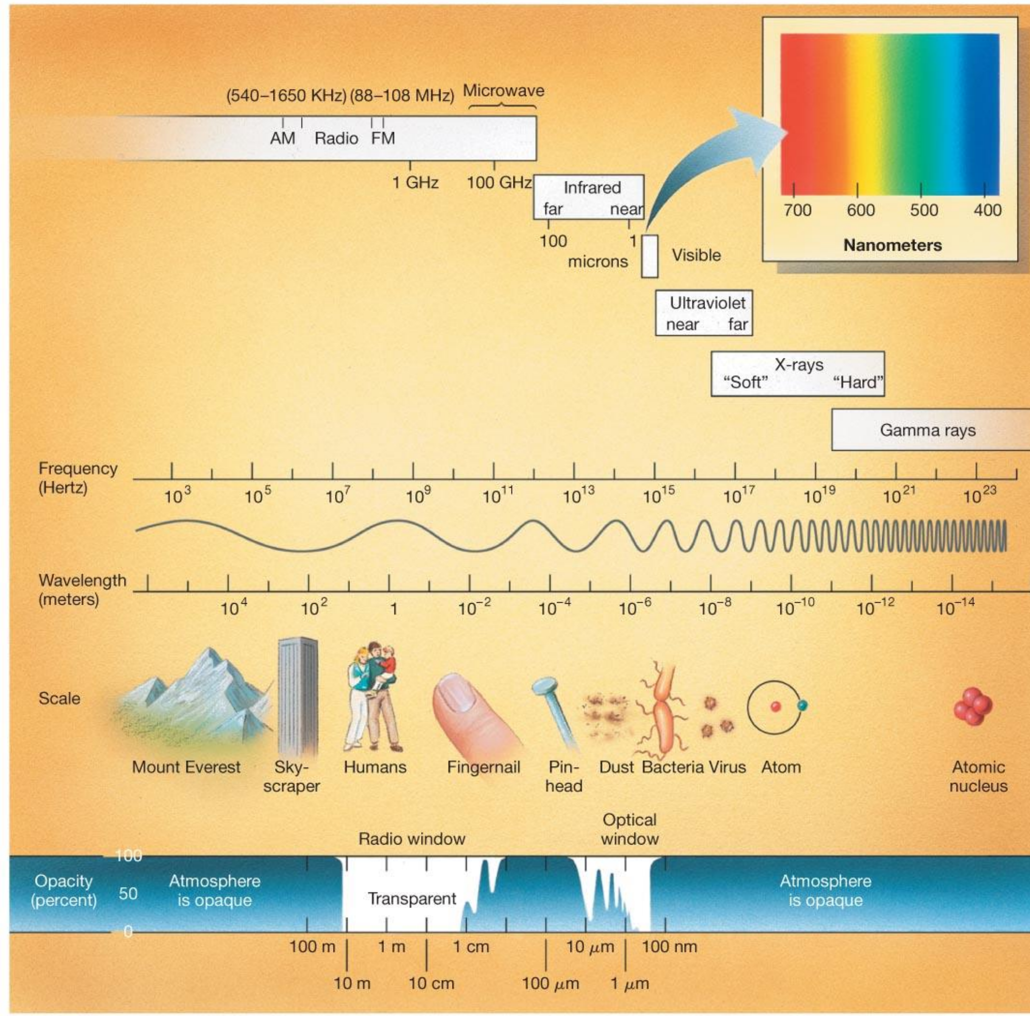
$$c = 3.0 \times 10^5 \text{ km/s}$$

This speed is very large, but still finite; it can take light millions or even billions of years to traverse astronomical distances

3.3 The Electromagnetic Spectrum

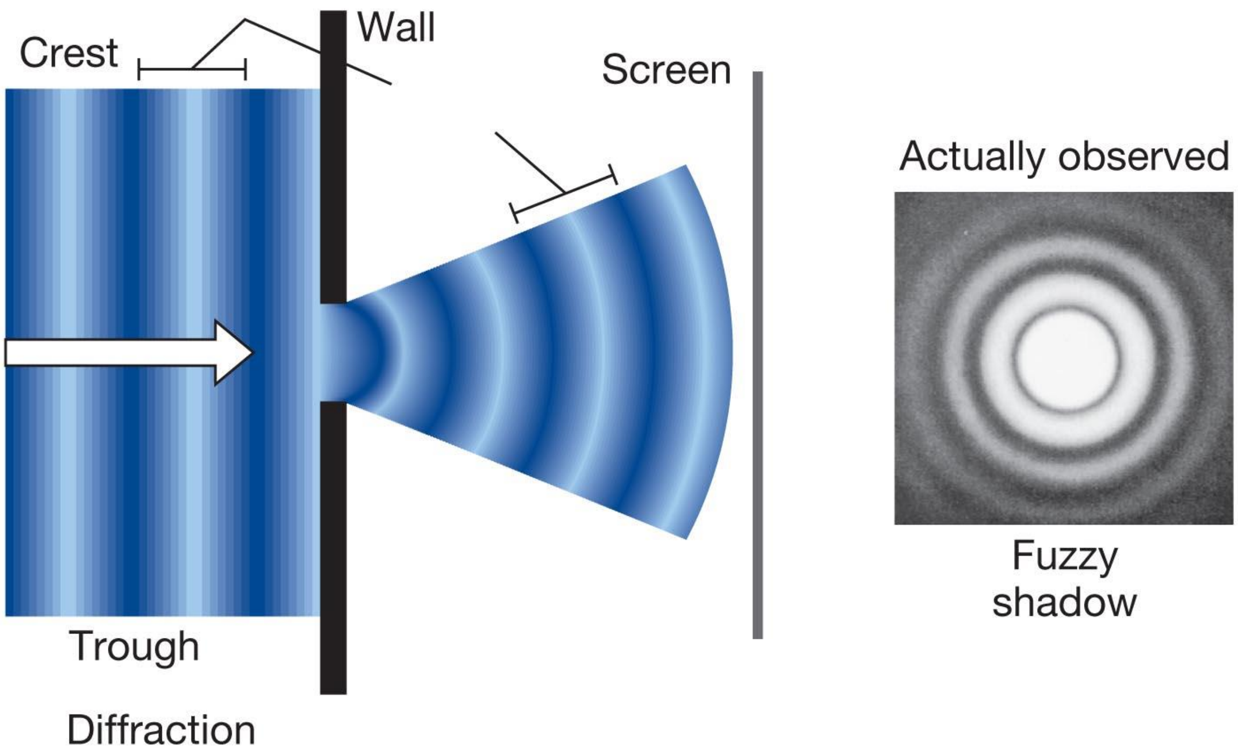
No limit on wavelengths; different ranges have different names

Note opacity of atmosphere



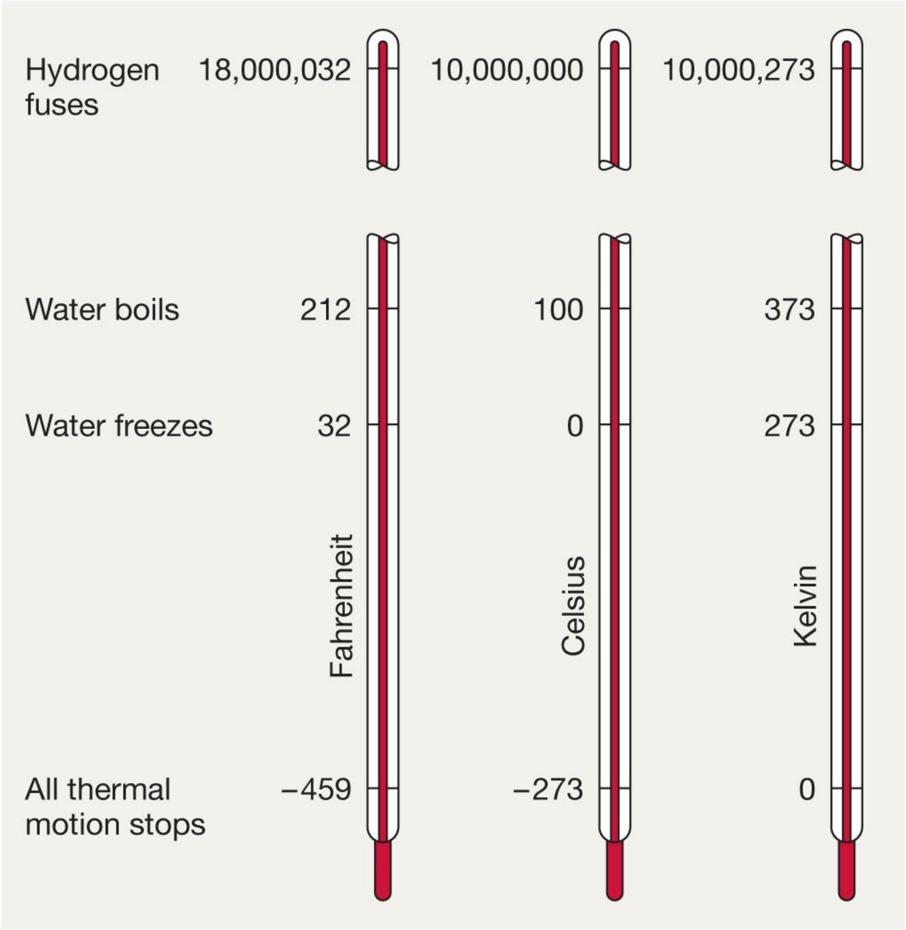
Discovery 3-1: The Wave Nature of Radiation

Diffraction is purely a wave phenomenon. If light were made of particles, we would see a spot the size of the hole, with no fuzziness.



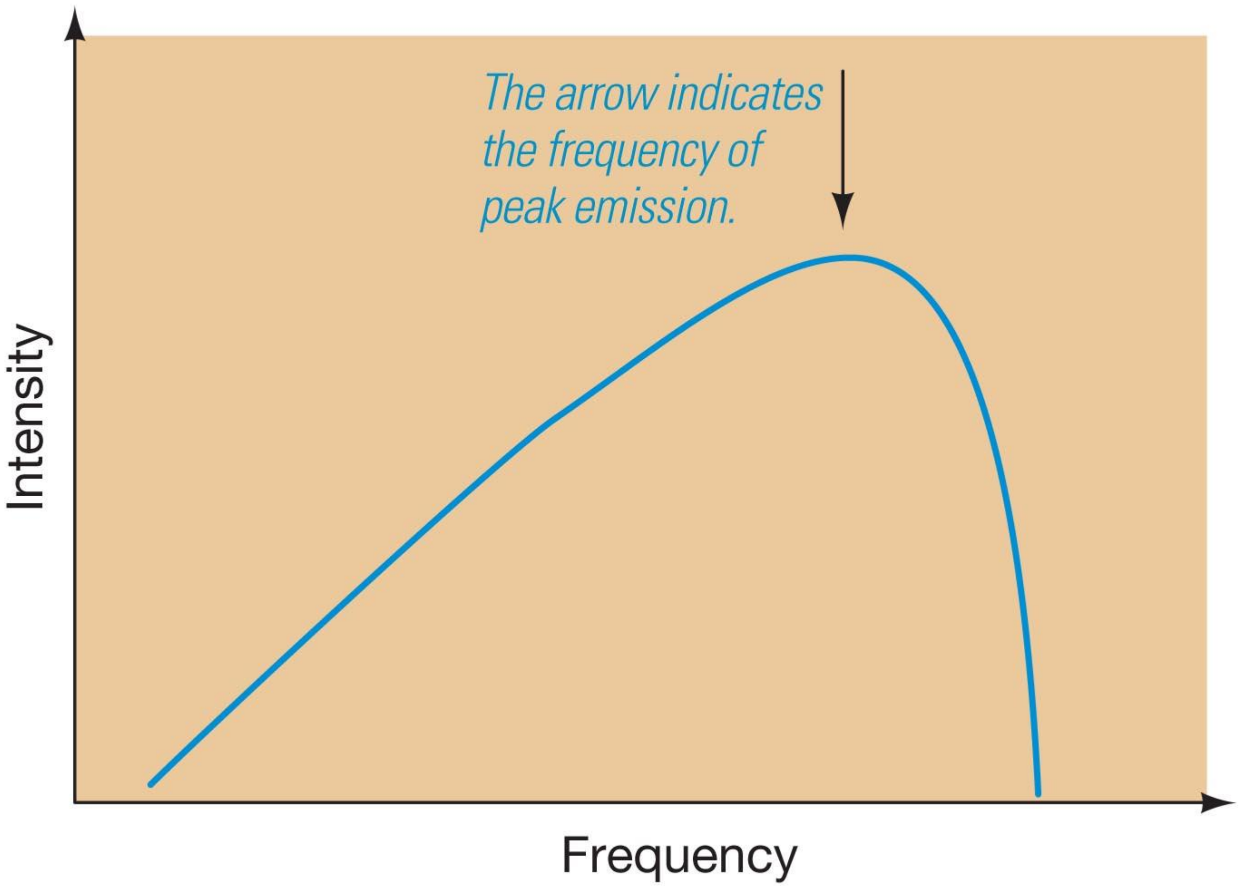
More Precisely 3-1: The Kelvin Temperature Scale

- All thermal motion ceases at 0 K
- Water freezes at 273 K and boils at 373 K



3.4 Thermal Radiation

Blackbody spectrum: Radiation emitted by an object depending only on its temperature



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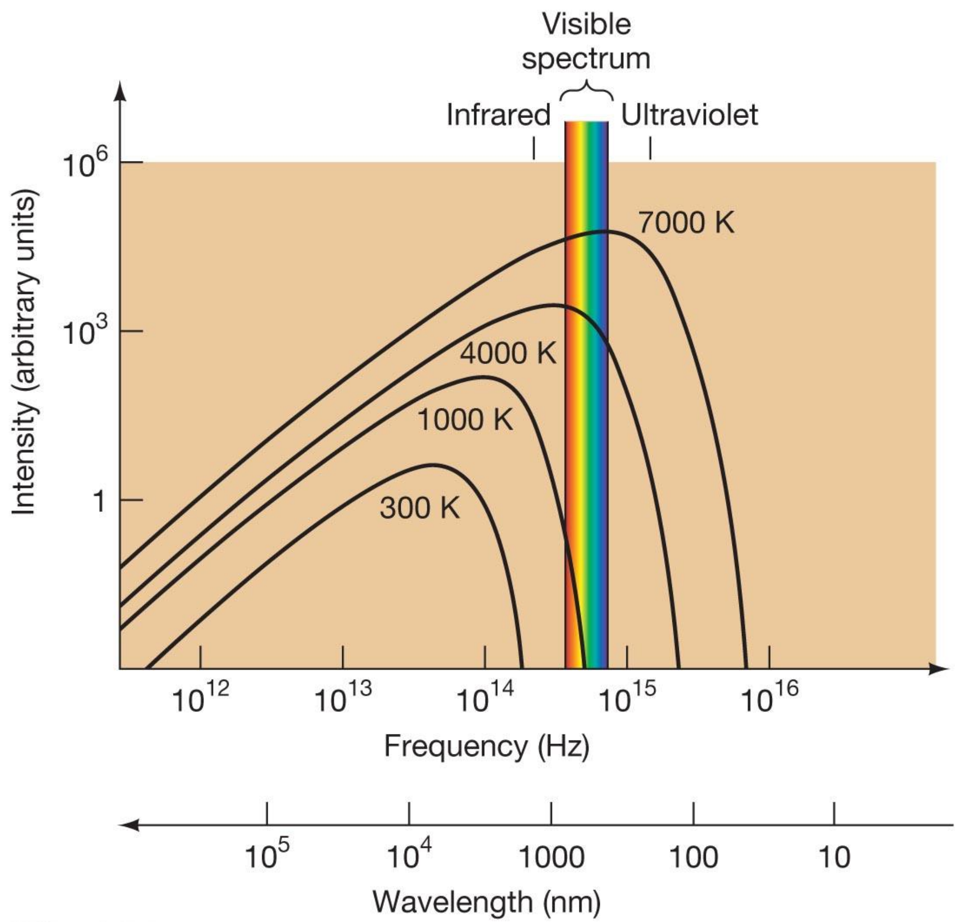
3.4 Thermal Radiation

Radiation Laws

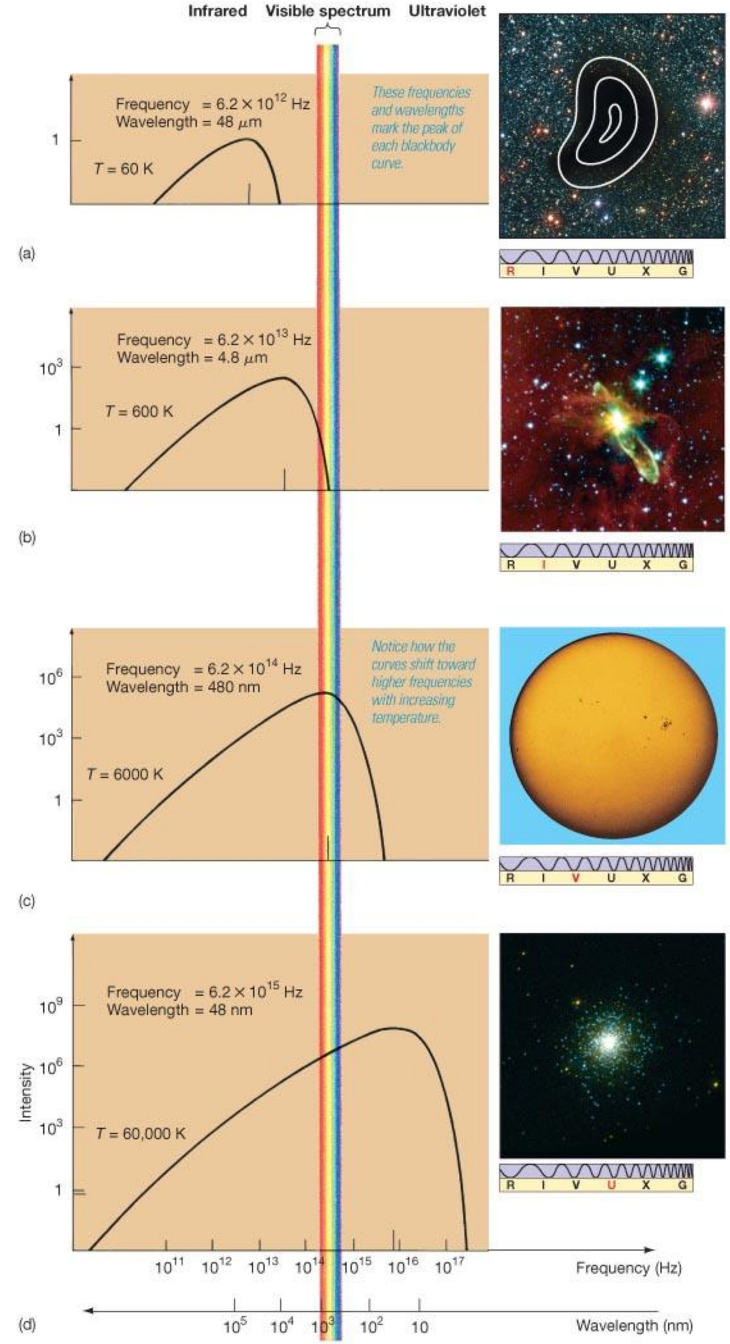
1. Peak wavelength is inversely proportional to temperature (frequency is directly proportional to temperature)



3.4 Thermal Radiation

Radiation Laws

2. Total energy emitted is proportional to fourth power of temperature (note height of curves)



More Precisely 3-2: More About the Radiation Laws

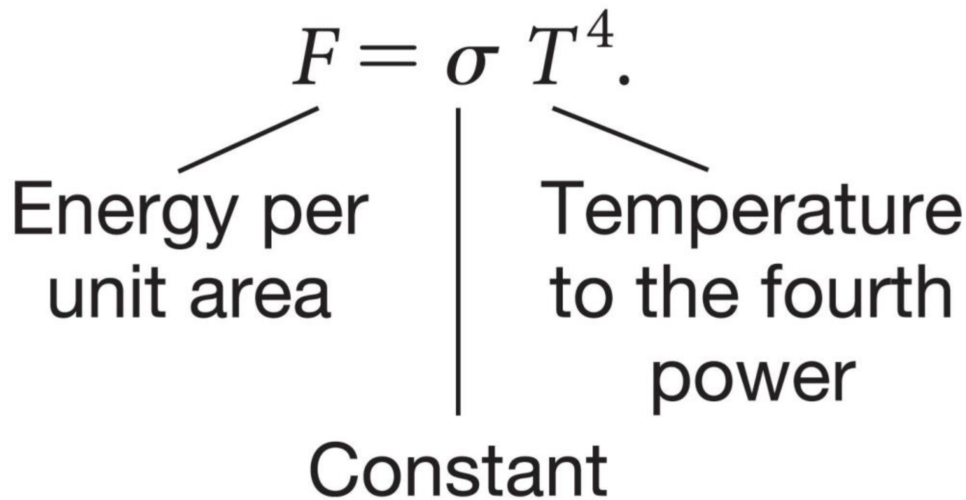
Wien's Law: If we measure T in kelvin and λ in mm, we find for the peak wavelength:

$$\lambda_{max} = 2.9\ \mathrm{mm}/T$$

Wien's Law can also be written in terms of the frequency, but this is the more familiar form.

More Precisely 3-2: More About the Radiation Laws

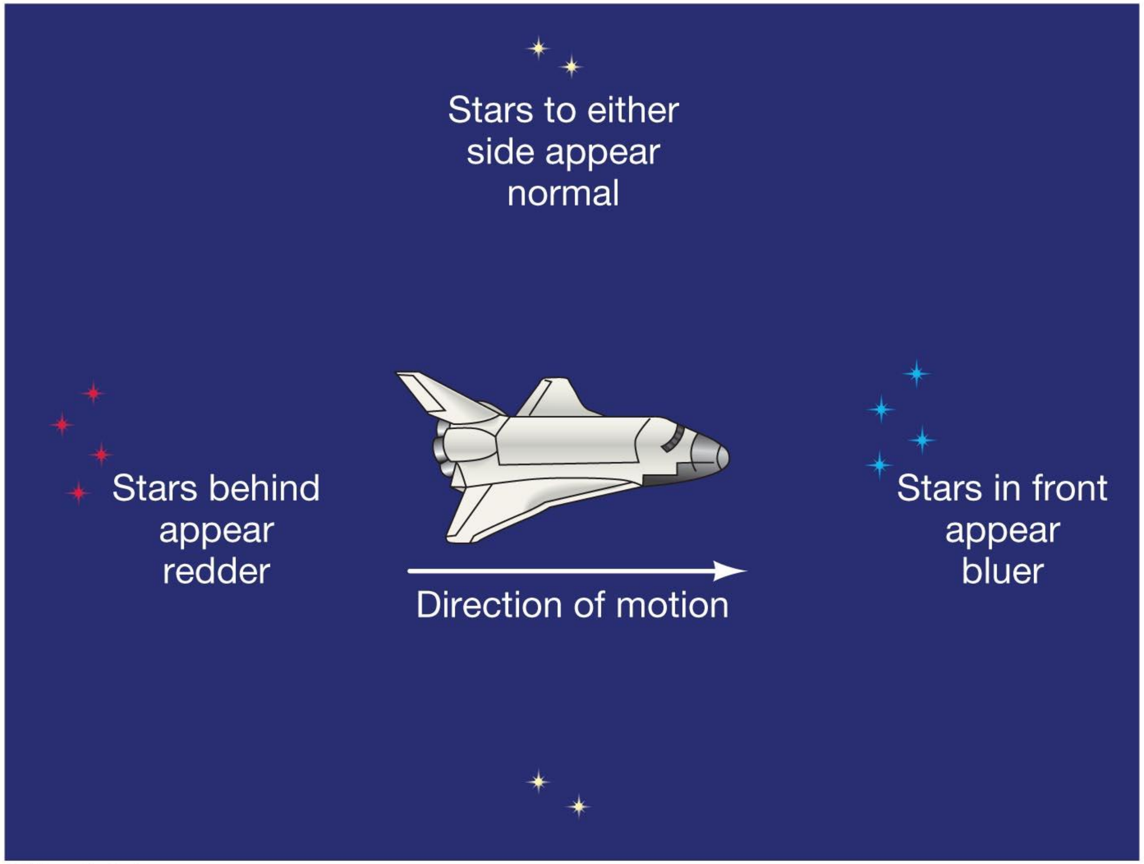
Similarly, for Stefan's Law:



If F is power per unit area and is measured in W/m^2, and T is measured in kelvin, the constant σ = 5.67 x 10^{-8} W/m$^2 \cdot$ K^4

3.5 The Doppler Effect

If one is moving toward a source of radiation, the wavelengths seem shorter; if moving away, they seem longer



3.5 The Doppler Effect

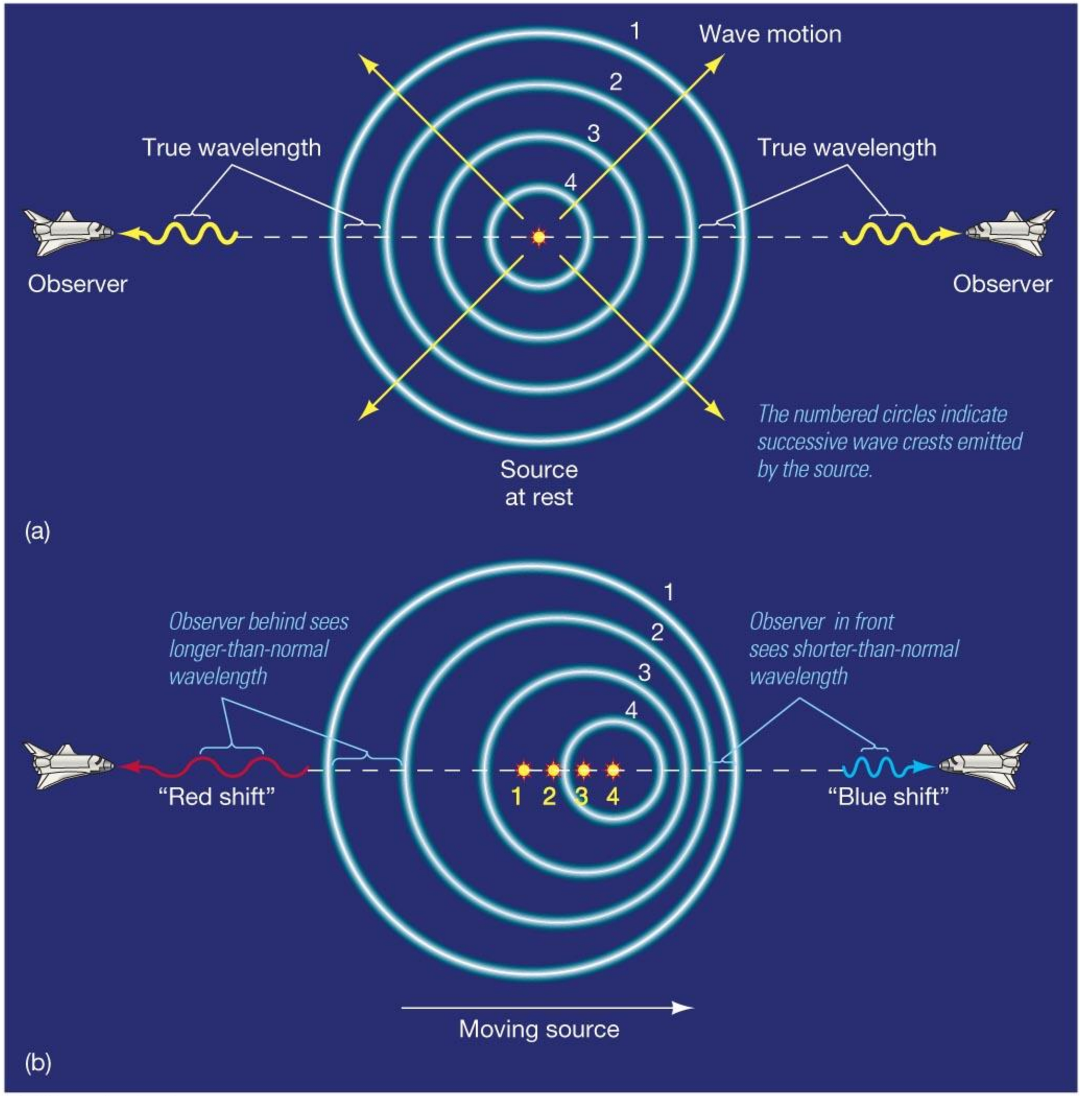
Relationship between frequency and speed:

$$\frac{\text{apparent wavelength}}{\text{true wavelength}} = \frac{\text{true frequency}}{\text{apparent frequency}}$$

$$= 1 + \frac{\text{recession velocity}}{\text{wave speed}}.$$

3.5 The Doppler Effect

Depends only on the relative motion of source and observer



More Precisely 3-3: Measuring Velocities with the Doppler Effect

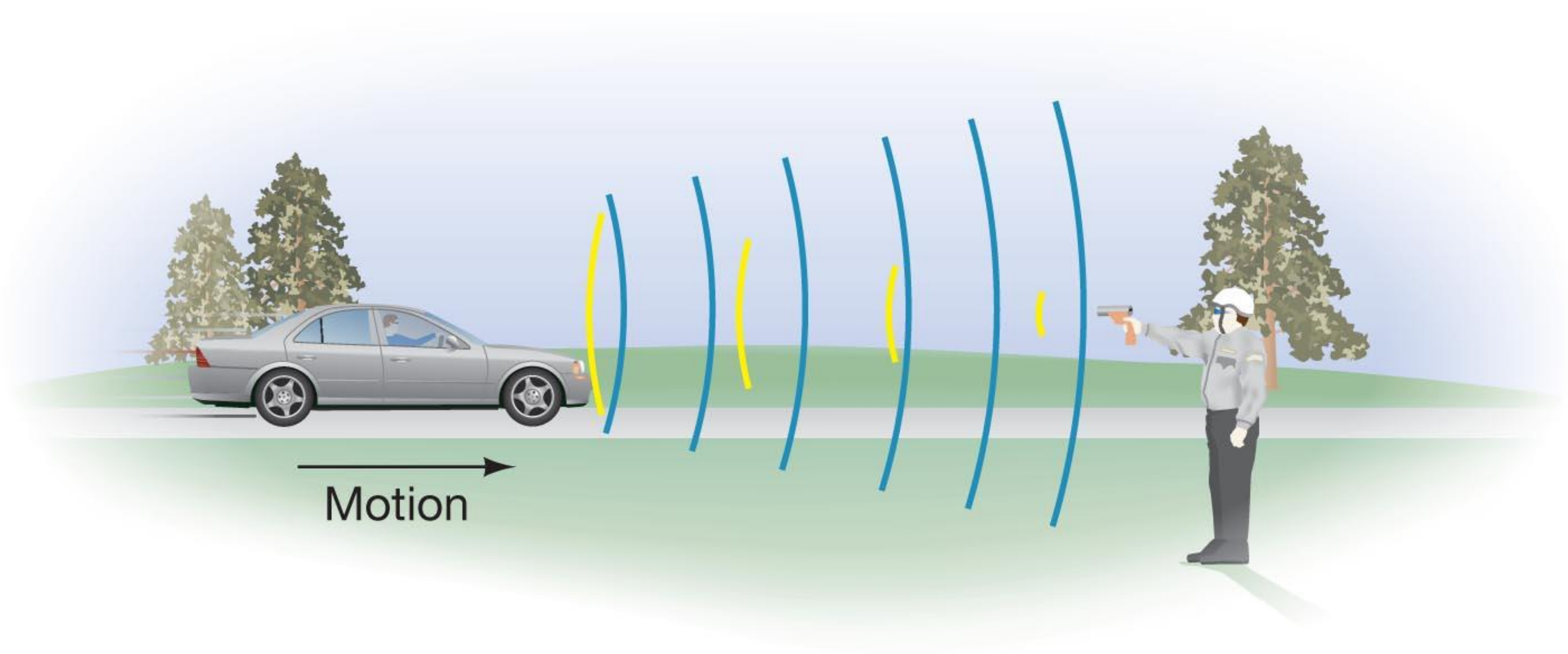
Example: For a speed of 30 km/s, the Doppler shift is given by

$$\frac{\text{change in wavelength}}{\text{true wavelength}} = \frac{\text{recession velocity}}{\text{wave speed}}$$

$$= \frac{30 \text{ km/s}}{300{,}000 \text{ km/s}} = 0.01 \text{ percent.}$$

More Precisely 3-3: Measuring Velocities with the Doppler Effect

This may seem small, but it is easily detectable with a radar gun!



Summary of Chapter 3

- **Wave: period, wavelength, amplitude**
- **Electromagnetic waves created by accelerating charges**
- **Visible spectrum is different wavelengths of light**
- **Entire electromagnetic spectrum:**

radio waves, infrared, visible light, ultraviolet, X-rays, gamma rays

Summary of Chapter 3 (cont.)

- Can tell the temperature of an object by measuring its blackbody radiation
- Doppler effect can change perceived frequency of radiation
- Doppler effect depends on relative speed of source and observer