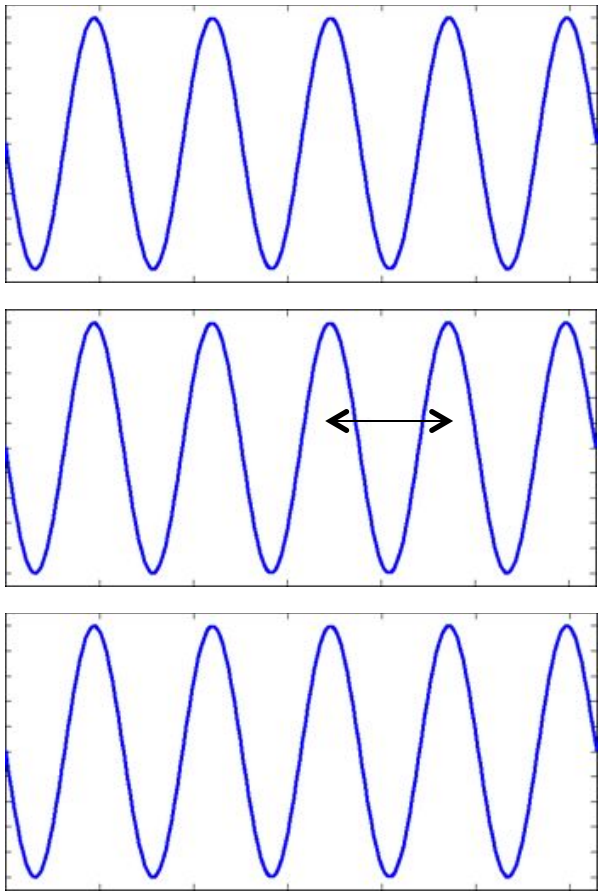
Introduction

- Light and Distance [Ch 3.1-3.3]
- Temperature [Ch 3.4]
- Doppler Effect [Ch 3.5]
- Angular Measure [Ch 1.3, box p 11]

Waves

Three Wave Properties

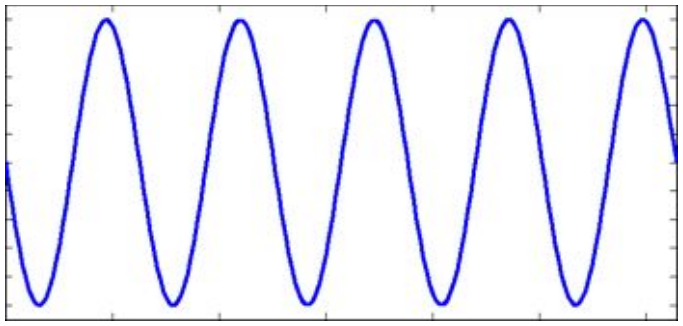


Velocity c [m/s]

Wavelength λ [m]

Frequency f or ν [Hz]
(# of waves passing each second)

Count here



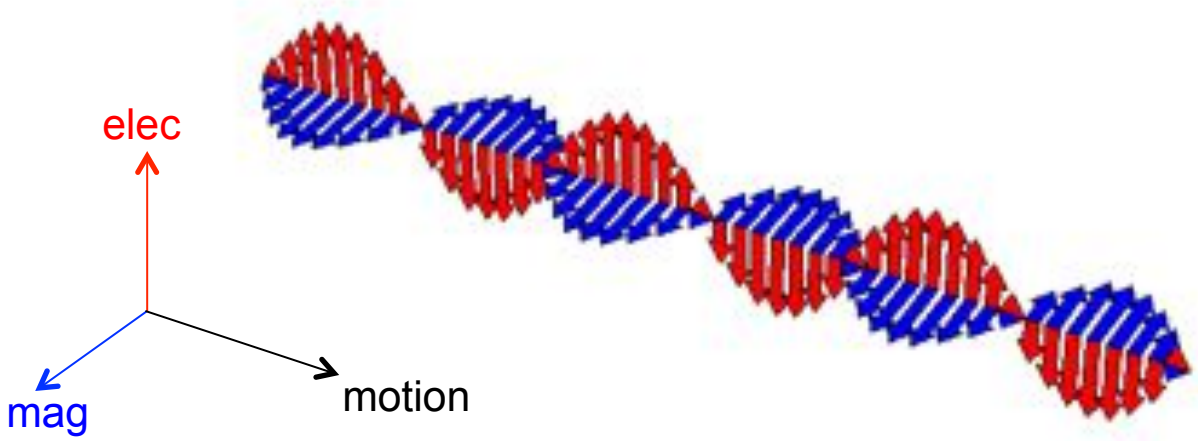
Three Wave Properties

- Not surprisingly, these 3 quantities are related: wavelength = wave speed divided by frequency, or $\lambda = c / f$

- *In this course we will mainly use wavelength rather than frequency.*

Light

- Light “acts like” a wave.
- The wave is a wave in electric field and magnetic field.



Light

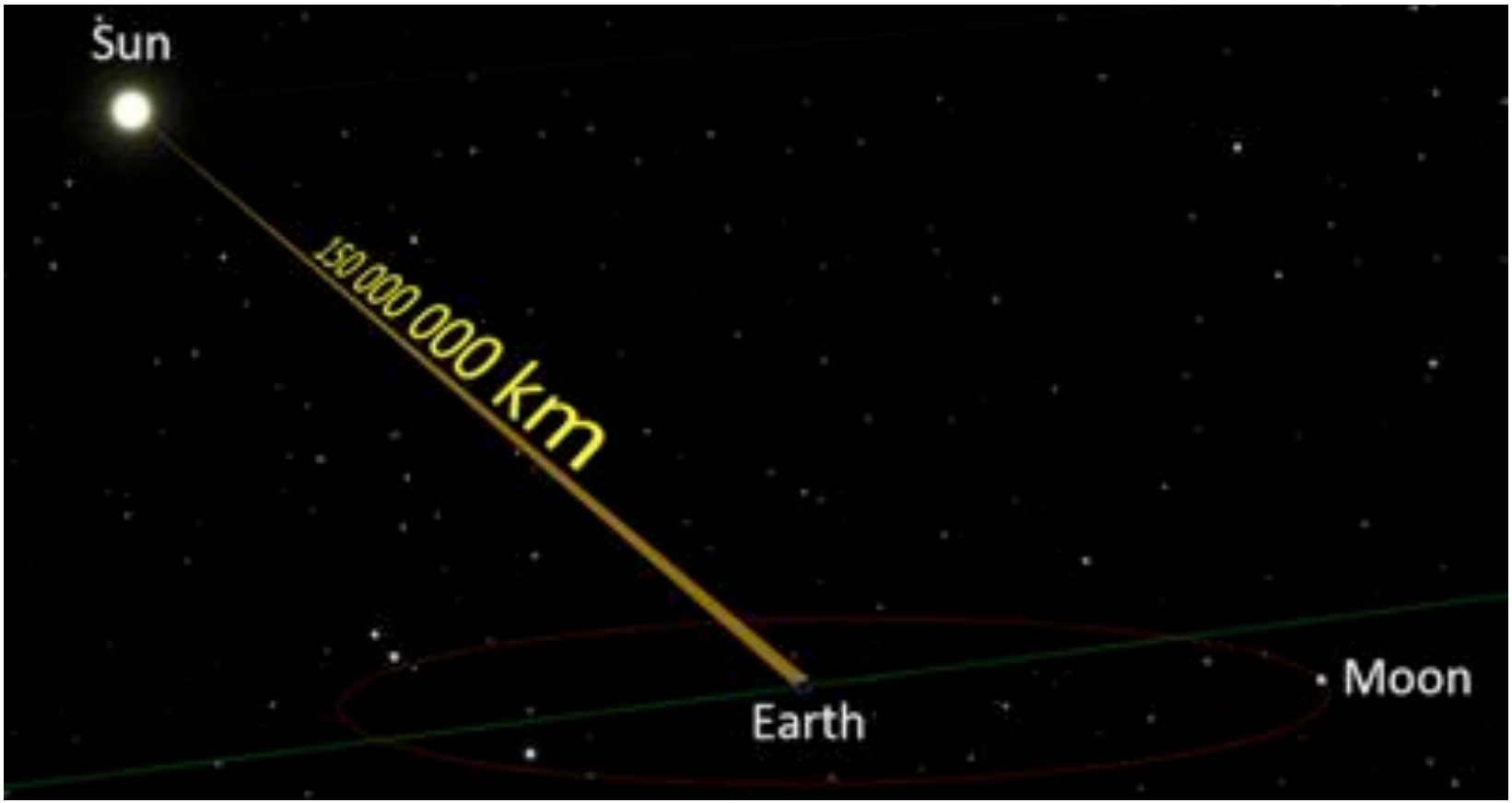
- Water waves, sound waves, … need a "medium" to propagate. But …
- Light needs no medium – propagates in a vacuum.

Speed of light, c

- c = 300,000 km per second!
- c = 3 x 10^8 meters per second (actually 299,792,458 m/s)
- Nothing can travel faster than the speed of light

- First “determined” by Ole Rømer 1656

Light distance



Light takes 8 min 19 sec to travel from the sun to the earth.
Or, sun is 8.3 light minutes in distance.

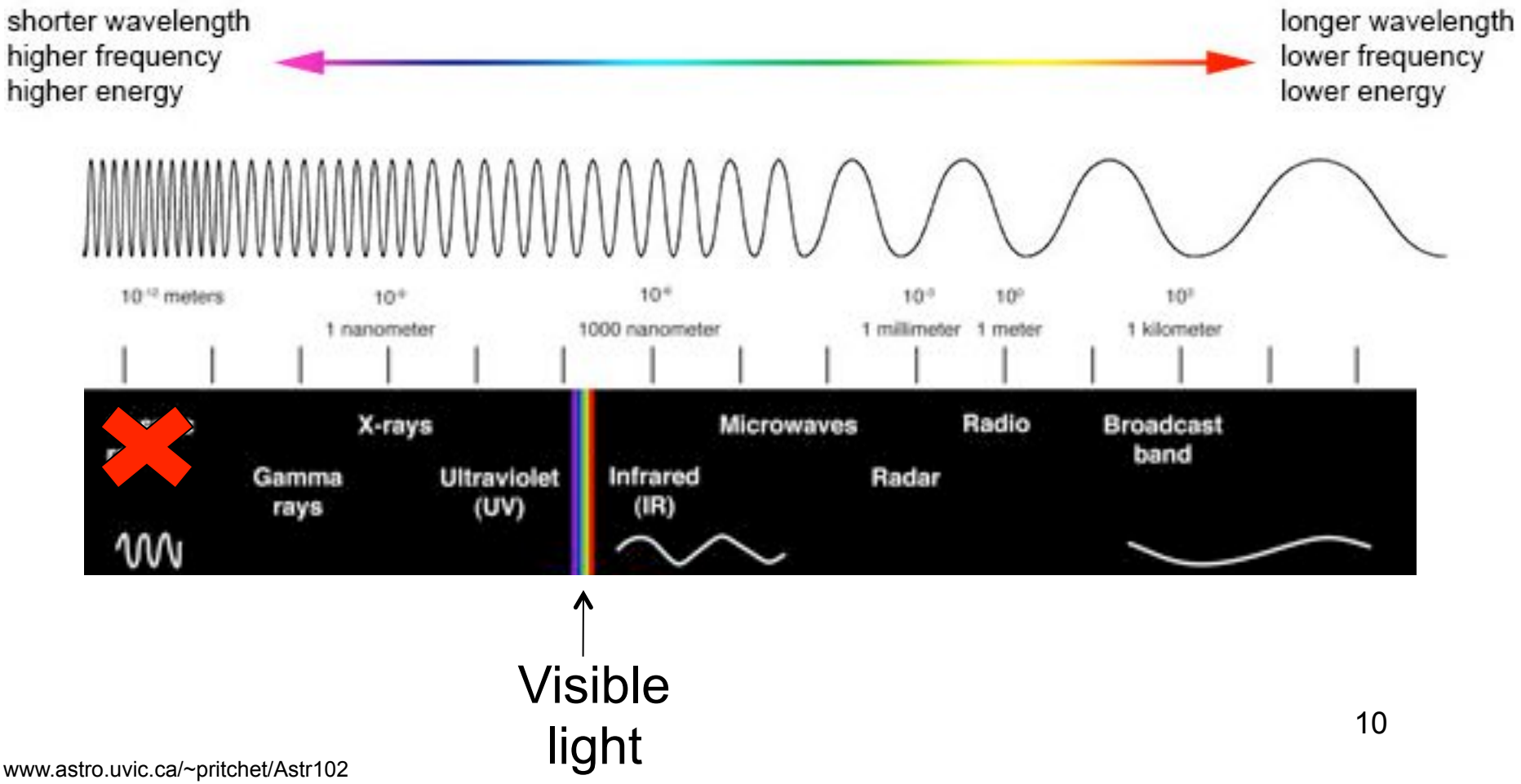
Light distance

- One light year = distance travelled by light in one year = about 10^{13} km
  - Nearest star is 4.2 light years distant

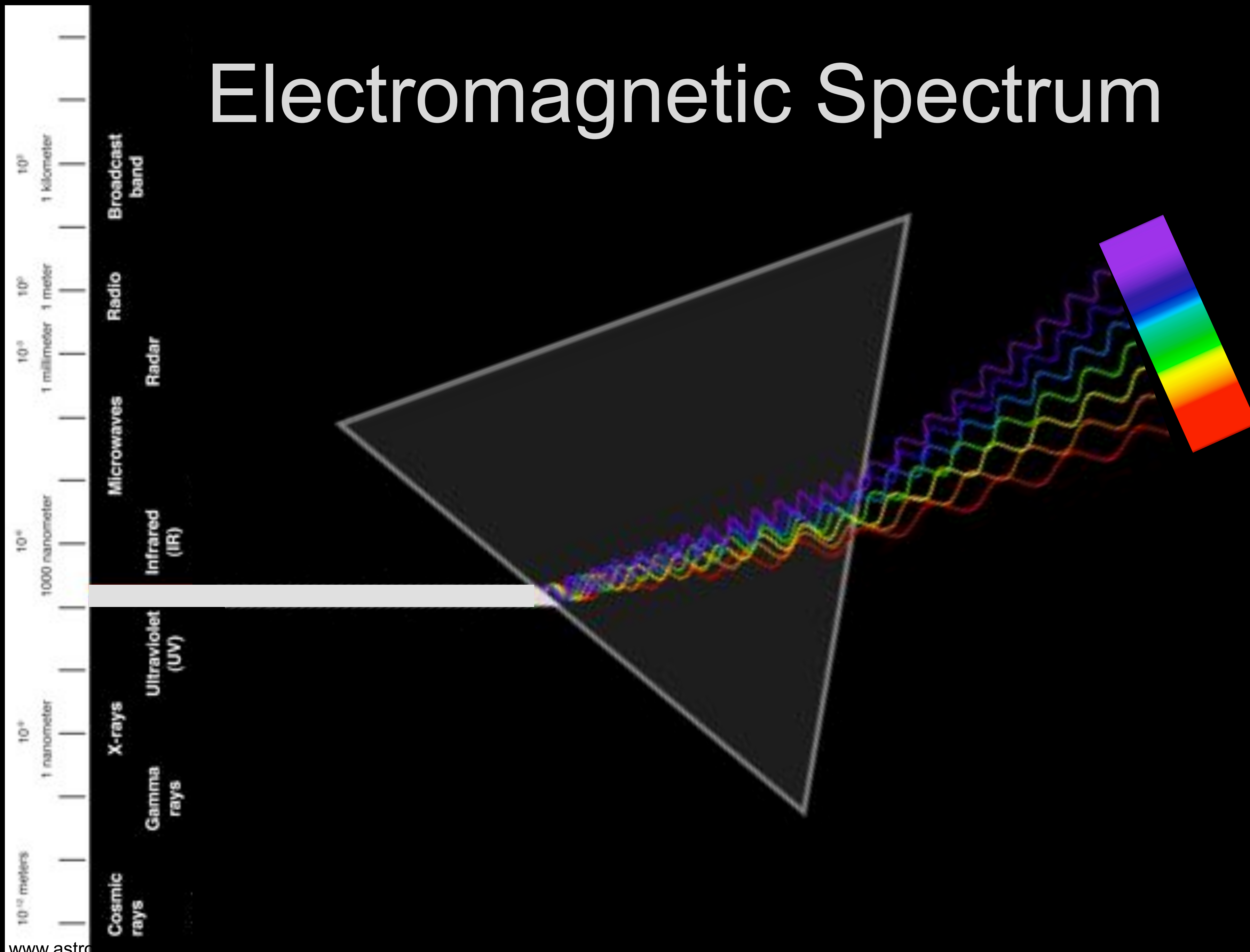
- *Alternate:* one parsec = 3.26 light years
  - Nearest star is 1.4 pc distant

The Electromagnetic Spectrum

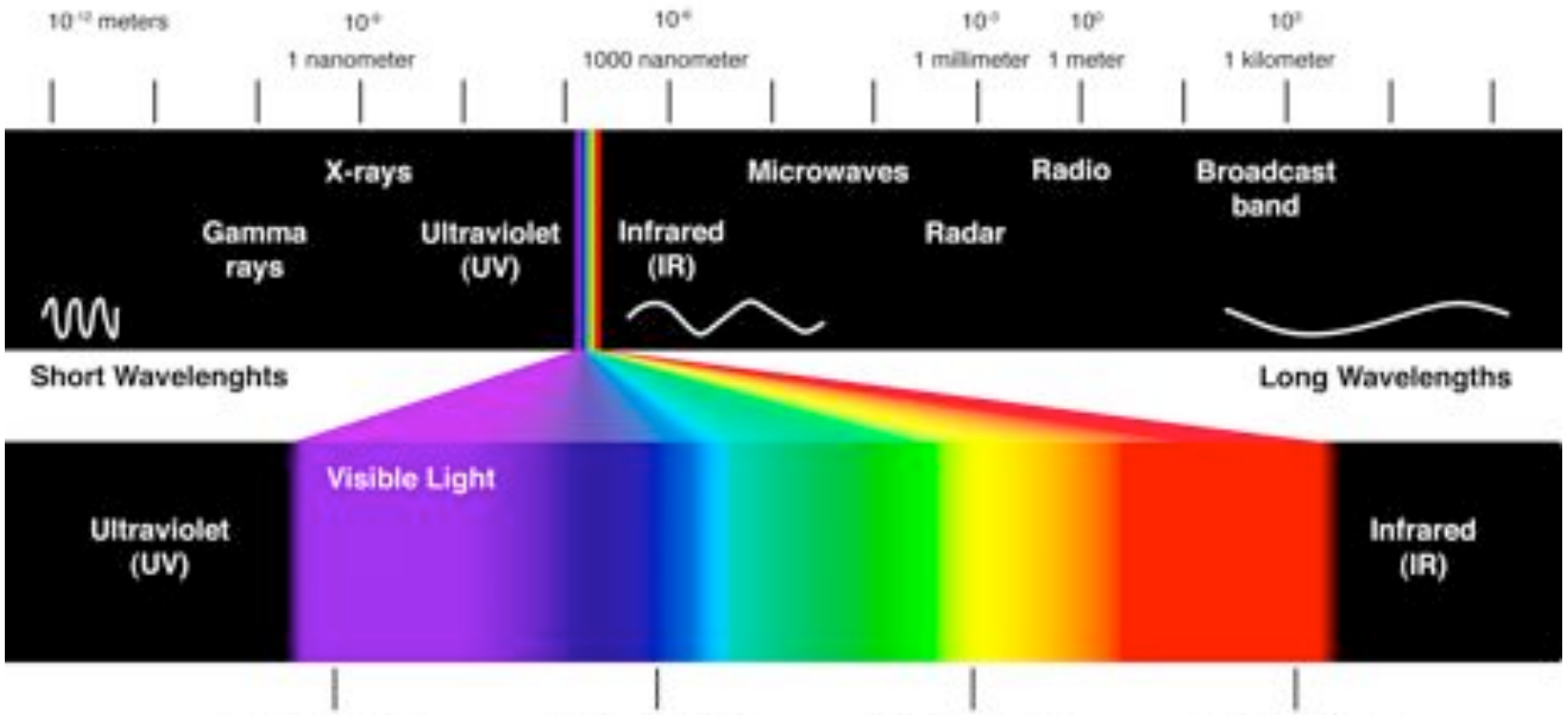
"The Spectrum of Light"



Electromagnetic Spectrum



Electromagnetic Spectrum

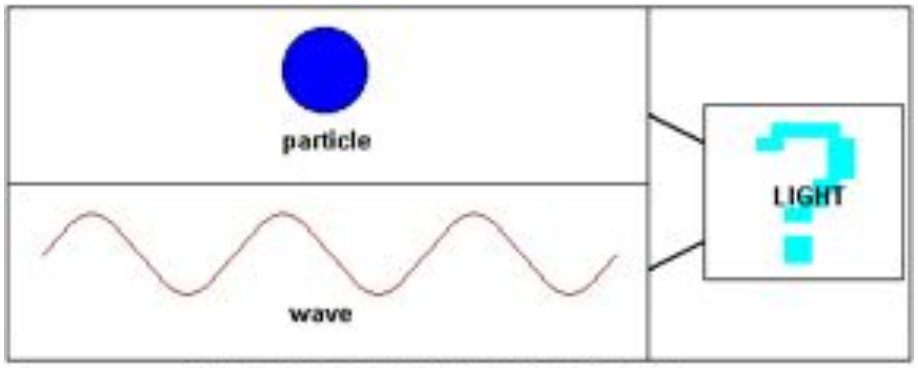


400nm 500nm 600nm 700nm

nm = nanometer = 10^{-9} meter

Nature of Light

- Light acts *both* as a wave *and* a particle!
- A particle of light is called a “photon”



How to imagine the wave-particle duality.

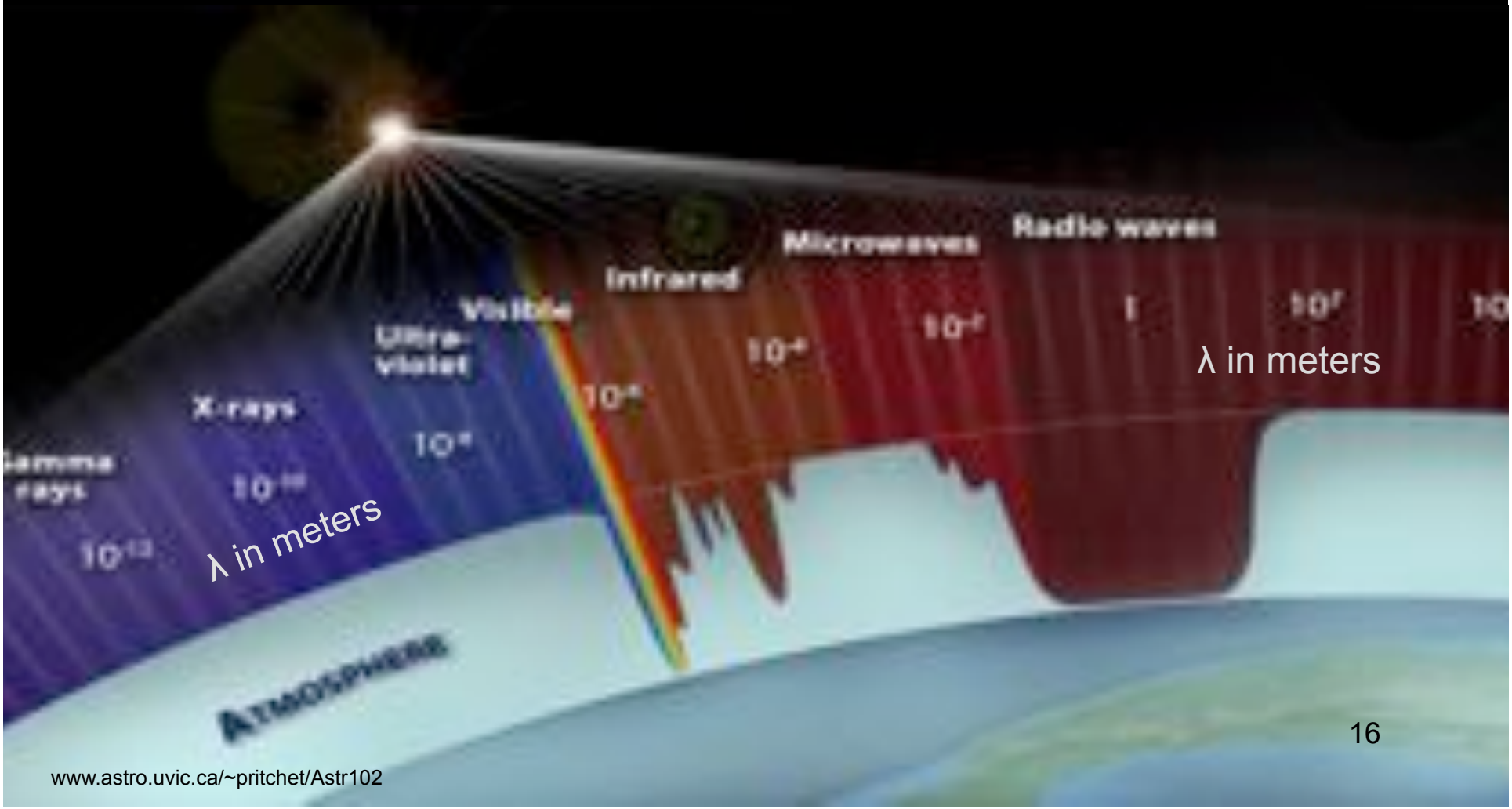
Nature of Light

"Once and for all I want to know what I'm paying for. When the electric company tells me whether light is a wave or a particle I'll write my cheque."

Nature of Light

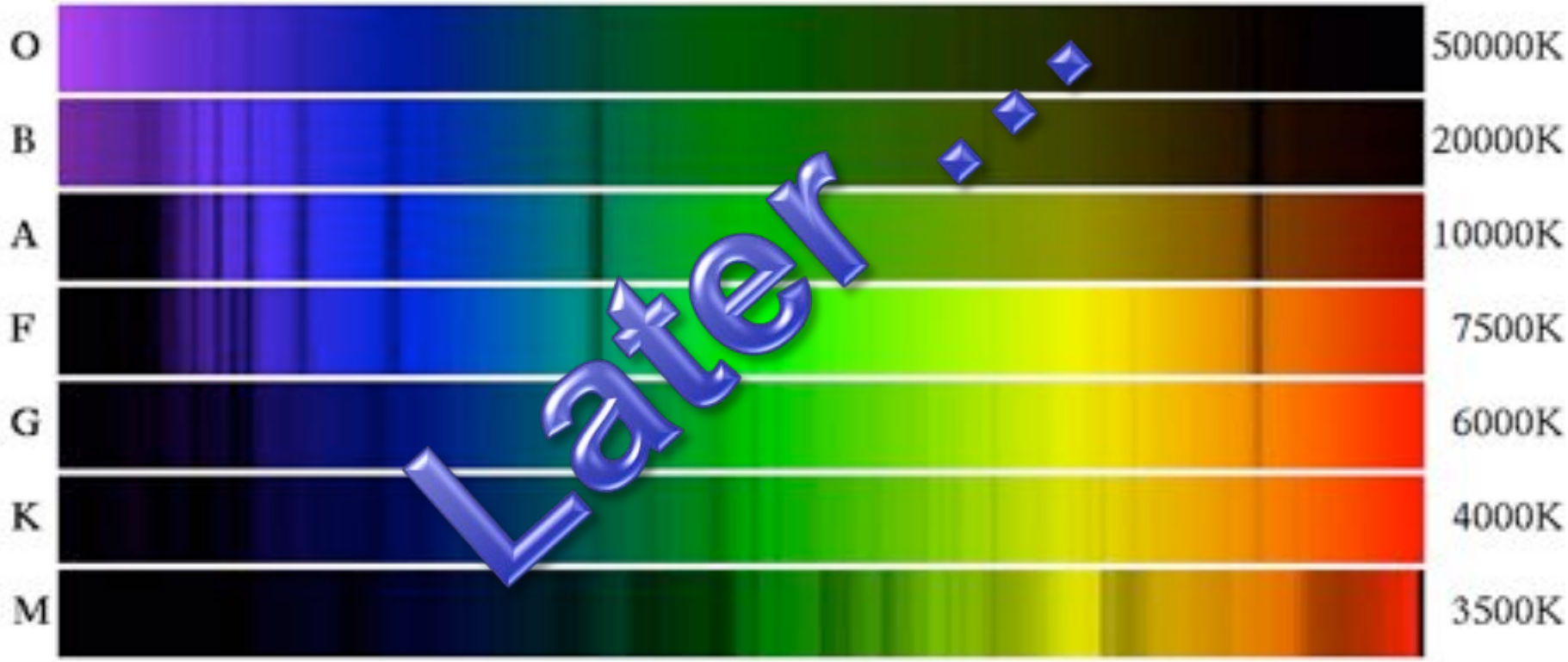
- Photons carry energy $E=hf$, where h is Planck's constant, 6.6×10^{-34} J s
- Smaller wavelength means higher energy

Earth's Atmosphere Absorbs Light

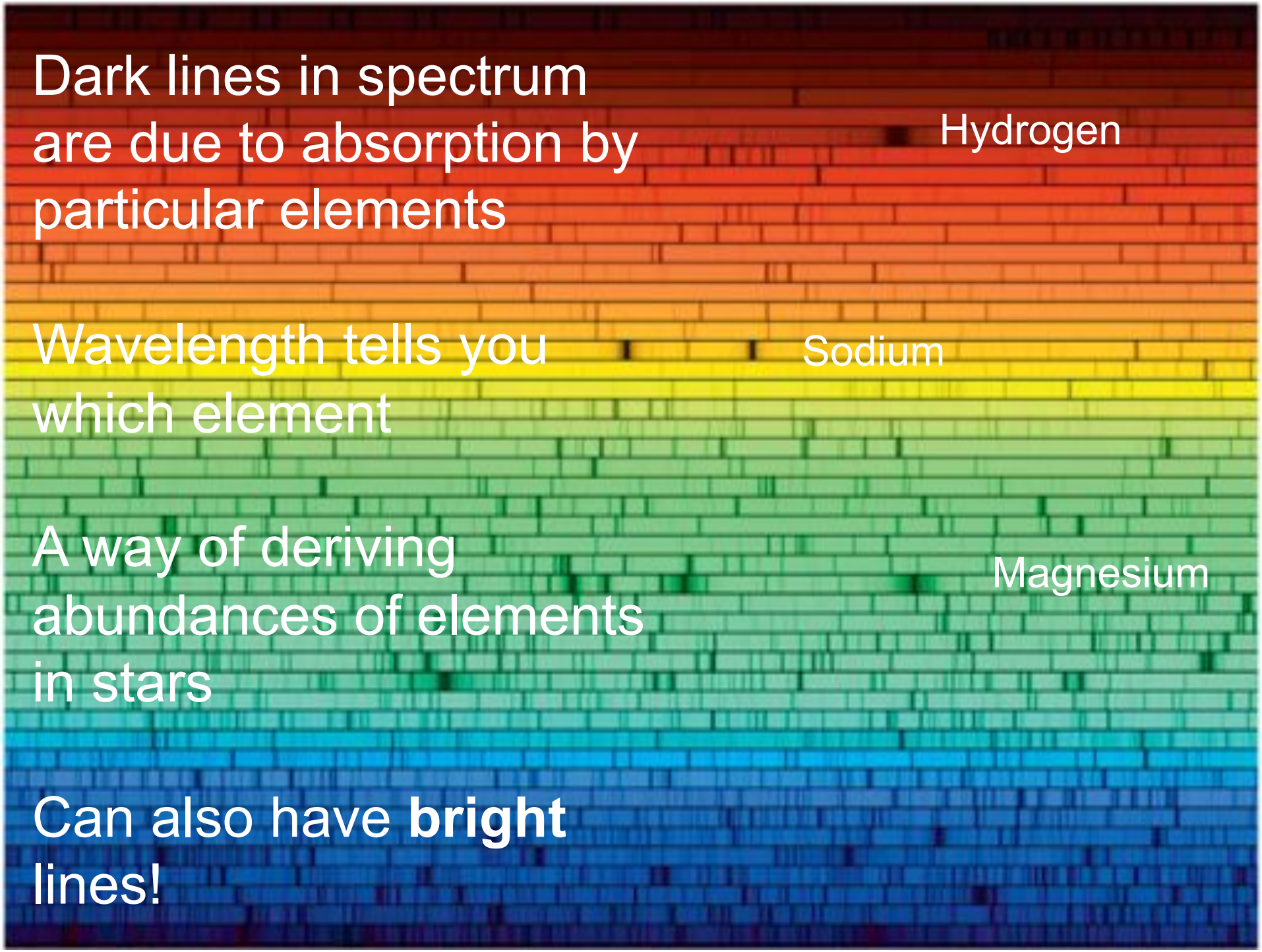


www.astro.uvic.ca/~pritchet/Astr102

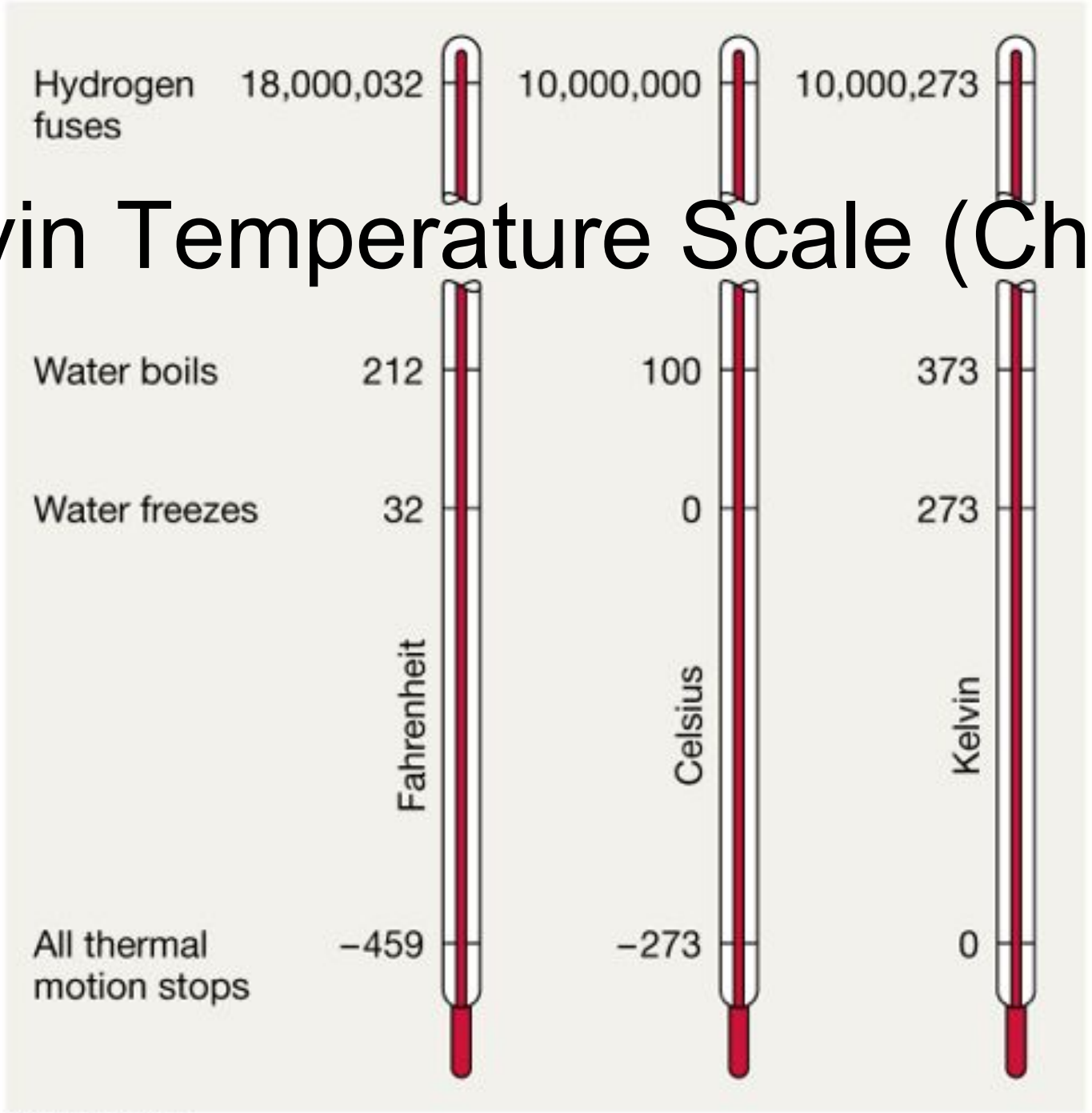
Two more things about light



1. black body radiation - hot=blue, cool=red
2. atomic energy levels - dark lines

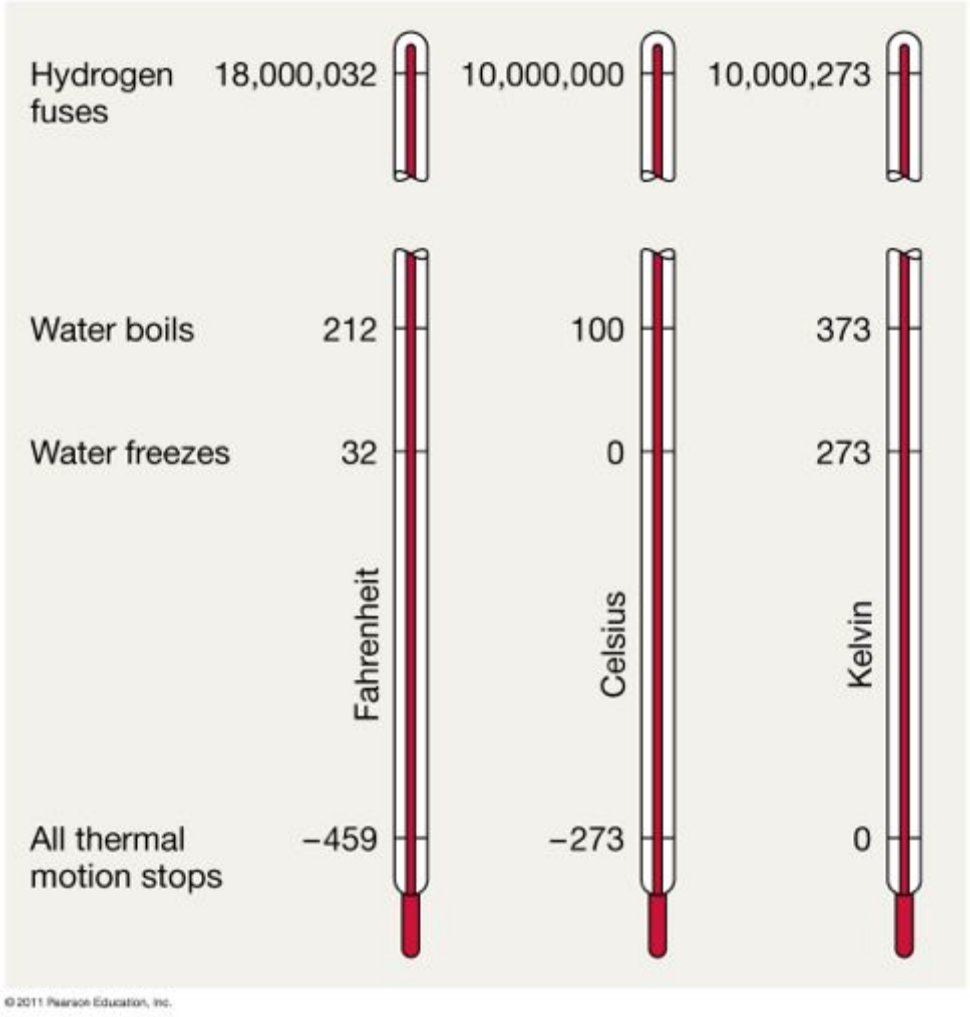

Dark lines in spectrum are due to absorption by particular elements
Hydrogen
Wavelength tells you which element
Sodium
A way of deriving abundances of elements in stars
Magnesium
Can also have **bright** lines!

Kelvin Temperature Scale (Ch 3)



Kelvin Temperature Scale (Ch 3)

- The hotter a body, the faster its atoms are moving!
- All thermal motion ceases at 0 K. "Absolute Zero".
- Water freezes at 273 K and boils at 373 K



The Doppler Effect

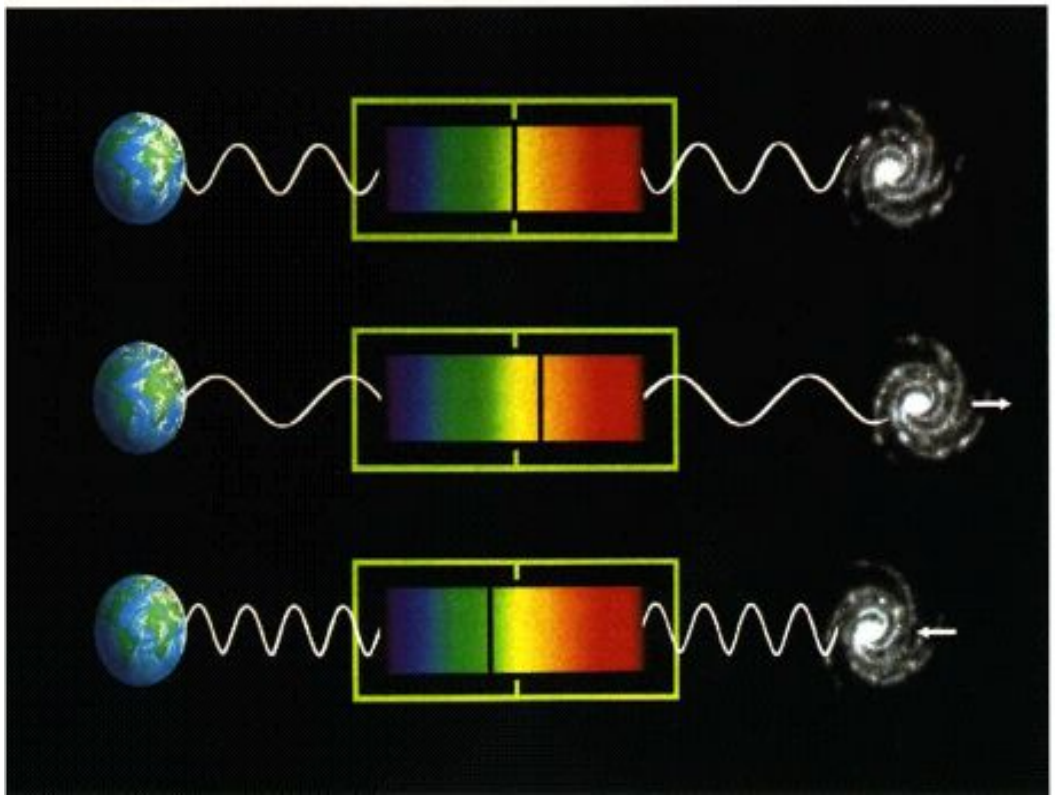
http://www.youtube.com/watch?v=8WgSQlRymwE

http://www.youtube.com/watch?v=GsCaSX6E-6U

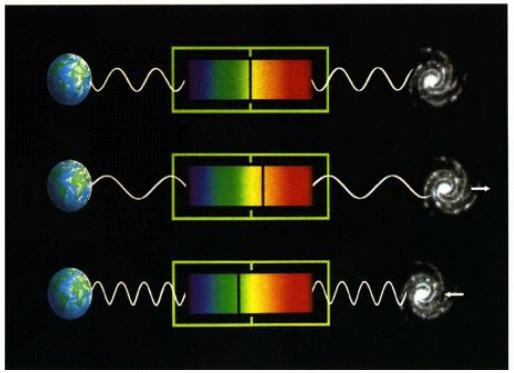
Doppler Effect [Ch 3.5]

Christian Doppler 1835

- ***Applies to any wave***
- Doppler proposed the effect to explain colour differences in binary stars [not correct]
- Buys Ballot tested the Doppler effect for sound waves in 1845 by using a group of musicians playing a calibrated note on a train in the Utrecht-Amsterdam line.



Doppler Effect



$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

v= velocity [- means approach]

c= speed of wave [300,000km/s for light]

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

- If velocity is away from us, change in wavelength is positive, or to the red.

Measuring Velocities with the Doppler Effect

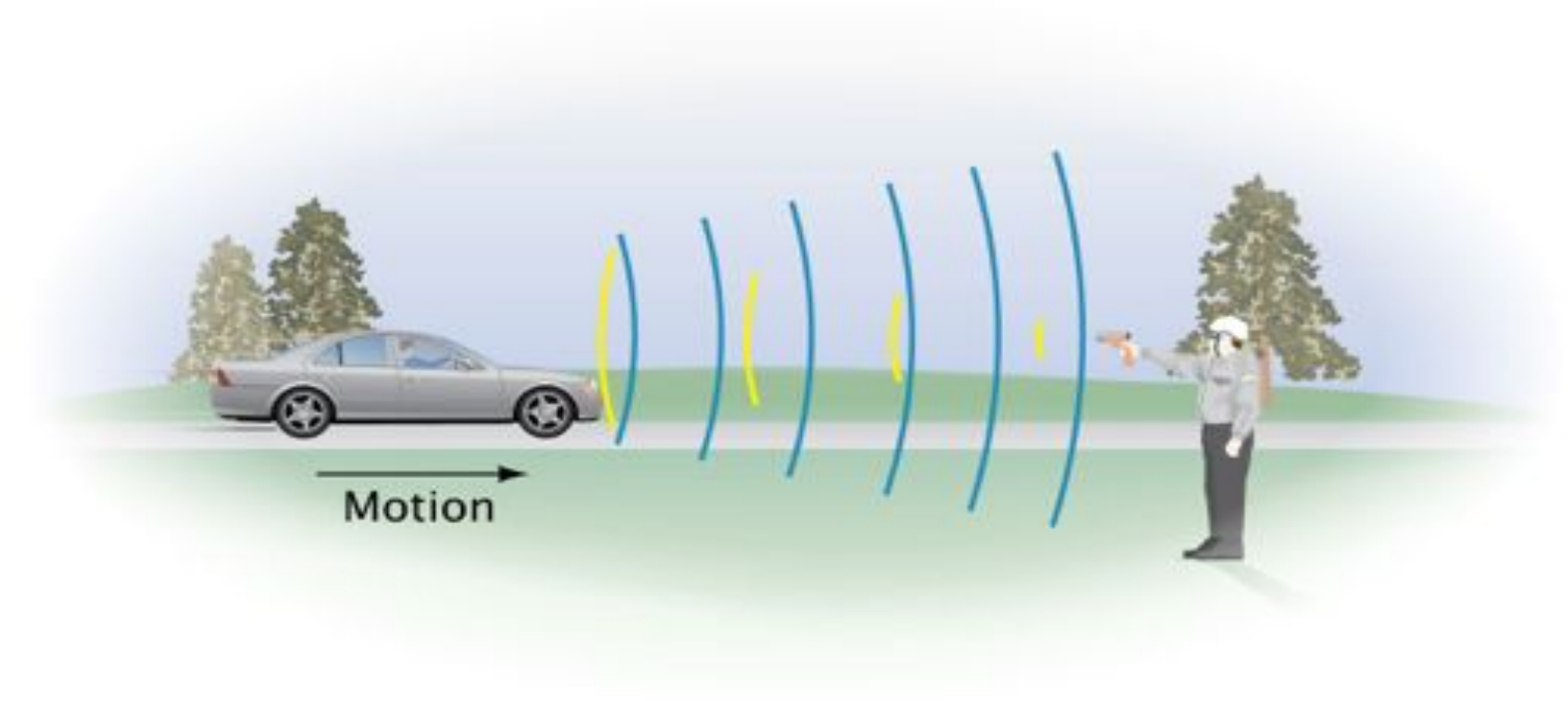
Example: For a speed of 30 km/s, the Doppler shift is given by

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

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

Measuring Velocities with the Doppler Effect

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



For the musicians (don't have to know)

- Car travels at 100 km/hr (assume)
- Pitch of trumpet is 440 Hz (A) (assume)
- Speed of sound is 1200 km/hr
- Fractional change in wavelength or frequency is then v/c=0.08=8% which is about 1 semitone – which is what was observed!

Doppler Effect – Big Bang Theory

Angular measure [AT Ch 1]

1 arcminute = 60 arcseconds	1’ = 60”
1 degree = 60 arcminutes = 3600 arcseconds	1^{o} = 60’ =3600”
360 degrees = a full circle	360^{o} = circle