Source Effects

What do waves “tell us” about their source?

Electromagnetic Radiation and Telescopes

I. **Waves** (chpt. 3)
Speed, frequency, wavelength, light, EMR etc.

II. **Spectroscopy** (chpt. 4)
Wein's Law, Doppler effect, spectral lines, etc.

III. **Telescopes** (chpt. 5)
Refractors, reflectors, resolution, magnification, etc.

	The student will be able to:	HW:
1	Define, illustrate, and apply the basic wave concepts of frequency, wavelength, and speed and relate these to source and medium.	1
2	Solve mathematical problems involving speed, frequency, and wavelength.	2 – 4
3	Describe and illustrate the nature of electromagnetic radiation.	5
4	State the six major regions of the electromagnetic spectrum in order of frequency and/or wavelength.	6 – 8
5	State the colors of the visible spectrum in order of frequency and/or wavelength.	
6	Define, illustrate, and apply the concepts of diffraction, interference, opacity and transparency.	9 – 10
7	Explain, illustrate, and apply the basic concepts of blackbody radiation.	11 – 12
8	Solve mathematical problems using Wein's law.	13 – 15
9	Explain, illustrate, and apply the concept of the Doppler effect and the astronomical terms of redshift and blueshift.	16 – 17
10	Describe the characteristics of continuous, emission, and absorption spectra and the conditions under which each is produced.	18 – 21
11	Explain how spectral lines and the width and intensity of those lines are related to properties of atoms and or molecules.	22 – 25
12	Describe and illustrate the two main types of optical telescopes – refracting and reflecting and contrast in terms of resolution, light gathering, and aberrations.	26 – 32
13	Describe how the Earth's atmosphere affects astronomical observations and current efforts to improve ground-based astronomy.	
14	Compare and contrast telescopes that create images using nonvisible radiation.	
15	Solve mathematical problems relating magnification to focal lengths of objective and ocular.	33 – 34
16	Solve mathematical problems relating angular resolution to wavelength and diameter.	35 – 38
17	Solve mathematical problems involving light gathering capacities.	39 – 42

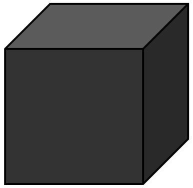
Effect of Source on Wave

I. **Blackbody Radiation & Wein's Law (effect of temperature)**
II. Doppler Effect (effect of motion)
III. Spectroscopy (effect of atomic properties)

Blackbody Radiation

- Any object will naturally emit some amount (and type) of electromagnetic radiation!
- This radiation is a result of the inherent temperature of the object. This radiation represents energy lost by the atoms that make up the substance.
- It is called *black*body radiation to distinguish it from radiation that may be reflected or otherwise emitted by the object. (*i.e.* even an otherwise perfectly black object would emit *this* type of radiation!)

Blackbody Radiation

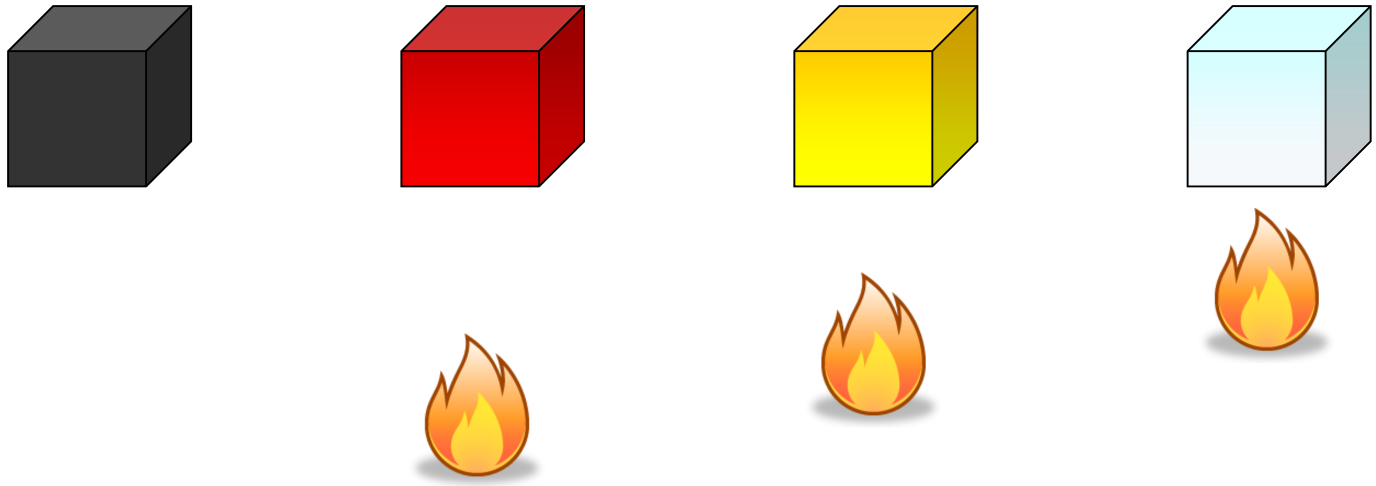


Oh, look! A "black body"!

(*i.e.* an object that happens to be black…)

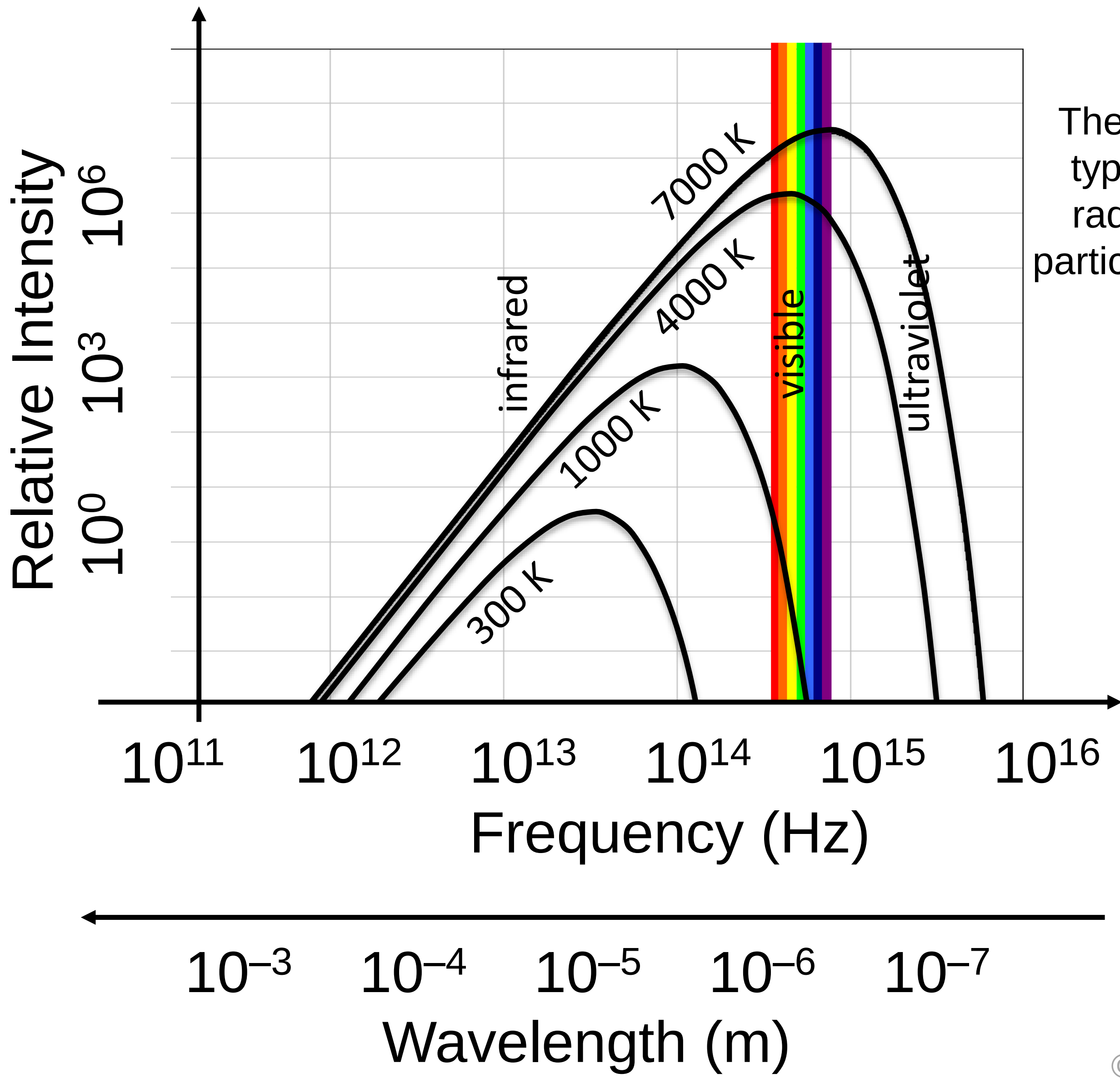
Let's put it in the fire!

Blackbody Radiation



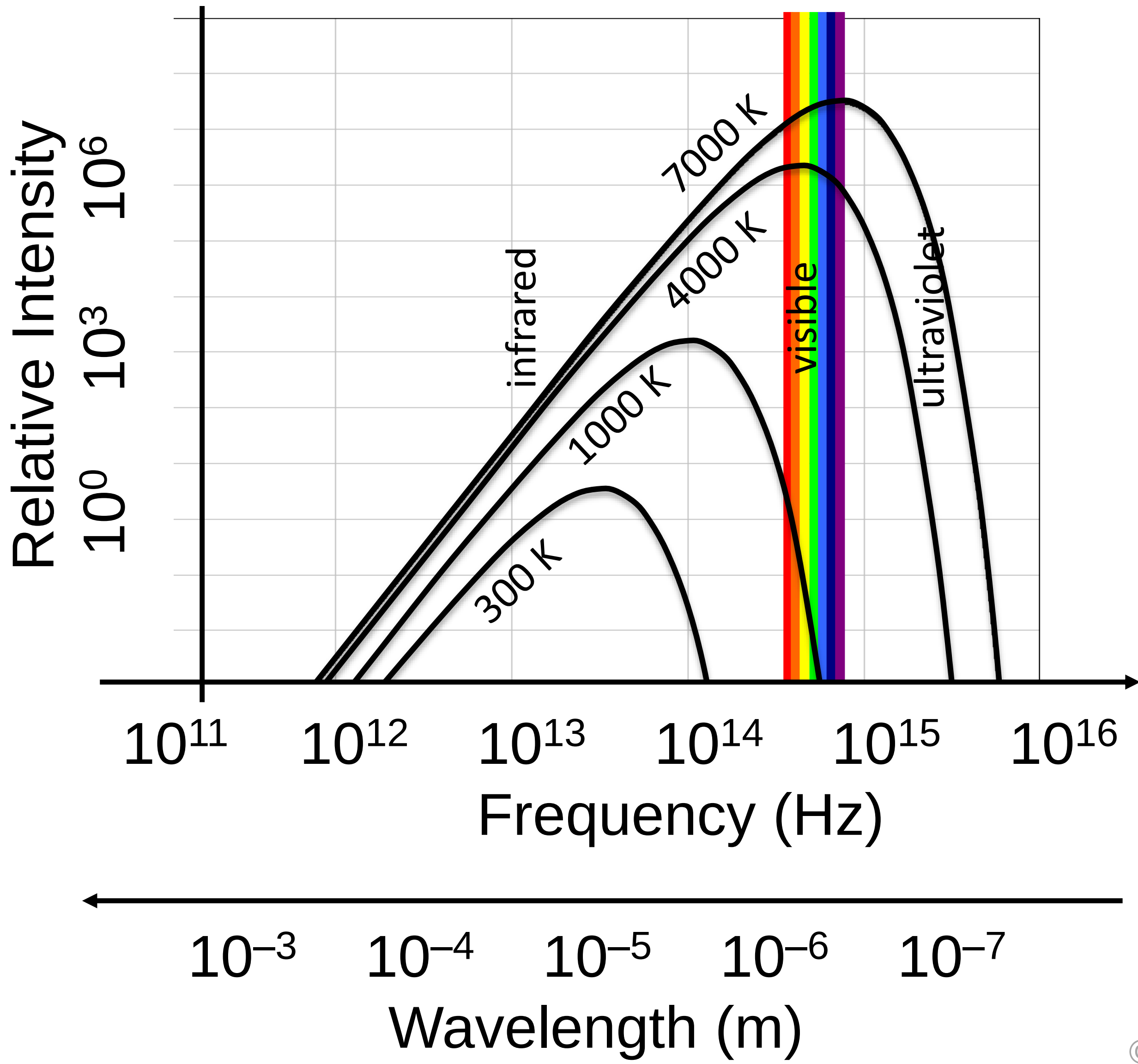
Imagine a cube of iron – at room temperature it appears almost black, very little color. However, as it temperature increases it starts to glow – first reddish, then yellow, orange, white… And, if the temperature increases enough, might turn bluish-white (though actual iron would melt before this occurs). The cubes shown hear represent objects at temperatures 300 K, 1000 K, 4000 K, and 7000 K.

Blackbody Radiation



The curves show the type and amount of radiation emitted at particular temperatures.

As an example – consider the curve for 1000 K (730 ºC, 1300 ºF). Most of the curve shows radiation in the infrared range of frequency and wavelength. The highest point of the curve is at about 10^{14} Hertz – an object at this temperature would emit more of this particular type of infrared energy than anything else. However, notice the curve extends into the visible region. This means that the object would emit *some* red, orange, and yellow light (but mainly red – glowing "red hot").

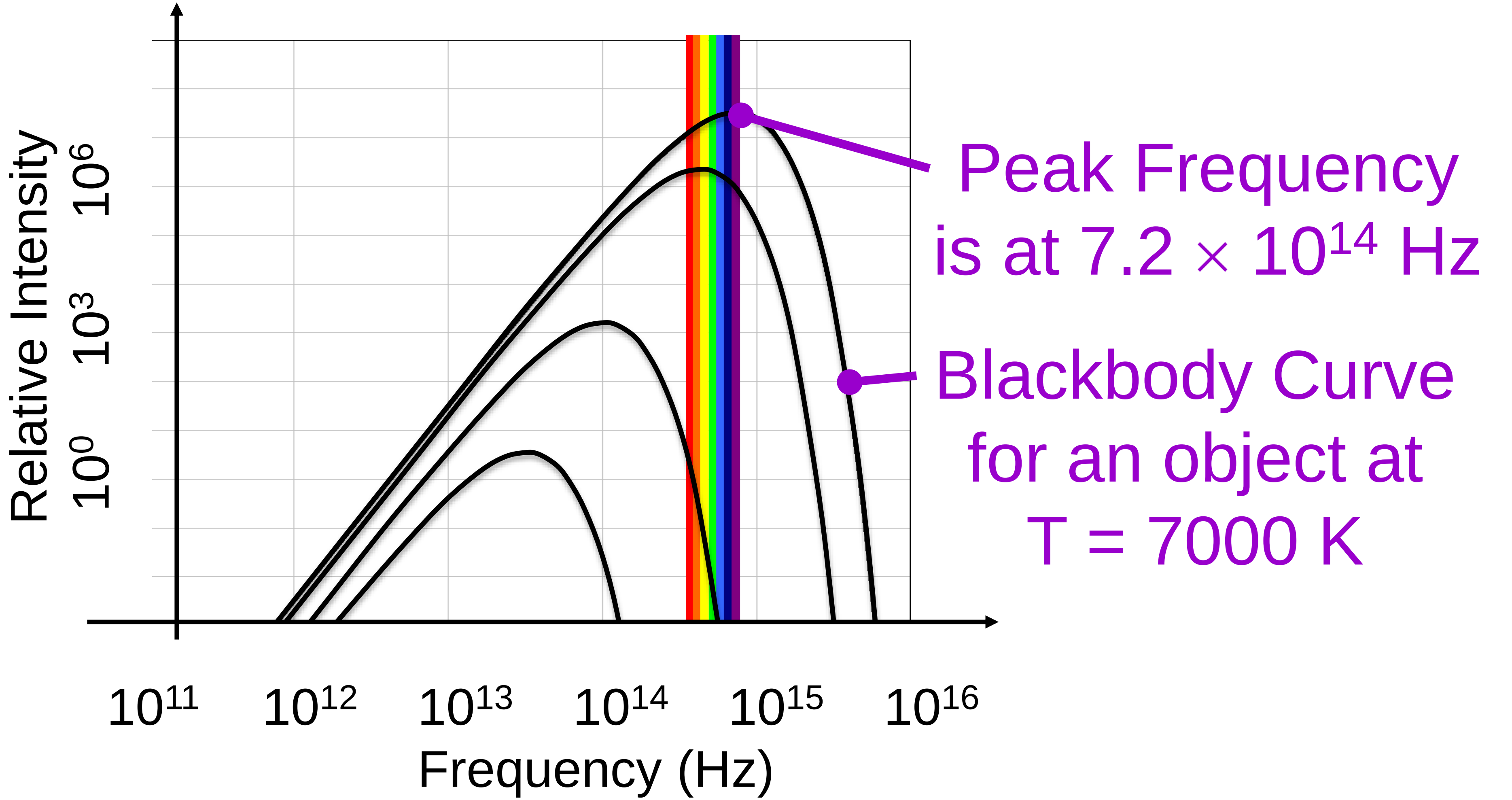


Blackbody Radiation

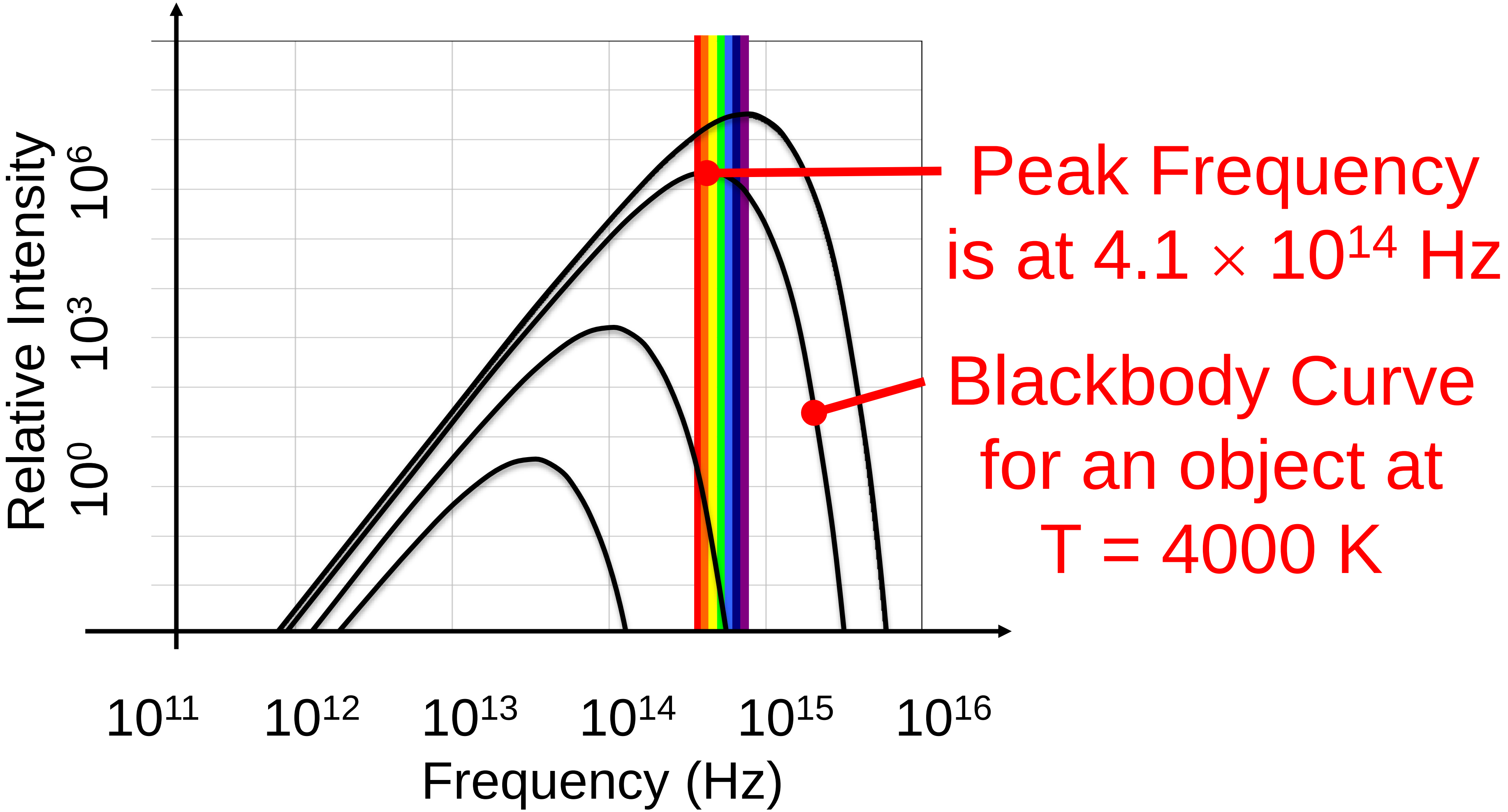
The hotter the object, the greater the *amount* of radiation and the greater the *frequency* of the radiation that it emits.

The blackbody curve reveals the frequency or wavelength at which the object emits the *most* radiation. This is called the peak frequency or peak wavelength.

Blackbody Radiation



Blackbody Radiation



Blackbody Radiation

Wein's Law relates the peak *wavelength* of the radiation to the temperature of the object.

$$\lambda_{peak} = \frac{0.29}{T}$$

where: λ = wavelength in cm
T = temperature in K

1. A certain star has a temperature of 7000 K. At what wavelength and frequency does it emit the most radiation?
2. An oven is heated to 204 ºC (400 ºF). Determine the peak wavelength and frequency of the radiation it emits.
3. At what temperature would an object's blackbody radiation peak at wavelength 532 nm (that of the green laser pointer)?
4. Suppose astronomers determine that a particular star emits radiation that peaks at wavelength 216 nm. What is the temperature of this star?

5. The Spitzer Space Telescope was designed to produce infrared images from 3 to 180 μm. This makes it best suited for studying objects with what range of temperatures?
6. The Spitzer Space Telescope was cooled to an operating temperature of 5.5 K. At what wavelength would the telescope's blackbody radiation peak?

Effect of Source on Wave

I. Blackbody Radiation & Wein’s Law
(effect of temperature)

II. Doppler Effect
(effect of motion)

III. Spectroscopy
(effect of atomic properties)

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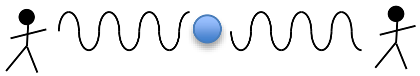
the Doppler Effect

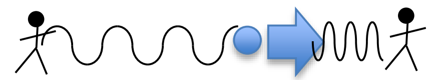
- The Doppler Effect refers to change in frequency and/or wavelength due to motion of wave source and/or observer.
- If source and observer are moving apart there is an increase in wavelength and decrease in frequency.
- If source and observer are moving together there is a decrease in wavelength and increase in frequency.

Source at rest:



No Doppler Effect. Same freqency and wavelength observed on all sides.

Source in motion:

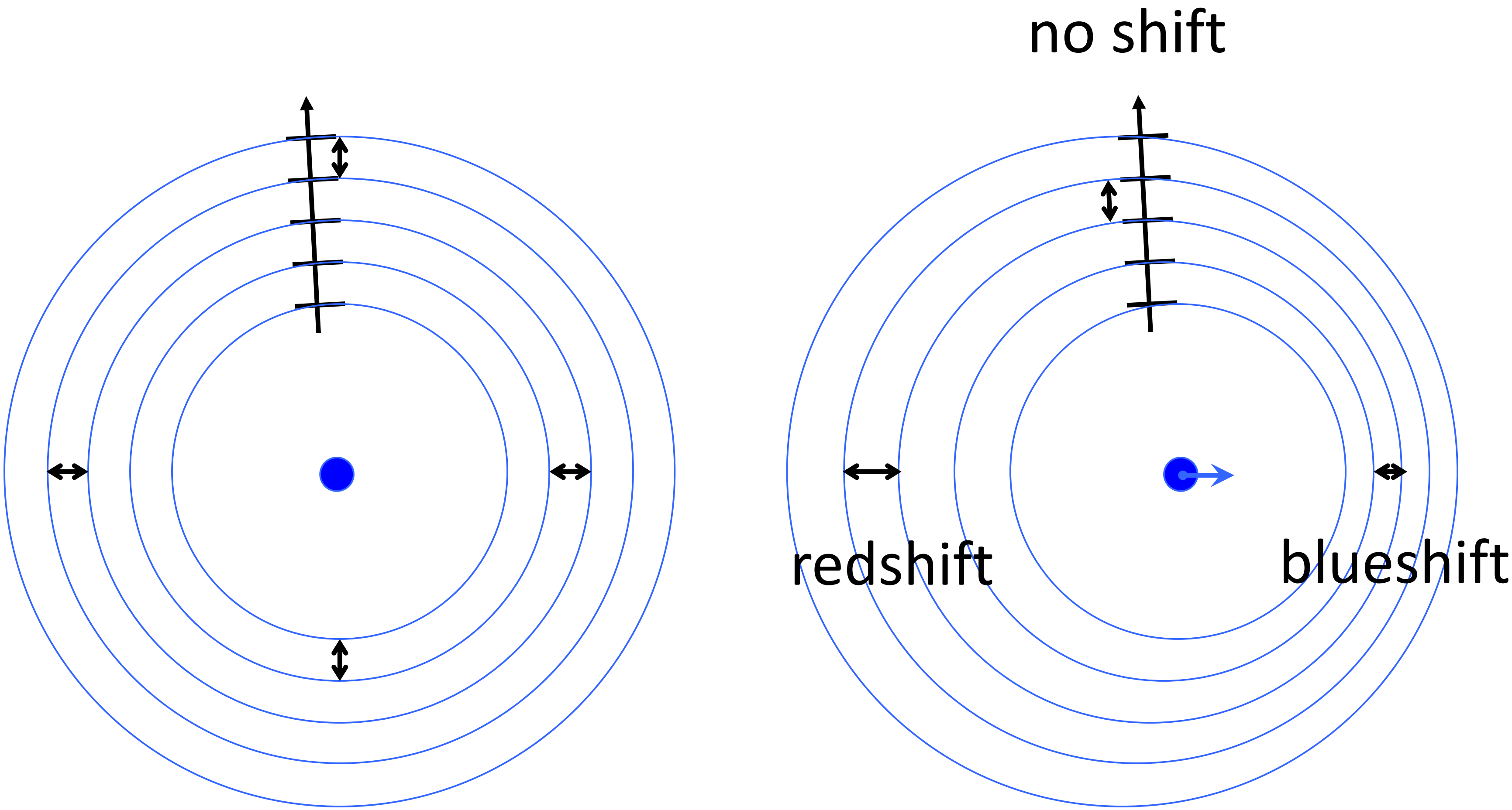


This guy observes lesser frequency longer wavelength than original wave.

This guy observes greater frequency shorter wavelength than original wave.

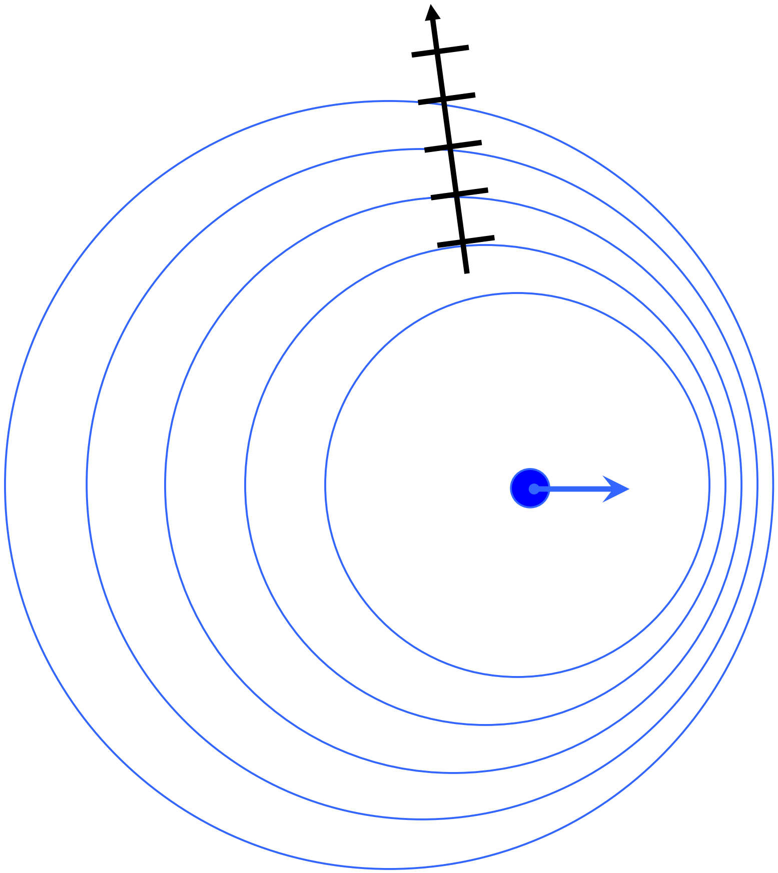
Redshift and Blueshift

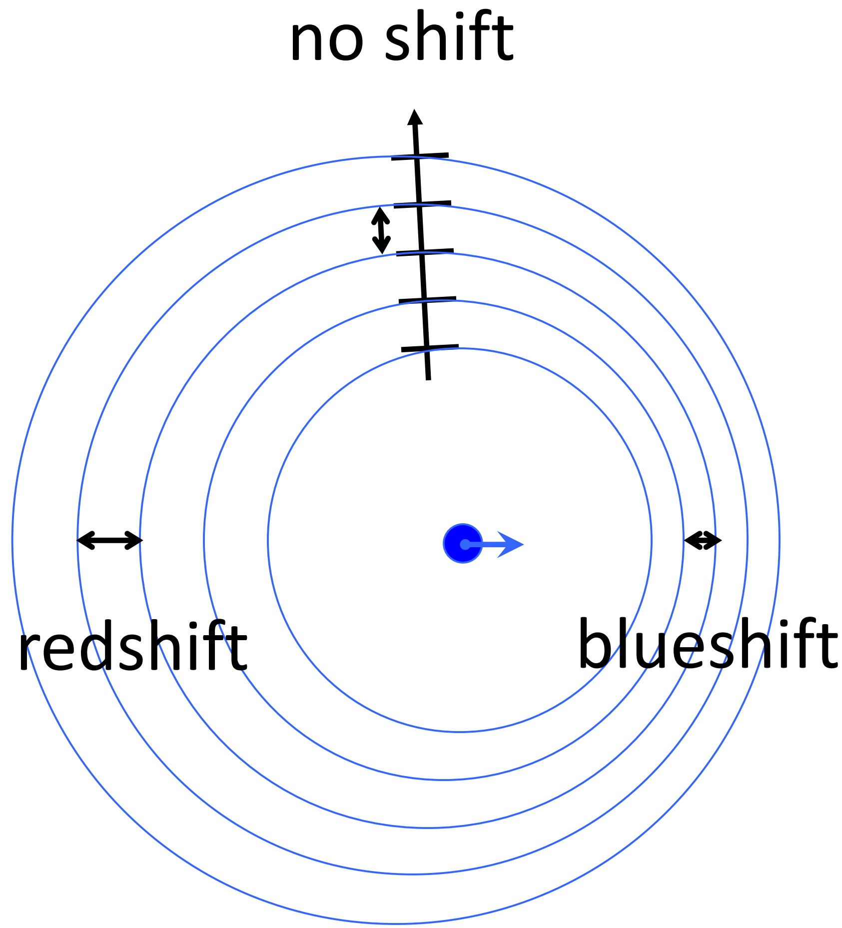
- Astronomers use the terms "redshift" and "blueshift" to describe the Doppler Effect on light and other forms of EMR.
- Redshift = source of light receding, wavelength increased (shifted toward red).
- Blueshift = source of light approaching, wavelength decreased (shifted toward blue).



Stationary Source:
Equal wavelength in
all directions

Moving Source:
Longer wavelength “behind”
Shorter wavelength “ahead”





Greater speed results in greater amount of “shift” in wavelength

Moving Source:
Longer wavelength “behind”
Shorter wavelength “ahead”